Original Article

Association between Meteorological Parameter and $PM_{2.5}$ Concentration in Karaj, Iran

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Abstract

Aim: The present study aimed to investigate the effect of meteorological parameters on particulate matter concentration ($PM_{2.5}$) in ambient air of Karaj metropolitan. **Materials and Methods:** In this cross-sectional descriptive study, 17 sampling points in Karaj city were chosen using GIS software. Sampling of $PM_{2.5}$ was carried out for 24 h using the sampling pilot during the four seasons in the air of Karaj city. Sampling of $PM_{2.5}$ was performed using PTFE filters, peripheral pump, and personal modular impactor. The concentration of particles collected on the filter was calculated by gravimetric method. Meteorological parameters including temperature, humidity, pressure, cloud coverage rate, ultraviolet (UV), and dew point were recorded during sampling through portable devices. Finally, the relationship between $PM_{2.5}$ concentration and meteorological parameters was assessed by SPSS24 and Excel software. **Results:** Seasonal variation trends of $PM_{2.5}$ particles showed that maximum and minimum annual concentrations have happened in autumn and spring seasons with a value of 67.48 and 19.85 μg/m^3, respectively. Furthermore, the citizens of Karaj are exposed to $PM_{2.5}$ pollutants four times more than the Environmental Protection Agency-recommended standard (10 μg/m^3). The findings of this study also show that there is a positive correlation between $PM_{2.5}$ particle concentration and temperature, relative humidity, and pressure ($P < 0.05$). Moreover, a weak and negative correlation was found between UV radiation, cloud cover, and dew point with $PM_{2.5}$ particle concentration ($P > 0.05$). **Conclusion:** The highest concentrations of particles were observed in autumn season. Furthermore, the particle concentration scatter map shows that the central and eastern regions and north of Karaj are more polluted than other areas. Therefore, to protect the health of citizens of Karaj, appropriate policies and strategies should be adopted to reduce the concentration of particulate matter and other pollutants in the ambient air of this city.

Keywords: Air pollution, Karaj city, meteorological parameters, $PM_{2.5}$

Introduction

Air pollution has long been clear to the public since the early twentieth century, with the London Smoke (1952) and Denora (1948) events.[1] Research by the World Health Organization (WHO) has shown that half the people of the world live somewhere that the concentrations of air pollutants are higher than the standard level.[2] The mother womb is believed to be the safest place in the world, but studies at the University of Belgium have shown that air pollution even can affect the fetus in the womb.[3] Hence, air pollution is one of the global problems that wherever we live on the earth, air pollution is existing high or low. Hence, it can be said that there is no clean air.[4,5] In addition to the heavy costs that air pollution on governments imposes, those include a variety of diseases ranging from asthma to stroke and eventually death.[6,7] According to the report by the World Bank in 2005 on the mortality rate and the resulting costs published, total death from air pollution in Iran is approximately 0.57% of GDP.[8] There are also about 45,000 mortalities annually from air pollution diseases in Iran.[9] Major air pollutants include CO, HCHO, NO_X, SO_2, O_3, and suspended particles. However, particles with aerodynamic diameter smaller than 2.5 microns ($PM_{2.5}$) are executed the most role in air pollution.[10] $PM_{2.5}$ particles with their strength and influence go deep into the lungs and cause respiratory disorders. Particles cause an effect on meteorological parameters including impact on

Access this article online

Quick Response Code:

Website: www.ijehe.org

DOI: 10.4103/ijehe.ijehe_14_20

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How to cite this article: Kermani M, Jafari AJ, Gholami M, Fanaei F, Arfaeiniae H. Association between meteorological parameter and $PM_{2.5}$ concentration in Karaj, Iran. Int J Env Health Eng 2020;9:4.

Received: 21-02-2020, **Accepted:** 06-04-2020, **Published:** 31-07-2020

the amount of solarization and ultimately change the earth's surface temperatures and reduce visibility.[11] The concentration of these particles depending on the geographical location, weather conditions and other factors can be changed.[12] This city faces a large volume of daily pollutant production due to the communication route of 15 provinces of the country, the existence of small and large industries, and some other sources. Population of this city because of the working positioners and occupation every year is growing. According to the report of the Karaj Environmental Protection Organization, the main pollutants in recent years were $PM_{2.5}$ particles.[13]

Numerous studies have been performed on the influence of particle concentration on the meteorological parameters. Ansari *et al*. (2017–2018) have reviewed the influence of changing meteorological parameters on the ambient fine particulate matter. It was found that there is a weak correlation between $PM_{2.5}$ particles and mean monthly temperature ($r = 0.42$, $P < 0.05$) and mean relative humidity ($r = 0.37$, $P < 0.05$).[14] The results of Jamshidi *et al*. on the concentration of $PM_{2.5}$ particles in Gachsaran showed that concentrations of these particles were increased in month of May, July, and August.[15] Furthermore, Tecer *et al*. find that there is an adverse correlation between meteorological parameters (include: temperature, precipitation, and pressure) and $PM_{2.5}$ particle concentration.[16] In another study which had been conducted in Malaysia, the concentration of particles has shown a negative effect on wind speed and relative humidity.[17] The study by Sammaritano *et al*. in Austria was showed that the highest concentration of particles was in winter season.[18] In the other hand, Zhang *et al*. in their article showed that the relative humidity and precipitation are negative correlation and temperature and wind speed are positive correlation to the concentration of particles in the air.[19] In the study conducted by Yet *et al*., the weak positive relationship was found between temperature and $PM_{2.5}$ particle concentration. In the study of Ye *et al*., a negative relationship between $PM_{2.5}$ concentration and wind speed has observation ($r = -0.28$, $P < 0.05$).[20]

Due to the above-mentioned reasons, this study aimed to: (i) investigate the concentration and seasonal variation of $PM_{2.5}$ in ambient air of Karaj and (ii) investigate the effect of meteorological parameters including temperature, relative humidity, pressure, ultraviolet (UV) rate, cloud coverage rate, and dew point on the concentration of $PM_{2.5}$ in the ambient air of Karaj, Iran.

Materials and Methods

Geographical location of the study area

Karaj is one of the major metropolises with a population of about 2.5 million located 48 km northwest of Tehran, capital of Iran. The length of this city is about 16 km and 1300 m above sea level and its surface area is approximately 175.5 km^2. Furthermore, the latitude and longitude of the city are 35°48´N and 51°00´E, respectively. Because of the connection between this city and 15 provinces of the country, it faces a large volume of pollutants daily. This reason causes an intensification of air pollution from the most important source of its formation, namely moving vehicles. On the other hand, various small and large industries i.e. petrochemical industries, gas and oil refineries, welding workshops, aluminum industries, cement factories and etc. are also active near the Karaj city and release high amount of PM into the ambient air of this city. Therefore, Karaj is one of the most polluted megacity in Iran because of above-mentioned reasons. Although there are sporadic studies on the concentration of particulate matter in this city, there is not exist integrated data that can be based on the organizational policies in order to advancement control of air pollution.[21] This study is a descriptive-analytical that was done to intentional measurement of $PM_{2.5}$ particles and influence of meteorological parameters such as temperature, relative humidity, pressure, UV rate, cloud coverage, and dew point seasonally in seasons spring, summer, autumn, and winter in 2018–2019 in Karaj city. In this study, 17 points from Karaj city with cooperation of the Health Department of Alborz Province were selected [Figure 1]. On the other hand, to ensure the security of installation of air pollution devices, all selected sites are health-care centers undercovered by Alborz University of Medical Sciences. Furthermore, these sites were selected based on the standards of US Environmental Protection Agency (EPA). It is necessary to mention that in order to achieve a desirable result, sampling was not performed on holidays and days associated with snow and rain.

$PM_{2.5}$ sampling and meteorological parameters

For the intention of sampling particles, $PM_{2.5}$ from a peripheral pump (Leland Legacy [SKC]) and a Personal Modular Impactor (PMI) holder was used. The PTFE filter (Zephon, USA) with a diameter of 2 mm was selected according to the type of holder. Forasmuch as purpose is to measurement $PM_{2.5}$ particles; therefore, the filter diameter used was selected one micron. Sampling time was selected based on guideline EPA-TO/13 A 24 h and flow rate samples according to the type of filter used and guideline of maker company on the 3 l/min adjustment. Because if the flow rate above this value enters the holder filter, due to Create turbulence in PMI(Personal Modular Impactor), PM2.5 particles do not fit properly on the filter. Accordingly, before each time sampling, the pump used was calibrated by a rotameter.

During the period of $PM_{2.5}$ particle sampling, meteorological factors including temperature (°C), relative humidity (%), pressure (Pa), UV, cloud cover (%), and dew point were also recorded using a portable PHB-318 device. Information as to cloud coverage, UV and dew points obtained it from Karaj Environmental Protection Agency (affiliated to Karaj Municipality). At the end of the sampling (24 h), again, these parameters were measured, and afterward, the obtained data were imported into Excel and average of them was calculated.

Statistical analysis

After calculating the $PM_{2.5}$ concentrations by gravimetric method and calculating the average meteorological parameters

in four seasons, Statistical Package for the Social Sciences (SPSS) software was used to obtain the correlation coefficient and correlation between meteorological data. At this step, the normality of data was identified by Kolmogorov–Smirnov, and to the reason of normality of data, Pearson's statistical test was used for correlation analysis. Whatever the correlation® Closter to −1 and +1, the intensity of the correlation will be more here. Boxplot diagram of $PM_{2.5}$ concentrations was drawn by R software. On the other hand, the GIS software for zoning $PM_{2.5}$ concentrations was used.

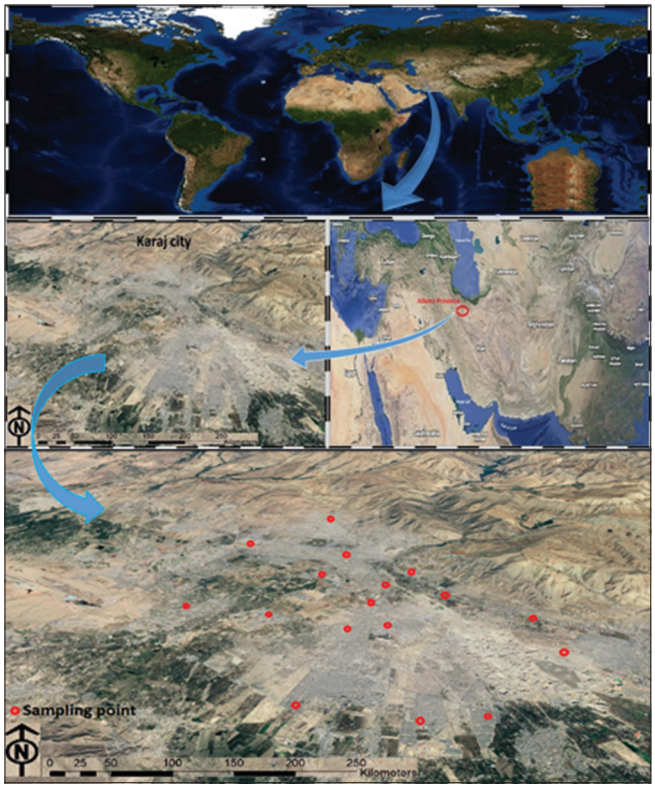

Figure 1: Geographical location and sampling points of study area

Results

Relationship between meteorological parameters and concentrations of $PM_{2.5}$

In Figure 2, a variation of average temperature, relative humidity, dew point, UV radiation, pressure, and cloud cover in four seasons during 2018–2019 is brought. The average of annual temperature (°c), humidity (%), pressure (Pa), UV radiation, cloud cover (%), and dew point is 16.19, 33.04, 0.89, 4.69, 30.17, and −1.30, respectively. On the other hand, Figure 3 shows a boxplot diagram concentration of $PM_{2.5}$ seasonally sampled points. As shown in this figure, the highest concentration of $PM_{2.5}$ was found in winter (110.22 μg/m^3) and the lowest is in spring (10.06 μg/m^3). Moreover, the annual average concentration of $PM_{2.5}$ is 40.64 μg/m^3 that is four times higher than the standard announced by the WHO (10 μg/m^3). Therefore, the citizens of Karaj are exposed to high concentrations of $PM_{2.5}$.

Figure 4 shows the distribution of $PM_{2.5}$ concentrations in Karaj during the period of study. This figure shows that the sampling points 11, 12, 16, and 17 have the highest annual mean concentration. Due to highways and factories in these areas, their concentration is much higher than the standard. Furthermore, points 1, 2, 4, 7, and 9 had lower annual mean concentrations than other points

Table 1 shows the relationship between the mean annual of $PM_{2.5}$ concentrations with the meteorological parameters. As shown in Table 1, a positive relationship between mean annual $PM_{2.5}$ concentrations with temperature ($r = 0.497$, $P < 0.042$), humidity ($r = 0.206$, $P < 0.05$), and pressure ($r = 0.236$, $P < 0.05$) in the period of study at Karaj was observed. In addition, a negative relationship between UV radiation ($r = -0.271$, $P < 0.369$), cloud cover rate ($r = -0.276$, $P < 0.428$), and dew point ($r = -0.524$, $P < 0.19$) was observed in Karaj at 2018–2019.

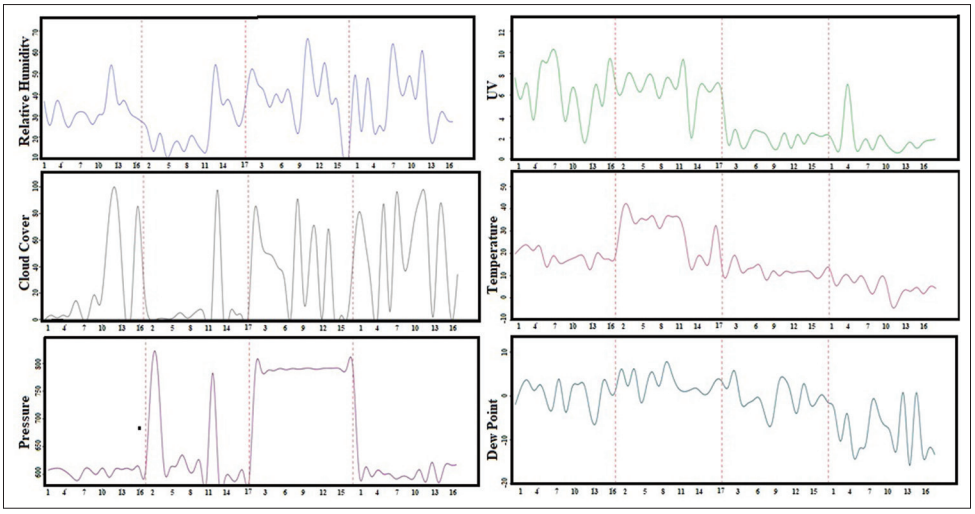

Figure 2: Average of temperature, dew point, cloud coverage, ultraviolet rate, relative humidity, and pressure seasonally in Karaj at 2018–2019

Discussion

Industrialization of the Asian continent in recent decades has created many environmental problems including the production of hazardous pollutants in air. On the other hand, meteorological parameters can be effects on amount of air pollutant. Factors such as traffic and burning fuels increase the concentration of pollutants in the air such as PM, CO, and NO. Furthermore, one of the influencing factors is inversion. There have been studies about the concentrations of particulate matter and correlation between them in air. In the study conducted by Asrari and Paydar *et al*., the maximum $PM_{2.5}$ concentration occurred in October.[22] Furthermore, in Miri *et al*.'s study, the maximum concentration for Tehran in winter was estimated.[23] On the other hands. Bahrami Asl and *et al*., in study at Tehran. In another study in Tehran, the maximum particle concentration in summer was reported.[24] Erener *et al*. reported that a peak of $PM_{2.5}$ concentration in the autumn is 44.45 μg/m^3 that was consistent with the results of our study.[25] In below, the relationship between parameters will be surveyed.

Temperature

According to a study which was done on more than 74 million people (74,225,200) in 13 countries at 1958, it turned out that extreme temperature accounts for <1% of all deaths, whereas low temperature ideally about 8% of all deaths includes. The highest deaths (66.6% of all) were happened at moderate and cold weather.[26] In the present study, there was a positive correlation between $PM_{2.5}$ concentration and temperature in Karaj at 2017–2018 (r = 0.497, P < 0.042). The results of this study are consistent with the study of Kioumourtzoglou.[27] Furthermore, Ansari and Ehrampoush found a positive relationship between temperature and $PM_{2.5}$ particle concentration (r = 0.42, P < 0.018). On the other hand, a Santi study showed that air temperature had a positive effect on air particle concentrations, and available concentration causes health effects, including deaths of people over 60 years of age.[28]Another study by Wang *et al*. showed that there was a positive relationship between temperature and $PM_{2.5}$ concentration.[29] Study results of Yao *et al*. confirm this.[30] Furthermore, Liu *et al*. observed that $PM_{2.5}$ concentration was positively correlated with air temperature in four seasons.[31]

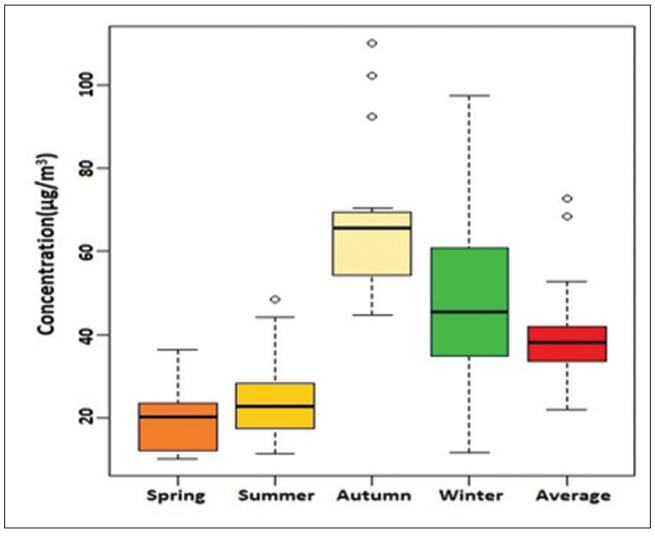

Figure 3: Box plot of $PM_{2.5}$ concentrations in Karaj city at 2018–2019

Relative humidity

Based on the results of this study, a positive relationship was observed between relative humidity and PM2.5 concentrations (r = 0.206, P < 0.05) in the period of study at Karaj. The results of this study were corresponded with the study of Gao *et al*.,[32] Bai *et al*.,[33] Lin *et al*.,[34] Ryu *et al*.,[35] Guo *et al*.,[36] Huang *et al*. and Hou *et al*.[37,38] However, Munir *et al*. in Mecca showed the negative correlation between moisture and $PM_{2.5}$ concentration.[39] Furthermore, Chence *et al*. found in their study a negative relationship between relative humidity and $PM_{2.5}$ concentration (r = 0.03 P < −0.79).[40]

Cloud coverage rate

The increased aerosols or pollutants in urban air caused by industrial or human activities affect air pollution rates.[41] Based on the results of this study, a negative relationship between $PM_{2.5}$ concentrations and the amount of cloud cover in Karaj at 2017–2018 was obtained (r = −0.276, P < 0.428). Whiteman *et al*. about the relationship of these two parameters as well reached to this conclusion.[42] Scottn Williams *et al*. state that cloud cover decreases in winter when the $PM_{2.5}$ concentration reaches its maximum which indicates a weak or negative correlation between these two parameters.[43] It should not be overlooked

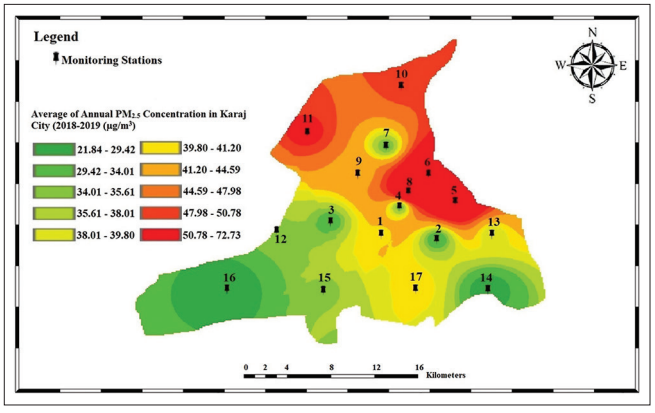

Figure 4: Distribution of average annual concentration of $PM_{2.5}$

Table 1: Correlation of between PM2.5 particles and meteorological parameter in Karaj at 2018-2019

	Temperature	Humidity	Pressure	UV	Cloud cover	Dew point
Correlation coefficient	0.0497	0.206	0.236	−0.271	−0.276	−0.524
P	0.042	0.05	0.05	0.362	0.428	0.19

UV: Ultraviolet

that the rate of cloud cover also affects the trend of precipitation changes, so that on rainy days, the particles are washed by the rain; as a result, the concentration of particles reaches its minimum value. Faridi *et al*. reached to this conclusion that $PM_{2.5}$ concentrations were negatively correlated with precipitation ($r = -0.19$, $P < 0.5$).[44] Following that, Ansari and Ehrampoush in 2017–2018 at Tehran Province found a negative relationship between $PM_{2.5}$ and precipitation ($r = -0.179$, $P < 0.127$).

Ultraviolet radiation

UV index in most countries of the world causes the most common cancers, including skin cancer. In Iran too, according to the cancer registry system most common during the years 2003–2004, skin cancer malignancy has been in the total population.[45,46] Based on contents, a negative relationship between $PM_{2.5}$ concentration and UV radiation was observed in Karaj during 2017–2018 ($r = -0.271$, $P < 0.362$). Barnard *et al.* in their study showed that air pollution can diminish the increase of UV levels.[47] In addition, Hoseinzadeh *et al*. reported a negative correlation between $PM_{2.5}$ and UV radiation. It was also expressed that the highest amount of UV radiation occurred in summer.[48]

Pressure

Correlation analysis in the present study showed that there was a positive relationship between air pressure (Pa) and $PM_{2.5}$ concentrations during the period of study ($r = 0.236$, $P < 0.05$). On cold days of the year, air pressure has increased; as a result, it increases the concentration of the particles. Panahi,[49] Yang *et al*.,[50] Lin and Zhu,[51] and Wu *et al*.[52] also came to this conclusion.

Dew point

The results of the present study have shown a negative correlation between $PM_{2.5}$ and dew point ($r = -0.524$ $P < 0.19$). Tai *et al*. showed a negative relationship between these two parameters in their study.[53] Furthermore, in another study by Li *et al*., this proved to be the concentration of $PM_{2.5}$, which was negatively correlated with dew point.[54]

Conclusions

The results of the current work indicated that Karaj citizens are exposed to $PM_{2.5}$ concentration at four times higher than the standard recommended by EPA. Therefore, citizens of Karaj are likely to be exposed to a variety of diseases caused by air pollution and their pollutants. Subsequently, it was found that temperature, relative humidity, and pressure increased the concentration of $PM_{2.5}$, and the rate of cloud cover, dew point, and UV reduces the concentration of them. According to the results of this study and high concentration of $PM_{2.5}$ in Karaj city and the harmful effects of these pollutants on the health of citizens, the need for better and accurate planning and follow-up of those officials for controlling or reducing this environmental dilemma is becoming more obvious.

Acknowledgments

This article is the result of MSc approved thesis, research project no. 33150. Thus, the authors are thankful for the funding provided by the Department of Environmental Health Engineering Research Center of Environmental Health Technology, Iran University of Medical Sciences.

Financial support and sponsorship

Iran University of Medical Sciences, Tehran, Iran.

Conflicts of interest

There are no conflicts of interest.

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