Original Article

Long-term Health Impact Assessment of $PM_{2.5}$ and PM_{10}: Karaj, Iran

Mohammad Hossein Vahidi[1], Farzad Fanaei[2], Majid Kermani[3,4]

[1]Department of Environmental Engineering, Islamic Azad University, West Tehran Branch, Tehran, Iran, [2]Student Research Committee, Iran University of Medical Sciences, Tehran, Iran, [3]Research Center of Environmental Health Technology, Iran University of Medical Sciences, Tehran, Iran, [4]Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

Abstract

Aim: This study was conducted to evaluate the effects of ambient concentrations of $PM_{2.5}$ and PM_{10} on the health-related aspects including the total mortality, respiratory and cardiovascular diseases, and hospital admissions due to respiratory and cardiovascular diseases in Karaj, Alborz Province, Iran, during 2012–2016 using the AirQ2.2.3 software. The effects of meteorological parameters on the $PM_{2.5}$ and PM_{10} levels were also investigated. **Materials and Methods:** Meteorological parameters, population, and the pollutant data were obtained from the Department of Environmental Protection, Karaj (Alborz, Iran). Statistical analysis was performed using the SPSS 24 software to study the relationship between the $PM_{2.5}$ and PM_{10} concentrations and the meteorological parameters. **Results:** Our results showed a direct relationship between the PM_{10} concentration and the temperature ($r = 0.34$, $P < 0.018$) and relative humidity ($r = 0.37$, $P < 0.5$). However, there was a negative relationship between the PM_{10} concentration with wind speed ($r < -0.328$, $P < 0.014$) and precipitation ($r < -0.179$, $P < 0.327$). Similarly, there was a direct relationship between the $PM_{2.5}$ concentration and the temperature ($r = 0.41$, $P < 0.014$) and relative humidity ($r = 0.37$, $P < 0.05$). On the other hand, a negative relationship was observed between the $PM_{2.5}$ concentration with wind speed ($r < -0.138$, $P < 0.010$) and precipitation ($r < -0.12$, $P < 0.201$). The total number of death, death due to cardiovascular and respiratory diseases, and hospital admissions due to cardiovascular and respiratory diseases were equal to 1619, 1096, 306, and 4822, respectively. **Conclusions:** The results of this study showed that the concentrations of $PM_{2.5}$ and PM_{10} should be reduced through applying the management strategies to improve the health of the residents in Karaj city.

Keywords: Air pollution, AirQ2.2.3 software, meteorological parameters, mortality, PM_{10}, $PM_{2.5}$

Introduction

The throughput of modern life has been influenced by air pollution, due to the advances in the sciences, so it can be said that there is absolutely no healthy air.[1] Nowadays, air pollution has passed over the boundaries of regions, villages, cities, and countries, and it has turned into a global concern.[2] Air pollution has natural causes, such as sandstorms, particulate pollution, or is caused due to the reasons that are entirely humanmade, such as the presence of cars, buses, and old trucks producing a lot of smoke.[3] Therefore, these agents present in the air produce pollutants.[4] Contaminants in the air contain dangerous and carcinogenic compounds, and the World Bank and the World Health Organization (WHO) have classified air pollution into the category of the carcinogens.[5] Totally 87% of the world population lives in countries where the level of air pollution is higher than the WHO guidelines.[6]

Access this article online

Quick Response Code:

Website: www.ijehe.org

DOI: 10.4103/ijehe.ijehe_16_20

The issue of air pollution is also linked to the internal policies of a country, so that the pollution problem can be controlled to a large extent if it is part of the state budget.[7] For instance, according to the report released by the World Bank, the cost associated with the death caused by air pollution is 0.57 of gross domestic product in Iran.[8] Fine particles are a serious threat that could endanger human health.[9] According to the

Address for correspondence: Dr. Majid Kermani, Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran.
E-mail: Kermani.m@iums.ac.ir

How to cite this article: Vahidi MH, Fanaei F, Kermani M. Long-term health impact assessment of $PM_{2.5}$ and PM_{10}: Karaj, Iran. Int J Env Health Eng 2020;9:8.

Received: 24-02-2020, **Accepted:** 15-06-2020, **Published:** 31-07-2020

WHO, nearly 7 million deaths and 3.7 million premature deaths occur in the rural and urban areas annually due to exposure to these fine particles.[10] Understanding the health effects following exposure to air pollution fosters our knowledge on air pollution-associated diseases.[11] However, air pollution can influence the skin, eyes, or other body systems. However, it mostly influences the respiratory system. Deaths due to heart disease, lung cancer, and chronic obstructive pulmonary disease most likely result from the exposure to the small particles. Although other factors influence them, one should not overlook the effect of air pollution.[12] The vulnerability of some people, especially sensitive age groups, is much higher than the others when they are exposed to air pollution.[13] Studies conducted over the past two decades have shown that one in every eight deaths occurs due to air pollution.[14] It is estimated that about 10,000 people die annually due to air pollution in Iran.[15] Meteorological parameters such as wind speed, relative humidity, annual precipitation, and air temperature can influence the particle concentrations positively and negatively.[16] Ansari and Ehrampoush studied the effect of the change in the trend of meteorological parameters by the $PM_{2.5}$ concentration in 2017–2018. They found a weak correlation between the $PM_{2.5}$ concentration with the mean monthly temperature ($r = 4$, $P < 0.05$) and the mean relative humidity ($r = 0.37$, $P < 0.05$).[17] Zhang *et al*. showed that the relative humidity and precipitation are negatively correlated with the concentration of air particles, and temperature and wind speed are positively correlated with the concentration of particles in the air.[18] In India, the concentration of particles has been reported to have a negative effect on the wind speed and relative humidity.[19] Aguilera Sammaritano *et al*., in a study conducted in Austria, reported the highest concentration of air particles in the winter.[20]

According to the abovementioned reasons, this study was conducted to (i) investigate the effect of the meteorological parameters including the temperature, relative humidity, wind speed, and precipitation on the concentrations of $PM_{2.5}$ and PM_{10} in the ambient air of Karaj (Alborz, Iran) and (ii) estimate the total mortality, mortality due to cardiovascular and respiratory diseases, and hospital admissions due to respiratory and cardiovascular diseases (HARD and HACD) using the $AirQ_{2.2.3}$ software (World Health Organization) during 2021–2016 in Karaj, Alborz Province, Iran.

Materials and Methods

Geographical location of the study area

Karaj, as a bustling metropolis in the center of Alborz Province with a population of nearly 3 million people, is located at 48 km northwest of Tehran (Capital of Iran). The city has 16 km length and is 1300 m above the sea level, with a total area of 175.5 km^2. It is located at the latitude of 35.4845 and longitude of 51.030 in the northern hemisphere. In general, its climate is similar to other parts of Alborz Province so that, in cold seasons, the weather is influenced by the north, northwest, and west, especially southwest climates with atmospheric rainfall from November and August continuing until May. It experiences a huge volume of public and personal transportation daily due to its communication path with more than 15 provinces of Iran and suffers from severe air pollution where the emission by the cars contributes to almost 75% of the pollution.

Air pollution data

The air quality data were collected from the Department of Environmental Protection (Karaj, Alborz, Iran) measured by the Transportation, Air Quality, and Climate Change Committee stations from July 2012 to February 2016. Urban areas of the Karaj city are divided into 14 districts for urban services. Three citywide air pollutant-monitoring stations monitor the air quality daily [Figure 1]. Daily concentrations of $PM_{2.5}$ and PM_{10} were obtained from the Department of Environmental Protection (Karaj, Alborz, Iran) for 5 years, and EXCEL software was used to remove the invalid data. Then, the valid data were entered into the software. The $AirQ_{2.2.3}$ protocol was followed for calculating the daily mean concentrations of $PM_{2.5}$ and PM_{10}.

$AirQ_{2.2.3}$ Software

The WHO has recommended the use of $AirQ_{2.2.3}$ software to estimate the health effects of long- and short-term exposure to air pollutants. All the calculations performed by the $AirQ_{2.2.3}$ software were based on the methodologies and functions regarding the concentrations of $PM_{2.5}$ and PM_{10}. The $AirQ_{2.2.3}$ software calculates the total mortality, respiratory mortality, hospital admissions due to respiratory disease, mortality caused by cardiovascular diseases, hospital admissions due to cardiovascular diseases related to being exposed to the PM_{10}, and total mortality related to being exposed to the $PM_{2.5}$. This software builds a relationship between the air quality data in various ranges of concentration with epidemiological

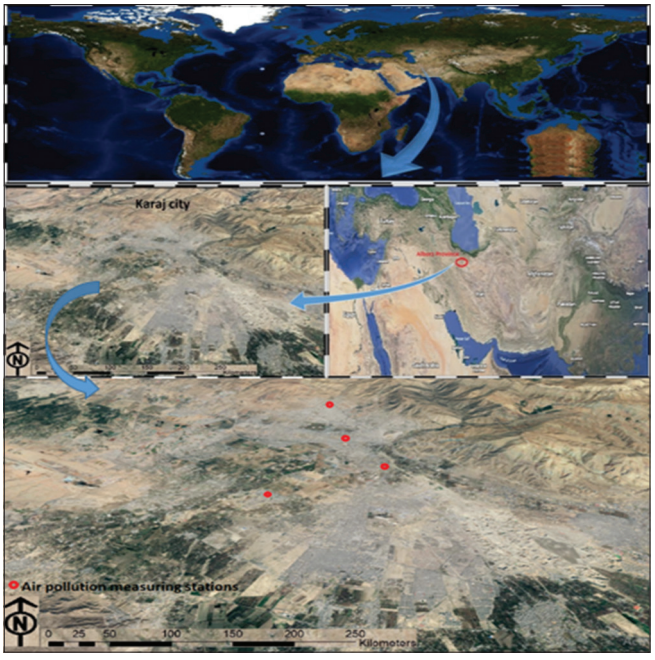

Figure 1: Map of the study area

parameters such as relative risk (RR), baseline incidence (BI in 105 people), and attributable proportion (AP) and shows its results as the mortality. The AP is calculated according to the following formula by the software:

where RR is the relative risk reflecting the rate of a pollutant's effect on human health as a result of an increase in the pollutant's concentration and P(c) is the proportional population in the target group. Notably, the attributable values for the population contract (IE) were calculated through the following formula before the estimation of BI for population target:

$IE = BI \times AP$.

After calculation of the population size, the number of cases attributable to the exposure (NE) can be estimated based on the following formula: $NE = IE \times N$.

AirQ software is consisted of two analysis parts: estimating the number of health consequences attributed to air pollution and estimating the burden attributed to air pollution using the age table method. In short, AirQ is a set of pages or screens where the information is entered and the health effects are estimated. The four main pages in the first part of AirQ are (1) supplier page related to the information organization that is responsible for data import, (2) location page where the specific information of each pollutant is entered before recording the air quality information on this page, (3) air quality data where the concentration data are entered in this page, and (4) parameter page showing the parameters required to evaluate the effects (including the health consequences, threshold, RR, and the incidence of the desired outcome in the community under study).

Statistical analysis

In the present study, the relationship between the $PM_{2.5}$ and PM_{10} concentrations with the meteorological parameters such as the relative humidity, temperature, precipitation, and wind speed was calculated. On the other hand, the total mortality, death due to cardiovascular and respiratory diseases, HARD, and HACD were investigated using the $AirQ_{2.2.3}$ software. In the first part of the study, the Pearson correlation coefficient was calculated by the SPSS (version 24) software Statistical Package for the Social Sciences (SPSS) to determine the relationship between the meteorological parameters and concentrations of the particulate matters ($PM_{2.5}$ and PM_{10}). The mortality rate was determined by the $AirQ_{2.2.3}$ software (provided by the WHO). The graphs used in this study were also obtained from the EXCEL and R software.

Results

Meteorological parameters and concentration of the pollutants

Figure 2 shows the average monthly temperature (°C), total monthly precipitation (cm), mean wind speed (m/s), and average relative humidity (%) in Karaj city from 2012 to 2016. The minimum and maximum relative humidity occurred in May and November (33.82%–64.51%), the minimum and maximum temperatures occurred in December and June (3.82–28.1), the minimum and maximum wind speed belonged to July and May (10–17.4), and minimum and maximum precipitation were in March and July (4.23°C–0.05°C), as shown in Figure 2. According to Figure 2, the mean annual and standard deviation were equal to 16.03 (±8.81), 47.19% (±10.16), 13.08 (s 2.41), and 16.9 (±19.78) mm for temperature, relative humidity, wind speed, and pressure, respectively. The relationship between these parameters will be discussed in the Discussion Section.

Table 1 shows the relationship between the mean annual concentrations of $PM_{2.5}$ and PM_{10} with the meteorological parameters. As shown in Table 1, there was a positive relationship between the mean annual PM_{10} and PM_{10} concentrations with the temperature ($r = 0.34$, $P < 0.018$, and $r = 0.41$, $P < 0.14$) and humidity ($r = 0.31$, $P < 0.05$, and $r = 0.37$, $P < 0.05$), respectively, during the study period in Karaj city. In addition, a negative relationship was observed between the precipitation with PM_{10} and $PM_{2.5}$ concentrations ($r = -0.179$, $P < 0.327$, and $r = -0.12$, $P < 0.201$) and wind speed with PM_{10} and $PM_{2.5}$ concentrations ($r = -0.328$, $P < 0.014$, and $r = -0.138$, $P < 0.010$), respectively, in Karaj city during 2012–2016.

Figure 3 shows the changes in the $PM_{2.5}$ and PM_{10} concentrations. As demonstrated in Figure 3, the highest and lowest mean concentrations of PM_{10} were observed in May 2012 (123.491) and March 2013 (35.41 μg/m³), respectively. Furthermore, for $PM_{2.5}$, these values were observed in May 2012 (61.75 μg/m³) and March 2014 (17.57 μg/m³), respectively. Furthermore, during the study period (2012–2016), the concentration of PM_{10} particles was equal to 64.26 μg/m³ and it was equal to 32.41 μg/m³ for $PM_{2.5}$ particles.

Mortality attributed to being exposed to the particles

Based on the AirQ2.2.3 model estimates, the total number of deaths, deaths due to cardiovascular and respiratory diseases, HARD, and HACD due to the exposure to $PM_{2.5}$ and PM_{10} particles were calculated in Karaj city during the study period, as shown in Table 2. Approximately 1619 total deaths occurred due to the exposure to PM_{10} (RR = 1.06), and 1096, 306, 4822, and 1895 death cases were reported due to cardiovascular diseases, respiratory diseases, HARD,

Table 1: Bivariate correlations between $PM_{2.5}$ and PM_{10} with climatic parameter in Karaj from 2012-2016

PM_{10}	Precipitation	Temperature	Wind speed	Reality humidity
R	−0.179	0.34	−0.328	0.31
P	0.327	0.018	0.014	0.05
$PM_{2.5}$	Precipitation	Temperature	Wind Speed	Reality humidity
R	−0.12	0.41	−0.138	0.37
P	0.201	0.014	0.010	0.05

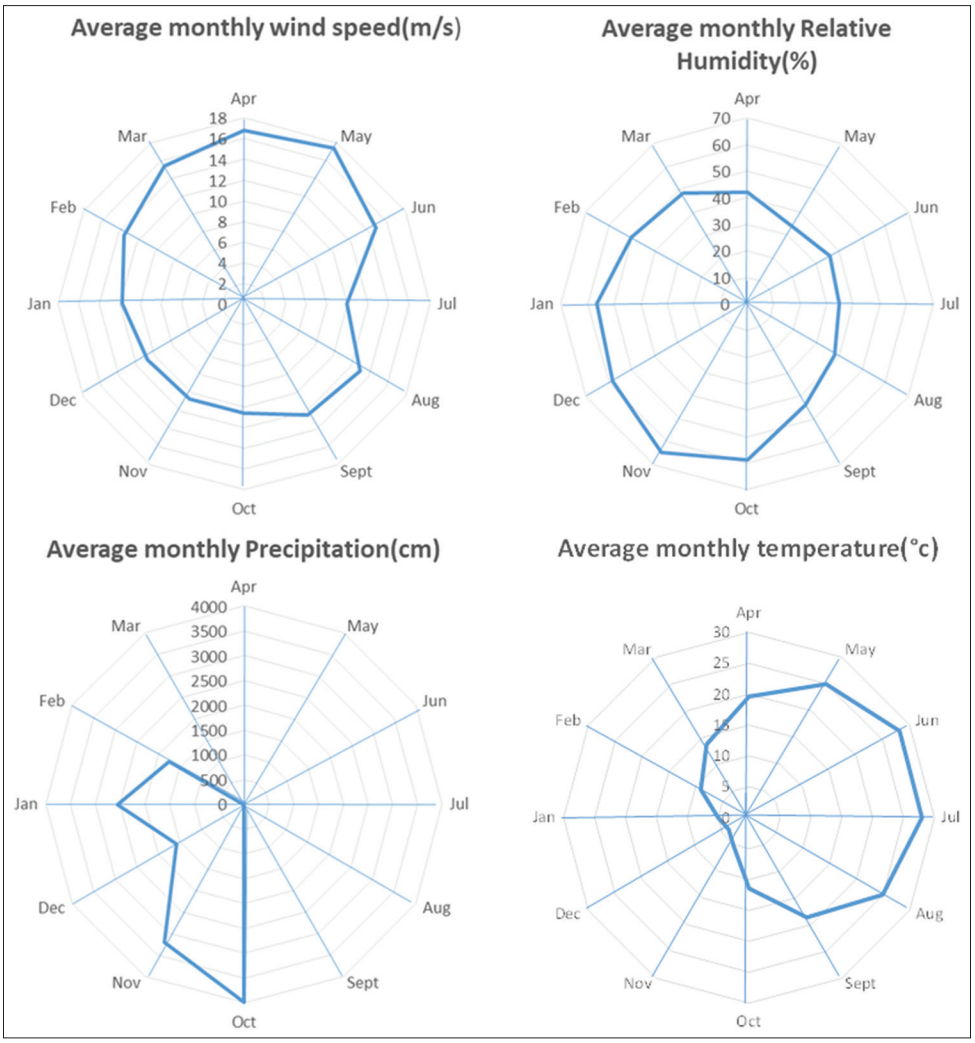

Figure 2: Average monthly temperature, total monthly precipitation, average monthly wind speed, and average monthly relative humidity for the period of study

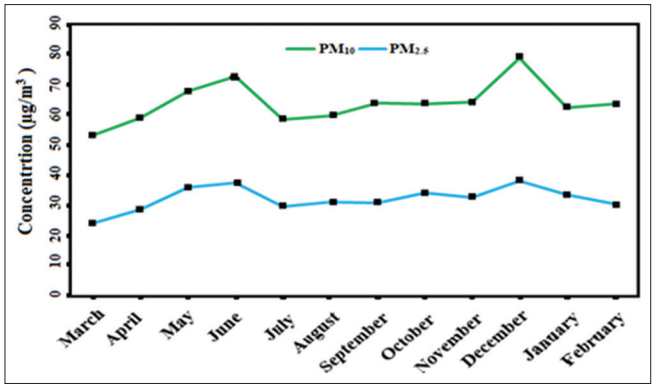

Figure 3: Average monthly concentrations of $PM_{2.5}$ and PM_{10} in ambient air of the study area (2012–2016)

and HACD, respectively, during the study period in Karaj city (2012–2016). Furthermore, 436 deaths per 100,000 people in Karaj city were related to the exposure to $PM_{2.5}$ particles during the study period, which is eight times the average death toll in the world.

Discussion

Industrialization in Asian countries has created many environmental problems including the production of hazardous pollutants in the air in the recent decades. On the other hand, meteorological parameters can influence the amount of air pollution. The concentration of airborne particulate matters depends on several factors including the temperature, humidity, precipitation, and wind speed. It can be said that the concentration of particles is higher in the cold seasons of the year due to more fuel consumption, heating, and stagnant wind speeds. The results of this study are consistent with the study conducted by Ghanbari Ghozikali *et al*., who reported the highest concentration of particles in the winter.[21] Miri *et al*. also found a higher concentration of $PM_{2.5}$ in the winter than the other seasons.[22] In addition, Mohammadi *et al*., in a study, showed the highest seasonal concentration of the particles in the winter.[23] However, Bahrami reported the highest concentration of the particles during the summer when the temperature was at the maximum point and the wind speed

Table 2: Estimated number of excess, relative risk, and baseline incidence of endpoint mortality due to PM_{10} exposure, Karaj (2012-2016)

	Total mortality	Cardiovascular mortality	Respiratory mortality	Hospital admissions cardiovascular disease	Hospital admissions respiratory disease
2012	397	247	73	467	1208
2013	349	303	69	397	953
2014	291	182	55	344	889
2015	289	180	54	339	875
2016	293	184	55	348	897
RR	1.06	1.009	1.013	1.008	1.009
BI	543.5	231	48.8	436	1260

RR: Relative risk, BI: Baseline incidence

was at the lowest level. Of course, dust storms also occur in the summer.[24] The results of the study showed that the residents of Karaj city are exposed to the fine particles (susceptible to air pollution) 3.5 times more than the WHO guidelines (10 $\mu g/m^3$).

The Relationship between the $PM_{2.5}$ and PM_{10} and Meteorological Parameters

In this descriptive-analytical study, the relative humidity, temperature, precipitation, and wind speed were investigated among the factors influencing the particle concentration. However, one should not overlook the effect of other factors. As shown in Table 1, there was a positive relationship between the PM_{10} and $PM_{2.5}$ concentrations and temperature in the present study ($r = 0.34$, $P < 0.018$, and $r = 0.41$, $P < 0.014$), respectively, which is consistent with the study by Achakulwisut ($r = 0.42$, $P < 0.5$).[25] In addition, Zhang *et al*. observed that $PM_{2.5}$ and PM_{10} concentrations were significantly and positively associated with the rest of the seasons except the winter.[26] In some cases, particle concentrations and ambient temperatures can be inversely correlated. For instance, Wang showed a negative relationship between the particles and ambient temperature.[27] Xue *et al*. found a positive relationship between the seasonal mean $PM_{2.5}$ and PM_{10} concentrations and temperature.[28] In this study, the concentration of PM_{10} particles changed seasonally with respect to the ambient air temperature in a direct but not very positive relationship. In addition, Hou *et al*. found a positive relationship between the PM_{10} concentration and temperature.[29] Furthermore, our results showed a positive relationship between the $PM_{2.5}$ and PM_{10} concentrations with monthly mean relative humidity ($r = 0.31$, $P < 0.5$, and $r = 0.37$, $P < 0.05$), respectively, in Karaj city during 2012–2016, which is consistent with the studies by Ansari and Ehrampoush,[17] Alvarez *et al*.,[30] and Huang *et al*.[31] Lou *et al*. investigated the effect of relative humidity on the $PM_{2.5}$ and PM_{10} concentrations over 2 years and showed that the relative humidity was positively associated with the particle concentration.[32] However, Zhang, in a study conducted in Beijing, found that the relative humidity had a negative effect on the particulate matter and PM_{10} concentration.[33] An increase in the volume of the clouds in the air reduces the amount of sunlight, and as a result, the temperature drops and subsequently the rainfall or atmospheric rainfall increases.[34] Topographic conditions in the area also influence the amount of sunlight and the concentration of the pollutants.[35] However, in this study, a weak or inverse relationship was observed between the $PM_{2.5}$ and PM_{10} concentrations and precipitation during the study period (2012–2016) in Karaj city, which is in line with the study by Erener *et al*., regarding the concentrations of PM_{10} and $PM_{2.5}$ ($r = -0.18$ $P < 0.314$, and $r = -0.19$, $P < 0.241$).[36] Rosenfeld *et al*. also found a negative relationship between the particle concentration and precipitation ($r = -0.19$, $P < 0.5$).[37] The average rainfall was equal to 16.92 mm in Karaj city during the study period (2012–2016), with an average downward trend. The results of this study are consistent with the study by Lin *et al*., who showed that the $PM_{2.5}$ and PM_{10} concentrations were inversely and negatively associated with the precipitation.[38] Statistical analysis revealed a negative relationship between the $PM_{2.5}$ and PM_{10} concentrations with wind speed ($r = -0.138$, $P < 0.010$, and $r = -0.328$, $P < -0.014$), respectively. Similar to the study by Lin *et al*., a negative relationship was observed between the wind speed and particle concentration.[39] Most of the winds also occurred in the northwest of Karaj city during the study period. Wind speed can also influence the particle concentrations through eliminating the particulate matters, resulting in the reduction of the particle concentrations, as reported in the study by Jafari *et al*.[40]

Total mortality

The number of deaths reported in this study was higher than those of the study by Mohammadi *et al*., (409 deaths). Although, this study has been conducted over 1 year.[23] The highest number of deaths in our study reported over 1 year occurred in 2012 (397 deaths). Orru *et al*. reported 296 premature deaths due to the exposure to the $PM_{2.5}$ particles and 312 premature deaths due to the exposure to the PM_{10} particles per 100,000 people in Tallinn city (Estonia).[41] Results of a study carried out in Tehran on four air pollutants (SO_2, NO_2, O_3, and PM_{10}) introduced the PM_{10} as the most frequent cause of early death and respiratory diseases.[42] Studies conducted in Tabriz and Shiraz cities have also indicated the high potential of PM_{10} for mortality and morbidity.[43,44] The mortality rate in our study was lower than that of the study conducted in Tehran possibly due to the fact that Tehran has a higher density, and as a result, more people are exposed to the particles than Karaj city. Furthermore, results of a study conducted in Tehran

showed that 5073 deaths occurred due to the exposure to the $PM_{2.5}$ particles.[45]

Cardiovascular diseases

In addition, an association was observed between the PM_{10} concentrations and cardiovascular disease. Xie *et al*. reported a nonlinear relationship between the PM_{10} concentration and mortality caused by cardiovascular diseases.[46] As illustrated in Table 2 4, 1096 people may have died due to the exposure to the PM10 in Karaj city during 2012–2016. Cardiovascular diseases vary in different age groups , and it can be said that the particles are the main cause of cardiovascular diseases.[47] Mohammadi *et al*. reported 543 deaths due to cardiovascular diseases as a result of being exposed to the PM_{10}.[48]

Respiratory diseases

Our results showed that 60% of deaths in Karaj city were due to respiratory and heart problems.[49] Studies conducted in San Diego, Chile, and Hong Kong have reported a significant association between air pollution and respiratory and cardiovascular diseases.[50] Gholizadeh *et al*. reported 7477 deaths due to respiratory diseases in Tehran city during 2002–2005.[51] The development of respiratory diseases also depends on the topographic conditions of the area. For example, proximity to the deserts in some cities can increase the burden of these diseases due to occurrence of the thunderstorms.[52] In the present study, 306 deaths (r = 1.013) occurred due to respiratory diseases during the study period in Karaj city. Godarzi *et al*, in a study reported that 95% of deaths were due to respiratory diseases.[53]

Hospital admissions due to respiratory and cardiovascular diseases

In the present study, 4822 and 1895 death cases were due to the HARD and HACD, respectively, in Karaj city during 2012–2016. Goudarzi *et al*. showed a significant relationship between the particle concentrations with HARD and HACD.[53] Geravandi *et al*. reported 1438, 1945, and 1393 death cases due to the HARD, respectively, in Ahvaz city during 2010–2012.[54]

Conclusions

The results of the current study indicated that the residents of Karaj city are 3.2 and 2–3 times more likely to be exposed to the $PM_{2.5}$ and PM_{10} particles than the Environmental Protection Agency standard. Subsequently, it was found that the temperature and relative humidity increased the concentrations of $PM_{2.5}$ and PM_{10} and the rate of precipitation and wind speed reduced their concentration. Therefore, the residents of Karaj city are likely to be exposed to a variety of diseases caused by air pollution and its pollutants. According to the results of this study, high concentrations of $PM_{2.5}$ and PM_{10}, and the harmful effects of these pollutants on the health of residents in Karaj city, there is a need for better and accurate planning and follow-up by the officials to control or reduce this environmental dilemma.

Acknowledgments

This article is the result of MSc approved thesis, Research Project No. 22840404962011. Thus, the authors are thankful for the funding provided by the Department of Environmental Health Engineering, Islamic Azad University, Tehran Branch, Ethics Code No. 22840404962011.

Financial support and sponsorship

Islamic Azad University, Tehran Branch, Tehran, Iran.

Conflicts of interest

There are no conflicts of interest.

References

1. Gouveia N, Mascolli MA. Air pollution: An important threat to infant health. BJOG 2018;125:1279.
2. Concentrations and mortality due to short- and long-term exposure to PM2.5 in a megacity of Iran (2014–2019).
3. Nabizadeh R, Yousefi M, Azimi F. Study of particle number size distributions at Azadi terminal in Tehran, comparing high-traffic and no traffic area. MethodsX 2018;5:1549-55.
4. Hajizadeh Y, Jafari N, Mohammadi A, Momtaz SM, Fanaei F, Abdolahnejad A. Environmental Science and Pollution Research 2020;1614-749.1-11.
5. World Health Organization. WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005: Summary of Risk Assessment. Geneva: World Health Organization; 2006.
6. Paul KC, Haan M, Mayeda ER, Ritz BR. Ambient air pollution, noise, and late-life cognitive decline and dementia risk. Annu Rev Public Health 2019;40:203-20.
7. Smith A. Integrated Pollution Control: Change and Continuity in the UK Industrial Pollution Policy Network. Rutledge; 2018.
8. Tavakoly M. Estimation of Acute air Pollution Conditions in Tehran due to the Concentration of Ozone and Particulate Matter Using Artificial Neural Network. Masters Thesis], Ministry of Science, Research, Technology Tarbiat Modares; 2015.
9. Abdolahnejad A, *et al*. Mortality and morbidity due to exposure to ambient NO2, SO2, and O3 in Isfahan in 2013–2014. Int J Pre Med 2018;9:201-10.
10. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu NN, *et al*. The Lancet Commission on pollution and health. Lancet 2018;391:462-512.
11. World Health Organization. Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease. World Health Organization; 2016.
12. Schraufnagel DE, Balmes JR, Cowl CT, De Matteis S, Jung SH, Mortimer K, *et al*. Air pollution and noncommunicable diseases: A review by the Forum of International Respiratory Societies' Environmental Committee, Part 2: Air pollution and organ systems. Chest 2019;155:417-26.
13. Shi Y, Zhao T, Yang X, Sun B, Li Y, Duan J, *et al*. PM2. 5-induced alteration of DNA methylation and RNA-transcription are associated with inflammatory response and lung injury. Sci Total Environ 2019;650:908-921.
14. Mirhosseini SH, Birjandi M, Zare MR, Fatehizadeh A. Analysis of particulate matter (PM 10 and PM 2.5) concentration in Khorramabad city. Int J Environ Health Eng 2013;2:3.
15. Bayat R, Ashrafi K, Shafiepour Motlagh M, Hassanvand MS, Daroudi R, Fink G, *et al*. Health impact and related cost of ambient air pollution in Tehran. Environ Res 2019;176:108547.
16. Gui K, Che H, Wang Y, Wang H, Zhang L, Zhao H, *et al*. Satellite-derived PM2.5 concentration trends over Eastern China from 1998 to 2016: Relationships to emissions and meteorological parameters. Environ Pollut 2019;247:1125-33.
17. Ansari M, Ehrampoush MH. Meteorological correlates and AirQ+ health risk assessment of ambient fine particulate matter in Tehran, Iran.

Environ Res 2019;170:141-50c.
18. Zhang H, Wang Y, Hu J, Ying Q, Hu XM. Relationships between meteorological parameters and criteria air pollutants in three megacities in China. Environ Res 2015;140:242-54.
19. Guttikunda SK, Nishadh K, Jawahar P. Air pollution knowledge assessments (APnA) for 20 Indian cities. Urban Climate 2019;27:124-41.
20. Aguilera Sammaritano M, Bustos DG, Poblete AG, Wannaz ED. Elemental composition of PM2.5 in the urban environment of San Juan, Argentina. Environ Sci Pollut Res Int 2018;25:4197-203.
21. Ghanbari Ghozikali M, Heibati B, Naddafi K, Kloog I, Oliveri Conti G, Polosa R, *et al*. Evaluation of chronic obstructive pulmonary disease (COPD) attributed to atmospheric O3, NO2, and SO2 using Air Q Model (2011-2012 year). Environ Res 2016;144:99-105.
22. Miri M, Derakhshan Z, Allahabadi A, Ahmadi E, Conti GO, Ferrante M, *et al*. Mortality and morbidity due to exposure to outdoor air pollution in Mashhad metropolis, Iran. The AirQ model approach. Environ Res 2016;151:451-7.
23. Mohammadi A, Mousavi S, Nemati S, Momtaz S, Abdolahnejad A, Miri M. Health effects of airborne particulate matter related to traffic in Urmia, north-west Iran. 2019;4:99-108.
24. Bahrami Asl F, Leili M, Vaziri Y, Salahshour Arian S, Cristaldi A, Oliveri Conti G, *et al*. Health impacts quantification of ambient air pollutants using AirQ model approach in Hamadan, Iran. Environ Res 2018;161:114-21.
25. Achakulwisut P, Anenberg SC, Neumann JE, Penn SL, Weiss N, Crimmins A, *et al*. Effects of increasing aridity on ambient dust and public health in the U.S. Southwest under climate change. Geohealth 2019;3:127-44.
26. Zhang P, Hong B, He L, Cheng F, Zhao P, Wei C, *et al*. Temporal and spatial simulation of atmospheric pollutant PM2. 5 changes and risk assessment of population exposure to pollution using optimization algorithms of the back propagation-artificial neural network model and GIS. Int J Environ Res Public Health 2015;12:12171-95.
27. Wang J, Ogawa S. Effects of meteorological conditions on PM2. 5 concentrations in Nagasaki, Japan. Int J Environ Res Public Health 2015;12:9089-101.
28. Xue W, Zhan Q, Zhang Q, Wu Z. Spatiotemporal variations of particulate and gaseous pollutants and their relations to meteorological parameters: The case of Xiangyang, China. Int J Environ Res Public Health 2019;17:136.
29. Hou X, Fei D, Kang H, Zhang Y, Gao J. Seasonal statistical analysis of the impact of meteorological factors on fine particle pollution in China in 2013–2017. 2018;93:677-98.
30. Alvarez H, Myers O, Weigel M, Armijos R. The value of using seasonality and meteorological variables to model intra-urban PM2. 5 variation 2018;182:1-8.
31. Huang J, Li G, Qian X, Xu G, Zhao Y, Huang J, *et al*. The burden of ischemic heart disease related to ambient air pollution exposure in a coastal city in South China. Environ Res 2018;164:255-61.
32. Lou C, Liu H, Li Y, Peng Y, Wang J, Dai L. Relationships of relative humidity with PM 2.5 and PM 10 in the Yangtze River Delta, China. 2017;189:582.
33. Zhang Y. Dynamic effect analysis of meteorological conditions on air pollution: A case study from Beijing. Sci Total Environ 2019;684:178-85.
34. Williamson S, Hik D, Gamon J, Jarosch A, Anslow F, Clarke G, Rupp T. Spring and summer monthly MODIS LST is inherently biased compared to air temperature in snow covered sub-Arctic mountains 2017;189:14-24.
35. Sun X, Luo X, Xu J, Zhao Z, Chen Y, Wu L, Chen Q, Zhang D. Spatiol temporal variations and factors of a provincial PM 2.5 pollution in eastern China during 2013–2017 by geostatistics 2019;9:1-10.
36. Erener A, Sarp G, Yıldırım Ö. Seasonal Air Pollution Investigation and Relation Analysis of Air Pollution Parameters to Meteorological Data (Kocaeli/Turkey). Conference of the Arabian Journal of Geosciences Springer; 2019. p. 355-8.
37. Rosenfeld D, Woodley W, Axisa D, Freud E, Hudson J, Givati A. Aircraft measurements of the impacts of pollution aerosols on clouds and precipitation over the Sierra Nevada 2008;113(D15):1-23.
38. Lin G, Fu J, Jiang D, Wang J, Wang Q, Dong D. Spatial variation of the relationship between PM 2.5 concentrations and meteorological parameters in China. Biomed Res Int 2015;2015:684618.
39. Lelieveld J, Evans JS, Fnais M, Giannadaki D, Pozzer A. The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature 2015;525:367-71.
40. Jafari N, Ebrahimi A, Mohammadi A, Hajizadeh Y, Abdolahnejad A. Evaluation of seasonal and spatial variations of Air Quality Index and ambient air pollutants in Isfahan using Geographic Information System 2017;2:263-72.
41. Orru H, Teinemaa E, Lai T, Tamm T, Kaasik M, Kimmel V, *et al*. Health impact assessment of particulate pollution in Tallinn using fine spatial resolution and modeling techniques. Environ Health 2009;8:7.
42. Naddafi K, Hassanvand MS, Yunesian M, Momeniha F, Nabizadeh R, Faridi S, *et al*. Health impact assessment of air pollution in megacity of Tehran, Iran. Iranian J Environ Health Sci Eng 2012;9:28.
43. Bahrami Asl F, Kermani M, Aghaei M, Karimzadeh S, Arian S, Shahsavani A, Goudarzi G. Estimation of diseases and mortality attributed to NO 2 pollutant in five metropolises of Iran using AirQ model in 2011-2012.2015;24:239-49.
44. Gharehchahi E, Mahvi AH, Amini H, Nabizadeh R, Akhlaghi AA, Shamsipour M, *et al*. Health impact assessment of air pollution in Shiraz, Iran: A two-part study. J Environ Health Sci Eng 2013;11:11.
45. Yarahmadi M, Hadei M, Nazari SS, Conti GO, Alipour MR, Ferrante M, *et al*. Mortality assessment attributed to long-term exposure to fine particles in ambient air of the megacity of Tehran, Iran. Environ Sci Pollut Res Int 2018;25:14254-62.
46. Xie W, Li G, Zhao D, Xie X, Wei Z, Wang W, *et al*. Relationship between fine particulate air pollution and ischaemic heart disease morbidity and mortality. Heart 2015;101:257-63.
47. Zhang W, Lin S, Hopke PK, Thurston SW, van Wijngaarden E, Croft D, *et al*. Triggering of cardiovascular hospital admissions by fine particle concentrations in New York state: Before, during, and after implementation of multiple environmental policies and a recession. Environ Pollut 2018;242:1404-16.
48. Mohammadi A, Azhdarpoor A, Shahsavani A, Tabatabaee H. Investigating the health effects of exposure to criteria pollutants using AirQ2. 2.3 in Shiraz, Iran. 2015;16:1035-43.
49. Hamid V. Health impact assessment of the ambient PM. Iran J Res Environ Health Spring 2019;5:65-76.
50. Sonego M, Pellegrin MC, Becker G, Lazzerini M. Risk factors for mortality from acute lower respiratory infections (ALRI) in children under five years of age in low and middle-income countries: A systematic review and meta-analysis of observational studies. PLoS One 2015;10:e0116380.
51. Gholizadeh M, Farajzadeh M, Darand M. The correlation between air pollution and human mortality in Tehran. Hakim Res J 2009;12:65-71.
52. Xu Q, Li X, Wang S, Wang C, Huang F, Gao Q, *et al*. Fine particulate air pollution and hospital emergency room visits for respiratory disease in urban areas in Beijing, China, in 2013. PLoS One 2016;11:e0153099.
53. Goudarzi G, Geravandi S, Idani E, Hosseini SA, Baneshi MM, Yari AR, *et al*. An evaluation of hospital admission respiratory disease attributed to sulfur dioxide ambient concentration in Ahvaz from 2011 through 2013. Environ Sci Pollut Res Int 2016;23:22001-7.
54. Geravandi S, Sicard P, Khaniabadi YO, De Marco A, Ghomeishi A, Goudarzi G, *et al*. A comparative study of hospital admissions for respiratory diseases during normal and dusty days in Iran. Environ Sci Pollut Res Int 2017;24:18152-9.