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The effect of meteorological parameters on $PM_{2.5}$ concentration changes in 2018 (Case study: Tehran)

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ABSTRACT

Introduction: Studies in different parts of the world have shown that exposure to air pollutants has a negative effect on human health.

Materials and methods: For statistical analysis between the dependent variable Particulate Matter less than 2.5 µm ($PM_{2.5}$) concentration and independent variables (wind speed, precipitation, humidity, and temperature) R version 3.6.2 was used. Spearman correlation coefficient was used to determine the correlation between the parameters with the dependent variable. In addition, the multiple linear regression model was used to investigate the relationship and prediction between the independent variables and the dependent variable. In the present study, the effect of meteorological parameters on $PM_{2.5}$ concentration in different seasons in Tehran in 2018 was studied using Pearson correlation and linear regression statistical analyzes.

Results: Based on the results, it was found that $PM_{2.5}$ had no significant relationship with meteorological parameters. Only in summer, there was a significant relationship between the dependent variable and the independent variable (wind speed) (p-value=0.01) and there was also an inverse relationship between these variables (r=-0.65). Multiple linear regression was also used to investigate the significant effect of independent variables on the dependent variable.

Conclusion: According to the coefficients of determination in this model, 47, 16, 45, and 20% of the dependent variable change in autumn, winter, spring, and summer, respectively, can be explained by meteorological parameters (independent). Due to the fact that the concentration of $PM_{2.5}$ in Tehran is higher than the national standard, more attention of officials is necessary to improve air quality in Tehran.

Introduction

Studies in different parts of the world have shown that exposure to air pollutants has a negative effect on human health [1]. Air pollution is one of the major problems that human beings face and is considered an important health problem [2-4]. So that it is among the 10 risk factors affecting human health in the world [5, 6]. In the meantime, in Tehran, there is no exception

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to this rule for the city of Tehran because of some natural conditions such as air inversion and air mixing depth, low precipitation, weak winds, the direction of prevailing winds, the density of polluting industries, and their inappropriate location, population density, and traffic situation. These conditions have caused the air pollution in Tehran about in 87% of the time yearly [7]. According to a report by International Agency for Research on Cancer) IARC(, air pollution and particulate matter are classified as carcinogenic compounds for humans (group one) [8, 9]. According to the latest Global Burden of Disease (GBD) estimate in 2015, the number of Particulate matter less than 2.5 μm ($PM_{2.5}$) deaths attributed to the outdoor air worldwide was about 4.2 million [4, 5]. In addition, in 2017, particulate matter is recognized as the sixth health risk factor in the world [5, 10]. The city of Tehran with a population of more than 12 million people per day and about 9 million at night is one of the polluted cities in term of air pollution emitted from vehicles [11]. One of the most important pollutants is particulate matter in the atmosphere. Particulate Matter (PM) refers to a complex mixture of pollutants consisting of smoke, dust, and a variety of solids and liquids that are in the gaseous medium [12]. Studies show that particulate matter with a diameter of less than 10 μm poses a serious threat to human health [13]. Among suspended particles, $PM_{2.5}$ has a stronger association with death [14]. $PM_{2.5}$ causes premature death, acute and chronic diseases [13-15]. Epidemiological studies show an association between air pollution, especially $PM_{2.5}$, with premature deaths, especially cardiovascular disease [15-18]. In addition to its effects on health, dust can lead to climate change on a global and local scale, changes in biological, geological, chemical or environmental cycle [19]. Numerous studies show that most of the dust occurs near the borders of Iran, Pakistan and Afghanistan. Meteorological parameters affecting the problem of air pollution can be divided into two primary and secondary categories. Primary parameters such as wind direction and speed, temperature, mixing height and secondary parameters such as precipitation, humidity, radiation and visibility. These parameters are significantly dependent on latitude, season and topography [20, 21]. Numerous studies have been performed on the concentration of pollutants and the effect of meteorological parameters on them. In a study, it was examined that the temporal changes of PM_{10} concentration in Kermanshah in July, had the maximum concentration and also the minimum concentration was dedicated to themselves in January [22]. In a study on air quality pollutants in the metropolis of Tehran in the 2000s, it was found that meteorological variables can be effective in the amount of air pollution in Tehran. Also, another important result of this research is the decreasing trend of PM_{10}, NO_2, CO, SO_2 pollutants during the studied years [23]. Due to the fact that particulate matters have many negative effects on human and plant health as well as a very important role in global climate change, in the present study, changes in $PM_{2.5}$ concentration were investigated. In addition, due to the fact that meteorological parameters can affect the concentration and distribution of pollutants, including particulate matters, in this study, the relationship between $PM_{2.5}$ concentration and meteorological parameters was investigated. Therefore, the present study aimed to investigate the daily, monthly and seasonal changes of $PM_{2.5}$ concentration in spring, summer, autumn and winter; and the effect of meteorological parameters on $PM_{2.5}$ concentration in spring, summer, autumn and winter in Tehran was performed.

Materials and methods

Time and place of sampling

The sampling place is in the east and southeast of Tehran, which includes areas 7, 8, 12, 13,

Table1. US Environmental protection agency standard for locating air pollution monitoring stations

Parameter	Standard
Distance from the street	>20 m
Distance from the nearest tree	>20 m
Distance from the source of air pollution	>20 m
Distance from obstacles	Double the height of the barrier
Distance from the ground	3-15 m

14, and 15 of Tehran. The US Environmental Protection Agency standard was used in order to select sampling sites according to Table 1[24]. The selected points are places with a height of at least 3 m above the ground.

For achieving a desired and standard results, sampling was not performed on holidays and days with snow and rain. This study was conducted during 4 seasons in 2018. The location of the sampling site in Tehran is shown in Fig. 1.

Sampling method

Sampling of $PM_{2.5}$

In this study, in order to determine the concentration of $PM_{2.5}$, a sample was taken according to EPA-TO 13A standard [25]. $PM_{2.5}$ sampling was performed for 24 h by an Aircheck sampling pump (skc, model 44xr) and a $PM_{2.5}$ holder filter with an average flow rate of 3 L/min (because 2.5 µm particles are not properly placed on the filter if a higher flow rate enters the holder filter, due to the turbulence inside the impactor [26]. Therefore, before each sampling, the pump should be used a rotameter to check flow, so that in case of flow drop, new pumps are used, then sampling was done.

Methods of data analysis

$PM_{2.5}$ concentration data used in this study were collected through sampling and the meteorological parameters (wind speed, precipitation, humidity and temperature) were collected through the Iran Meteorological Organization (Tehran). For statistical analysis between the dependent variable (pollutant concentration) and meteorological parameters (wind speed, precipitation, humidity and temperature), R version 3.6.2 was used. In this study, daily data on $PM_{2.5}$ concentration were considered as dependent variables and daily data on meteorological parameters (wind speed, precipitation, humidity and temperature) were considered as independent variables. Spearman correlation coefficient was also used to determine the correlation between the parameters with the dependent variable. Also, the multiple linear regression model was used to investigate the relationship and prediction between the independent variables and the dependent variable.

Results and discussion

Figs. 2, 3, 4 show daily, monthly and seasonal concentrations during the study period. The highest concentration was for January and

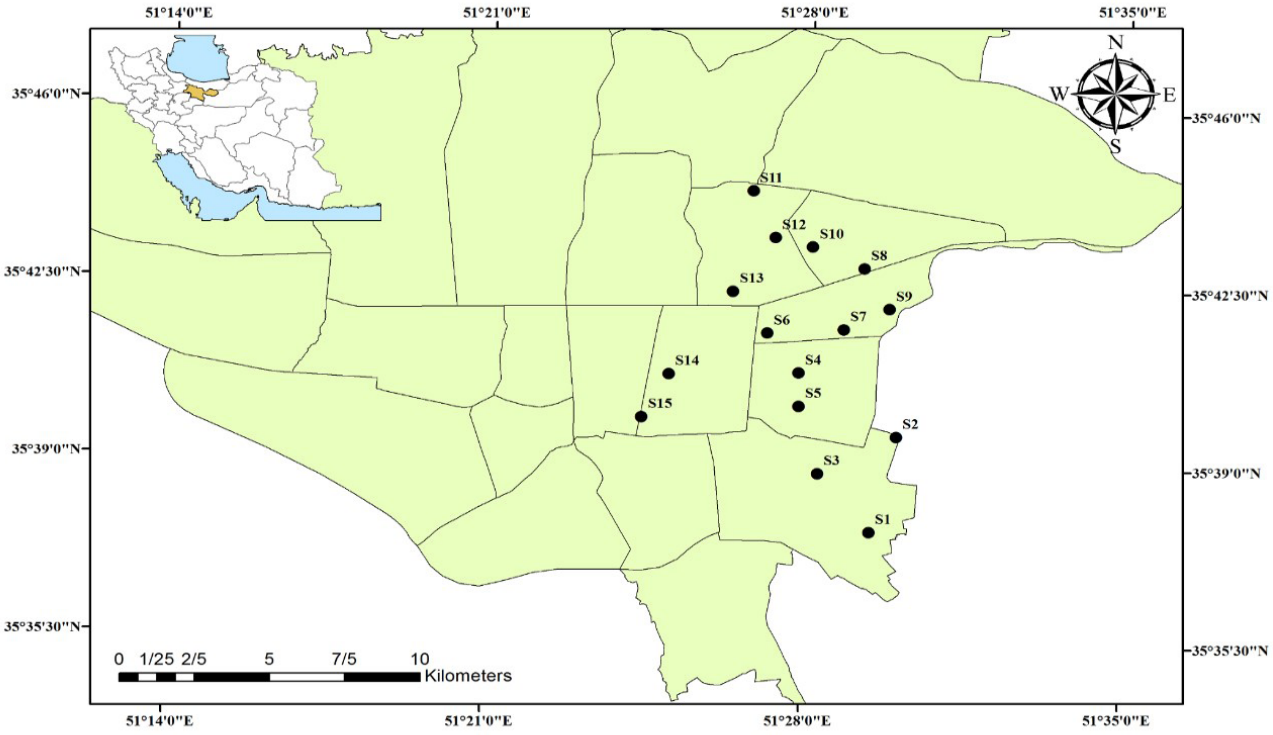

Fig. 1. Sampling area and points in Tehran

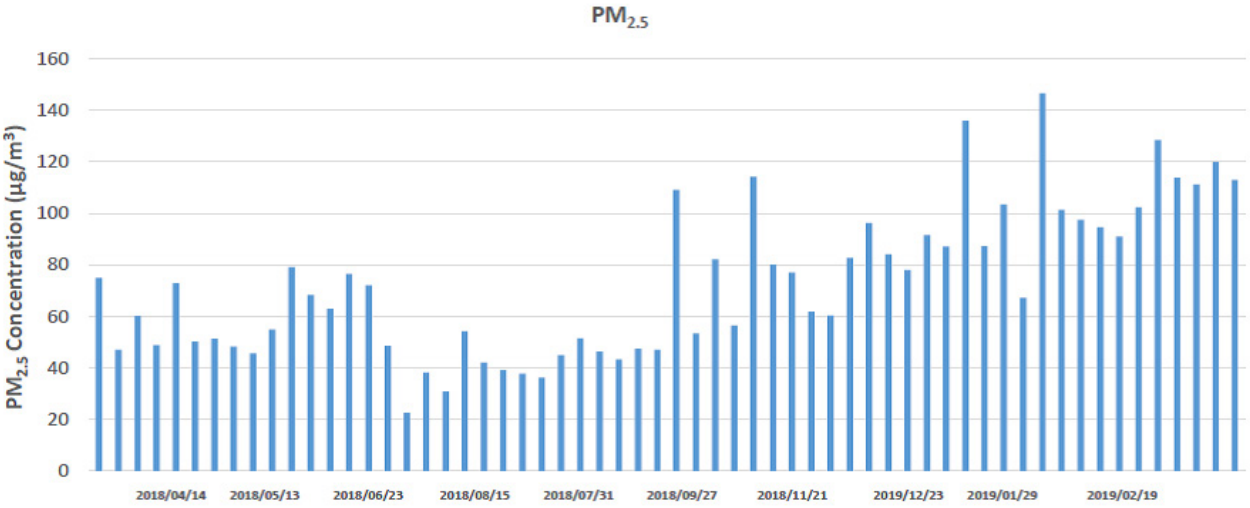

Fig. 2. Daily concentration of $PM_{2.5}$ (µg/m^3)

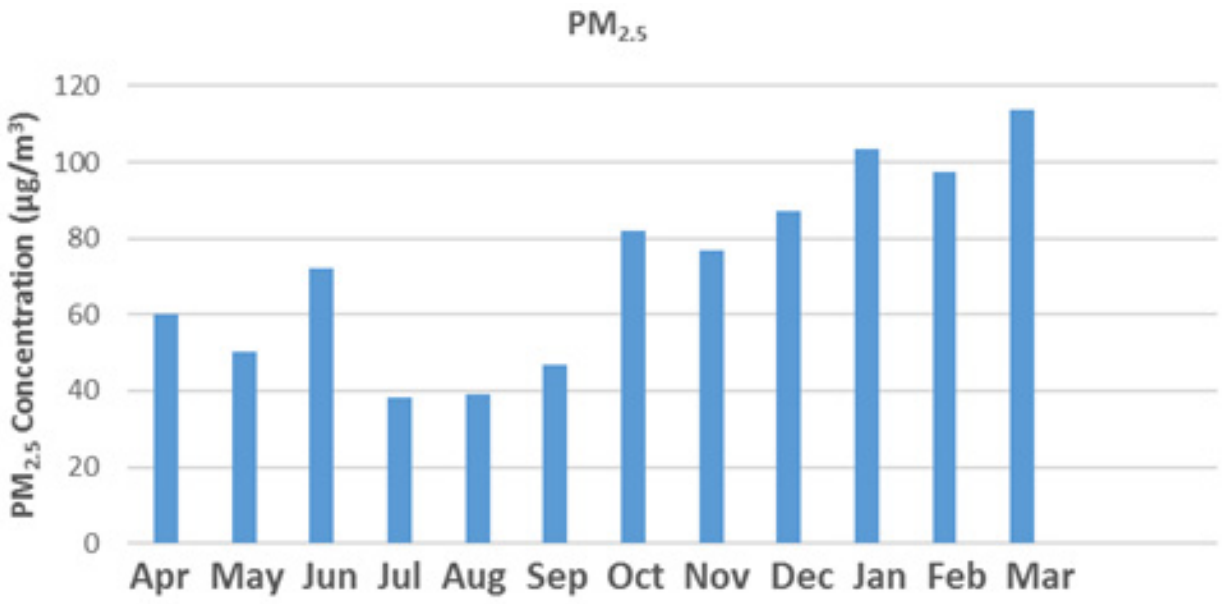

Fig. 3. Monthly concentration of $PM_{2.5}$ (µg/m^3)

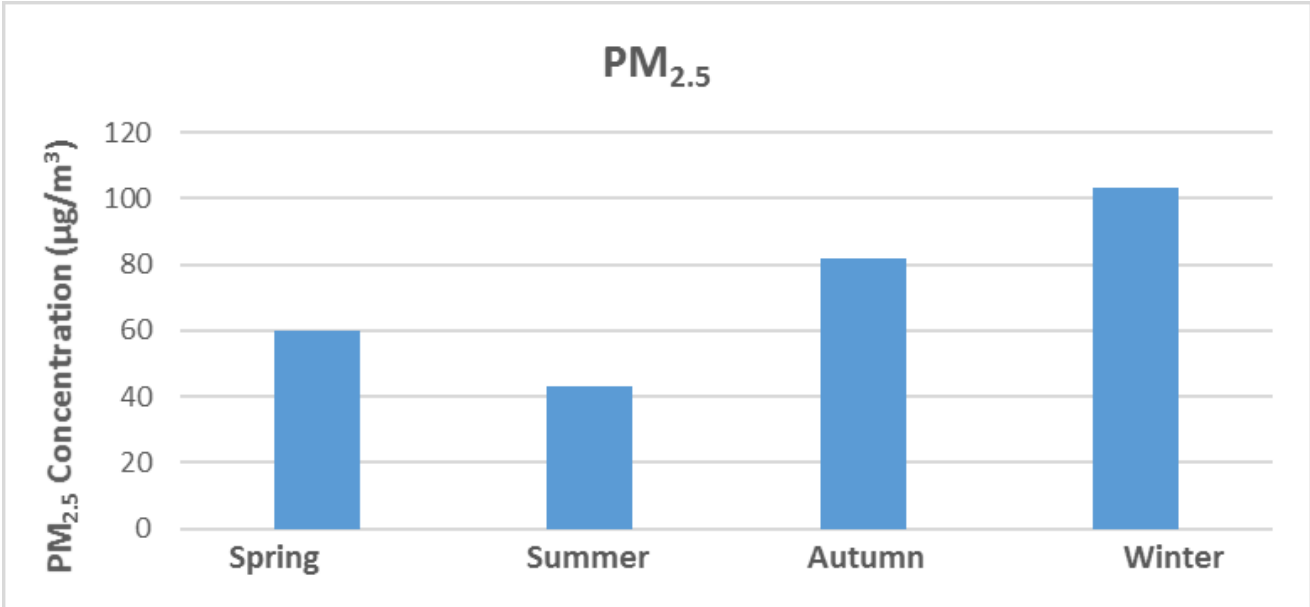

Fig. 4. Seasonal concentration of $PM_{2.5}$ (µg/m^3)

Table 2. Pearson correlation between dependent variable and meteorological parameters

Independent variable				Dependent variable	Season
Precipitation	wind speed	Relative humidity	Temperature		
r=-0.32	r=-0.48	r=-0.1	r[1]=0.19	$PM_{2.5}$	Spring
Sig=0.25	Sig=0.07	Sig=0.72	Sig=0.51		
r=-0.24	r=-0.65	r=-0.15	r=0.17	$PM_{2.5}$	Summer
Sig=0.39	Sig=0.01	Sig=0.59	Sig=0.53		
r=0.50	r=-0.34	r=-0.01	r=-0.17	$PM_{2.5}$	Autumn
Sig=0.06	Sig=0.21	Sig=0.96	Sig=0.53		
r=0.41	r=0.12	r=0.06	r=-0.04	$PM_{2.5}$	Winter
Sig=0.12	Sig=0.66	Sig=0.82	Sig=0.90		

[1] Correlation coefficient; the bold values are significant

Table 3. Investigation of the significant effect of independent variables on the dependent variable through multiple linear regression model

p-value	F	Adjusted R-square	R-square	p-value	t	Coefficients	Variables	Season
0.16	2.05	0.23	0.45	**0.01**	**2.89**	**1.4550**	**constant**	Spring
				0.42	0.83	0.0076	Temperature	
				0.16	-1.49	-0.0099	Precipitation	
				0.32	1.04	0.0067	Relative humidity	
0.65	0.64	-0.11	0.20	0.31	-1.04	-0.0120	wind speed	Summer
				0.01	**2.84**	**1.6110**	**constant**	
				0.71	0.37	0.0036	Temperature	
				0.97	-0.03	-0.0032	Precipitation	
				0.99	0.002	0.0001	Relative humidity	
0.14	2.21	0.26	0.47	0.26	-1.18	-0.0175	wind speed	Autumn
				<0.001	**8.49**	**2.0126**	**constant**	
				0.97	-0.04	-0.0002	Temperature	
				0.02	**2.63**	**0.01576**	Precipitation	
				0.92	0.10	0.0002	Relative humidity	
0.75	0.47	-0.17	0.16	0.09	-1.82	-0.0233	wind speed	Winter
				<0.001	**9.94**	**1.8127**	**constant**	
				0.96	0.04	0.0003	Temperature	
				0.35	0.97	0.0053	Precipitation	
				0.58	0.56	0.0009	Relative humidity	
				0.39	0.90	0.0169	wind speed	

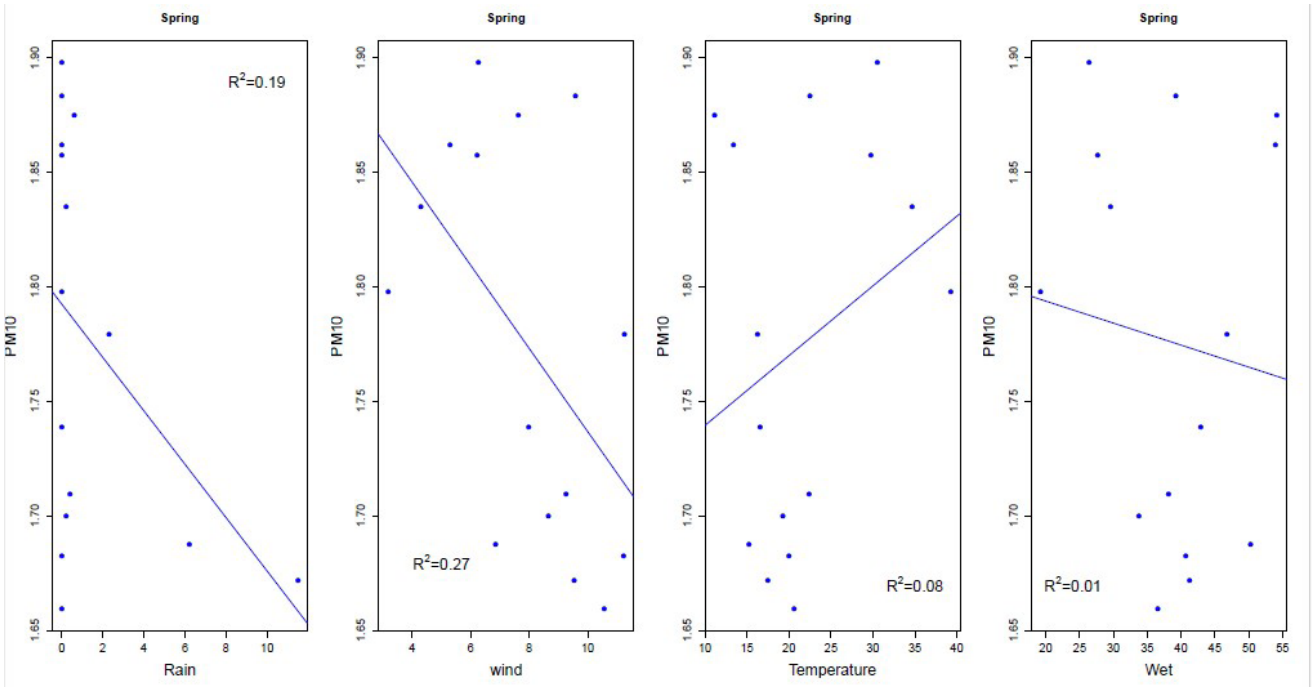

Fig. 5. Regression relationship between meteorological parameters and $PM_{2.5}$ concentration in spring

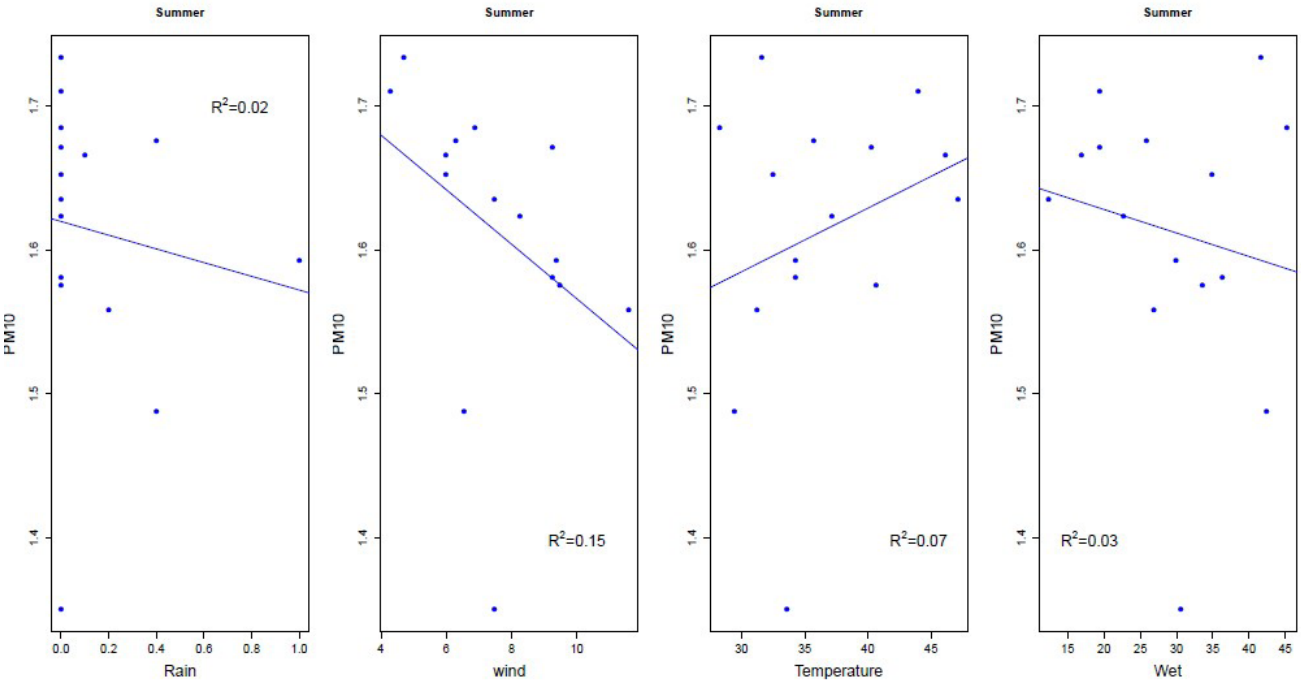

Fig. 6. Regression relationship between meteorological parameters and $PM_{2.5}$ concentration in summer

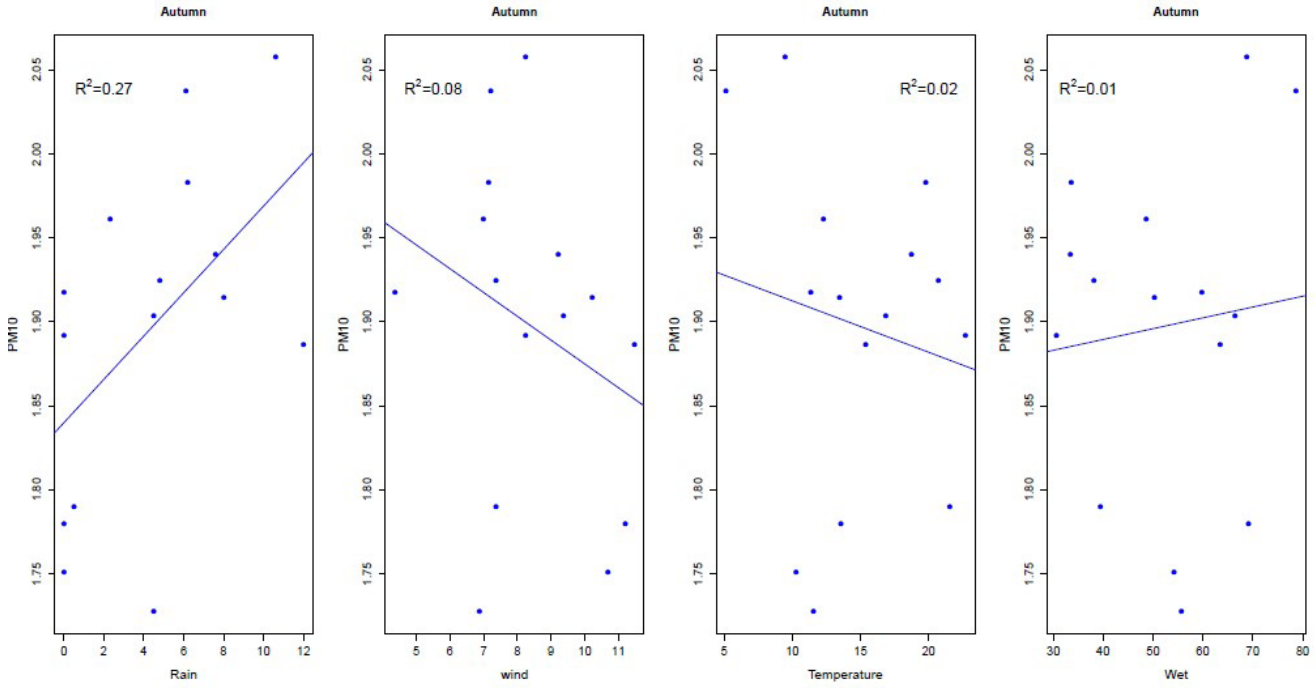

Fig. 7. Regression relationship between meteorological parameters and $PM_{2.5}$ concentration in autumn

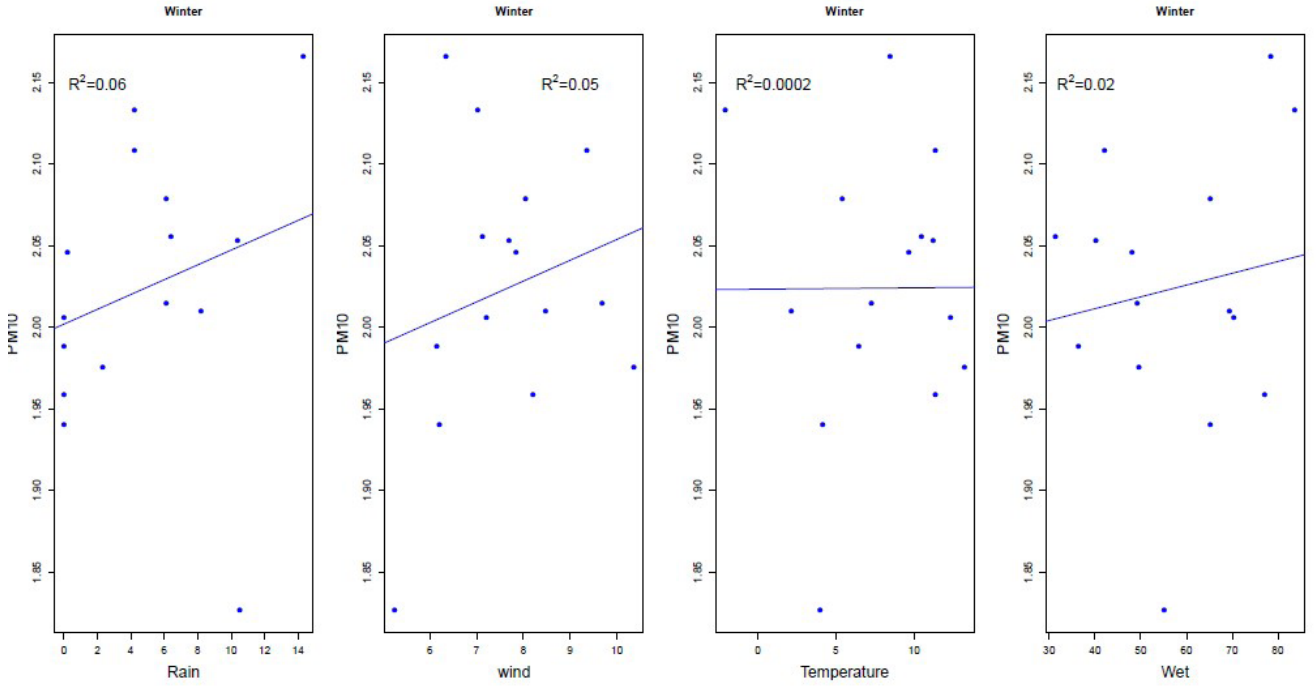

Fig. 8. Regression relationship between meteorological parameters and $PM_{2.5}$ concentration in winter

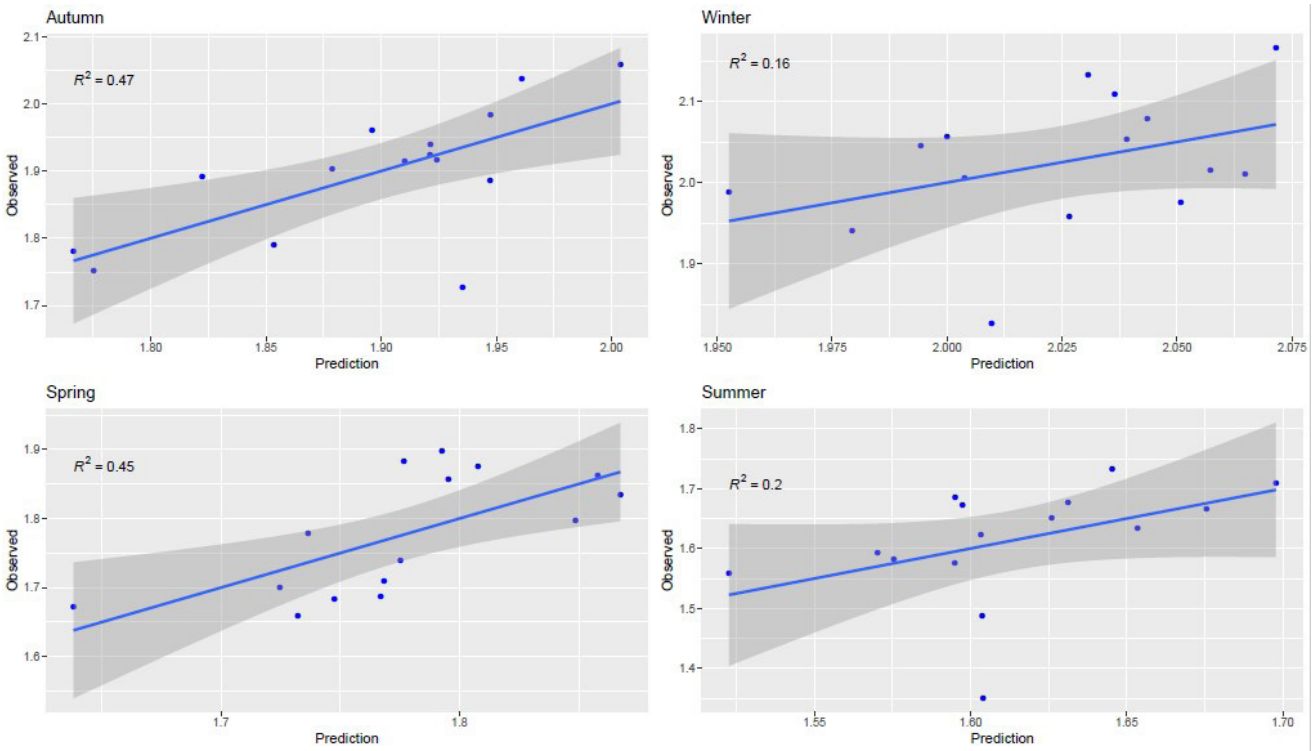

Fig. 9. Relationship between predicted and observed values in spring, summer, autumn and winter

According to the outdoor air quality standard of the Department of Environment in Iran, the standard of $PM_{2.5}$ particles is equal to 35 µg/m^3 for 24 h. Therefore, based on the findings of the present study, the concentration of $PM_{2.5}$ was higher than the standard in all months studied. According to the study conducted in Kermanshah, the highest particle concentration of pm was related to summer [22]. However, in the present study, according to Figs. 1 and 2, the highest particle concentration is related to winter, which can be due to the different source and origin of particles in these two cities. In the present study, Pearson correlation and linear regression equations were used to investigate the effect of meteorological parameters on $PM_{2.5}$ particle concentrations. Pearson correlation between $PM_{2.5}$ and meteorological parameters showed that $PM_{2.5}$ had no significant relationship with meteorological parameters. Only in summer, there was a significant relationship between the dependent variable and the independent variable (wind speed) (p-value=0.01) and also there was an inverse relationship between these two variables (r=-0.65) (Table 3). Multiple linear regression was used to investigate the significant effect of independent variables on the dependent variable. According to Table 3 and according to the coefficients of determination in this model, 47, 16, 45 and 20% of the dependent variable change in autumn, winter, spring and summer, respectively, can be determined by meteorological parameters (independent). (Table 3). A study conducted in Malaysia showed that particle concentration was directly correlated with temperature but negatively correlated with relative humidity [27]. A study conducted in Tehran in 2016 showed that PM_{10} had a positive correlation with wind speed and a negative correlation with rainfall and dew point [28].

Conclusion

In the present study, the effect of meteorological parameters on $PM_{2.5}$ concentration in different seasons in Tehran in 2017 was studied by Pearson correlation and linear regression statistical analyzes. Based on the results, it was found that $PM_{2.5}$ had no significant relationship with meteorological parameters. Only in summer, there was a significant relationship between the dependent variable and the independent variable (wind speed) (p-value=0.01) and there was also an inverse relationship between these two variables (r=-0.65). Multiple linear regression was also used to investigate the significant effect of independent variables on the dependent variable. According to Table 3 and according to the coefficients of determination in this model, 47, 16, 45 and 20% of the dependent variable change in autumn, winter, spring and summer, respectively, can be determined by meteorological parameters (independent). Because the concentration of $PM_{2.5}$ in Tehran is higher than the national standard, it is more attention of city officials and managers to create and adopt efficient decisions and scenarios to improve air quality in Tehran and reduce economic and health losses and costs that demands to air pollution.

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Competing interests

The authors declare that there are no conflicts of interest.

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Ethical considerations

The authors declare that ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed.

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