Original Article

Access this article online

Quick Response Code:

Website: www.jehp.net

DOI: 10.4103/jehp.jehp_166_16

Cardiovascular, respiratory, and total mortality ascribed to PM_{10} and $PM_{2.5}$ exposure in Isfahan, Iran

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Abstract:

BACKGROUND: Air pollution is an important environmental issue due to its proven serious impacts on human health. The aim of this study was to estimate the attribution of particulate matter with an aerodynamic diameters of ≤ 2.5 and 10 ($PM_{2.5}$ and PM_{10}) in the prevalence of cardiovascular and respiratory diseases and premature deaths in Isfahan in 2013–2014.

MATERIALS AND METHODS: This descriptive, ecological study was conducted to assess health impacts of $PM_{2.5}$ and PM_{10} on the population using Air $Q_{2.2.3}$ software, suggested by the World Health Organization (WHO).

RESULTS: The results showed that the annual mean, winter mean, summer mean, and the 98 percentile of PM_{10} concentration in Isfahan were 108, 100, 116, and 264 μg/m^3, respectively. The number of deaths per year related to $PM_{2.5}$ was 670 and that for PM_{10} was 713 cases. The number of annual deaths due to cardiovascular and respiratory diseases attributed to PM_{10} was 316 and 68 cases, respectively.

CONCLUSION: The results of this study revealed that about 44.3% of total annual death due to cardiovascular diseases and 9.55% of that due to respiratory diseases were attributed to PM_{10} exposure. In the other word, residents were exposed to $PM_{2.5}$ and PM_{10} concentrations higher than the WHO guidelines which caused a notable increase in the rate of mortality.

Keywords:

Air pollution, AirQ software, Isfahan, mortality, $PM_{2.5}$ and PM_{10}

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Received: 30-01-2017
Accepted: 16-09-2017

Introduction

Air pollution is considered one of the most important environmental issues due to its well-known serious impacts on human health. In the recent years, health concerns of urban air polluted with emerging pollutants such as O_3, NO_2, and particulate matters (PMs)[1,2] are exist in both developed and developing countries.[3] In the recent two decades, epidemiological studies have shown that air pollution causes cardiovascular and respiratory problems, lung function defect, chronic bronchitis, and death.[1] According to a study carried out by the World Health Organization (WHO) throughout 1100 cities in 91 countries from 2003 to 2010, the greatest concentration of PM_{10} was reported in Ahvaz and Ulan Bator (Mongolia), respectively, amounting 372 and 279 μg/m^3.[4] They have reported that 11 cities in the world had an annual PM_{10} concentration above 200 μg/m^3 and only some of Canadian and American cities had the concentrations <20 μg/m^3.[5] Among of air pollutants, PM has particular importance due to its specific characteristics such as composition and size distribution. This pollutant has very high surface area and can adsorb a wide range of organic materials such as polycyclic aromatic hydrocarbons,

How to cite this article: Abdolahnejad A, Jafari N, Mohammadi A, Miri M, Hajizadeh Y, Nikoonahad A. Cardiovascular, respiratory, and total mortality ascribed to PM_{10} and $PM_{2.5}$ exposure in Isfahan, Iran. J Edu Health Promot 2017;6:109.

nitro-polycyclic aromatic hydrocarbons, heavy metals, pathogens, and radioactive materials. It contains very fine particles that penetrate to lower respiratory system, enters into the blood, and immigrate to the other organs even brain.[6] In urban environments, vehicular traffic is the most important source of PM emissions.[7] The WHO has reported that PM_{10} can cause respiratory and cardiovascular diseases such as asthma, bronchitis, heart attacks, lung function reduction, and can increase mortality rate. Whereas, in some European cities, with increasing 10 μg/m^3 in PM_{10} concentration, mortality rate increases about 6%.[5] PM can contribute in the prevalence of lung cancer and cardiovascular diseases.[8,9] In Europe, $PM_{2.5}$ concentration in the air of urban areas has been increasing, and some recent cohort studies have approved the relation between $PM_{2.5}$ long-term exposure and mortality increase. Such studies have confirmed strong correlation between PM concentration and the number of hospital admission due to heart and respiratory problems.[8,10] Similar studies have been carried out worldwide (China, Italy, Mexico, and Iran) to determine the short-term effects of PM using the AirQ model.[1,11-13] Primary standards for PM_{10} 24-h and the annual average suggested by the WHO are 50 and 20 μg/m^3, respectively, and annual average standard of $PM_{2.5}$ is 10 μg/m^3.[14] The presence of numerous vehicles in the city, vast deserts in the surrounding areas, and so many large industries in the suburb of Isfahan city are caused this city accounts for one of Iran's more polluted cities.[15,16] This study aimed to assess the health impacts of ambient PM_{10} and $PM_{2.5}$ exposure in Isfahan city and their attribution in the morbidity rate.

Materials and Methods

Study area

Isfahan city, the capital of Isfahan province, with a population of >1.7 million is the third most populous city of Iran located in the center of Iran in the area of 493.8 km^2. Isfahan has been situated in longitude 59°39′E and latitude 32°38′N with a height of 1570 m above sea level. In the age pyramid related to the Isfahan, the largest age group is 25–29 years old that is almost 12% of the population of Isfahan representing the young population of the city. The life expectancy for men and women in Isfahan is 82.52 and 79.9 years, respectively. Figure 1 shows the Map of the study area and locations of monitoring stations.

AirQ software 2.2.3 (WHO)

This is a descriptive, ecological study which evaluates the health impacts of $PM_{2.5}$ and PM_{10} on the population using the Air $Q_{2.2.3}$ software recommended by the WHO. This software correlates air quality data in various ranges of concentration with epidemiological parameters such as relative risk (RR), baseline incidence (BI), and attributable

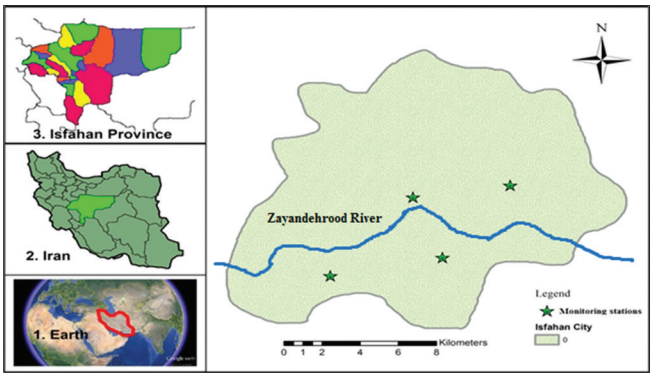

Figure 1: Map of the study area and monitoring stations location (Isfahan, Iran)

proportion (AP), and shows its results as mortality. The AP in this software is calculated according to the following formula.

$$AP = (\sum \{[RR(c) - 1] \times P(c)\}) / (\sum \{[RR(c) \times P(c)]\})$$

Where

RR (c) is the RR of health outcome in the target group

P (c) is the population proportion of the target group

By knowing the amount of BI in the target population can calculate attributed value to population contract (IE) by the following formula:

$$IE = BI \times AP$$

And finally, the number of cases attributable to the exposure (NE) can be estimated by the following equation by knowing the size of population (N).[17,18]

$$NE = IE \times N$$

One year data of $PM_{2.5}$ and PM_{10} concentrations (from April 2013 to March 2014) were collected from four air pollution monitoring stations which are located near to Ahmadabad, Eliaderan, Valiasr, and Azadi Squares. These monitoring stations are operated by Isfahan Department of Environment. The data were processed by Excel software according to the WHO guidelines. From April to September and from October to March were considered as hot and cold seasons, respectively. Then, hot and cold seasonal averages, annual averages, and their maximum, as well as annual 98 percentile for $PM_{2.5}$ and PM_{10}, were extracted. The BI of the total deaths, deaths attributed to cardiovascular and respiratory diseases were estimated using death and diseases data obtained from health center of Isfahan province. In case of needs for other epidemiological parameters which were not available for the city the WHO calculated values were applied. Finally, these data were entered

into Air Q software according to the WHO guideline and parameters such as AP, IE, and NE related to PM_{10} and $PM_{2.5}$ were calculated.

Results

Table 1 shows $PM_{2.5}$ and PM_{10} concentrations as $\mu g/m^3$ in monitoring stations located in Ahmadabad, Eliaderan, Valiasr, and Azadi districts in Isfahan city. Total average concentrations of both $PM_{2.5}$ and PM_{10} were the highest in Ahmadabad and the lowest in Azadi stations. The PM_{10} annual average concentration, winter, summer, and 98 percentile in Isfahan city were 108, 100, 116, and 264 $\mu g/m^3$, respectively.

Table 2 shows summary of air pollutants and meteorological variables in Isfahan city. Table 3 shows the BI, RR, AP indexes, and total death numbers attributable to $PM_{2.5}$ and PM_{10}. According to the Table 3, total death numbers attributable to $PM_{2.5}$ and PM_{10} with BI 598.3 in 10^5 people with moderate RR were 670 and 713 cases, respectively. Table 3 also shows death number and hospital admissions due to respiratory and cardiovascular diseases attributable to PM_{10} in the range of moderate RR. Death numbers of PM_{10} attributable cardiovascular and respiratory diseases with BI 247.1 in 10^5 people and with moderate RR were 316 and 68 cases, respectively. The numbers of hospital admissions due to PM_{10} attributable respiratory and cardiovascular diseases were 1614 and 623 people, respectively.

Figure 2 shows the percentage of days that people were exposed to different concentrations of PM_{10} (A) and $PM_{2.5}$. According to Figure 2 for instance, each person has exposed 14% of annual days to PM_{10} concentrations of 100–109 $\mu g/m^3$. While that the people of Isfahan have exposed in 23% of annual days to $PM_{2.5}$ concentration of 50–59 $\mu g/m^3$.

Discussion

According to Table 1, maximum annual average concentrations of both PM_{10} and $PM_{2.5}$ in the Isfahan ambient air were obtained in the Ahmadabad station. This is due to high traffic volume and vehicle transportation in this area which is one of the busiest and big squares in Isfahan. High traffic is considered as a major source of PM emission.[8] Minimum annual averages of the pollutants were attained in the Azadi station. However, the annual average of $PM_{2.5}$ and PM_{10} concentration (64 and 108 $\mu g/m^3$) were 3.2 and 2.7 times greater than the WHO guidelines (20 and 40 $\mu g/m^3$) and their annual maximum concentration (202 and 491 $\mu g/m^3$) were 10.1 and 12.27 times greater than the WHO guidelines.[19] Similar studies carried out in India,[20] Italy,[1] Estonia,[21] and in some of Iran's cities such as Ahvaz,[22] Tabriz,[23] Shiraz,[16] and Tehran[17] have reported the amount of this pollutants higher than standard limits. The elevated levels of PM_{10} and $PM_{2.5}$ in Isfahan can be attributed to the increased vehicular traffic due to population inflation, high tourism volume, presence of deserts and mines, especially lead and zinc mines, and energy conversion sectors such as power plants and oil refineries around the city.[24] Average $PM_{2.5}$ and PM_{10} concentration in the summer were 116, and 100 $\mu g/m^3$ and those in the winter were lower than summer amounting 68 and 60 $\mu g/m^3$, respectively. It can be due to seasonally variation of the meteorological condition of the city which lays in the arid and semi-arid region, drought and reduction of vegetation, strong winds, and reduction of relative humidity as well as entry of dust from Western and Southwestern borders among spring and summer. The results of this study are in agreement with the results have been reported for Tehran, Khorramabad, and Ahvaz.[12,17,25]

The results presented in Table 3 indicate that a total number of deaths attributable to $PM_{2.5}$ and PM_{10}, with a BI 598.3 per 10^5 people have average RR equal to 670 and 713 cases, respectively. During 2013–2014, total cases of 10537 nonaccidental deaths have been registered in the Isfahan; so, premature deaths caused by $PM_{2.5}$ and PM_{10} with average RR were about 6.35% and 6.76% of the total deaths, respectively. More than 800,000 cases of deaths globally are related to $PM_{2.5}$.[4] In Russia,[26] Estonia,[27] Italy,[1] and Japan,[28] 4%, 5%, 4%, 5%, and 8% of total deaths have been attributed to $PM_{2.5}$. In Sanandaj,

Table 1: Particulate matter 2.5 and particulate matter 10 concentrations as $\mu g/m^3$ in the measuring stations

Parameter	Stations name								Total mean	
	Ahmadabad		Eliaderan		Valiasr		Azadi			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
Annual mean	93	155	64	107	57	95	45	75	64	108
Winter mean	96	158	60	100	53	89	32	53	60	100
Summer mean	90	151	71	118	61	101	57	97	68	116
Annual 98 percentile	200	334	157	262	175	291	101	169	158	264
Annual maximum	383	638	295	492	307	511	193	323	202	491
Winter maximum	96	424	212	354	293	489	31	149	60	354
Summer maximum	90	638	295	492	307	511	57	323	68	491

PM=Particulate matter

11.7% of the total recorded deaths were related to PM_{10}.[29] Similar studies conducted in Italy, Milan,[1] Tehran,[17] Tabriz,[23] and Khorramabad,[25] have shown that the number of deaths attributed to PM_{10} was 1370, 2194, 368, and 320 cases, respectively.

Table 3 also shows the number of deaths due to cardiovascular and respiratory diseases attributed to PM_{10}. The number of deaths caused by cardiovascular diseases with BI 247.1 and average RR was 316 people, and that due to respiratory diseases with BI 37 and average RR was 68 cases. Strukova *et al*. have estimated that about 46000 premature deaths in Ukraine in 2006 have been attributed to air pollutants, especially $PM_{2.5}$ and PM_{10}. Within them, about 27,000 deaths were due to heart and respiratory diseases and lung cancer.[30]

In this study, deaths due to PM_{10} attributable cardiovascular and respiratory diseases accounted for 44.3% and 9.55% of the total deaths due to PM_{10}. The number of deaths due to cardiovascular and respiratory diseases was 1367 and 402 cases in Tehran, 612 and 114 cases in Ahvaz, 120 and 23 cases in Sanandaj, and 28 and 6 cases in Trieste, Italy, respectively.[12,29,17,31] The number of hospital admissions due to cardiovascular and respiratory diseases attributed to PM_{10} with BI 436 and 1260 was 623 and 1614 cases, respectively.

RR shows that the increased risk caused by contact to a pollutant which is obtained thought time-series studies. It studies the daily relationship among air pollution and health effects, such as mortality due to cardiovascular and respiratory diseases. In Isfahan, with per 10 μg/m^3 increase in pollutant values, the value of RR for the increase of total mortality caused PM_{10} and $PM_{2.5}$, were 0.8% and 0.5%. Increasing 10 μg/m^3 in the PM_{10} concentration caused an increase in the RR and total mortality by 0.74% and 5.24%, respectively. Recent studies in Europe have shown that 10 μg/m^3 increase in the PM_{10} concentration has led to mortality increase by 6%.[5] In a study conducted in Tehran a mortality increase of 6.4% has been reported.[17] According to the WHO guidelines decreasing of PM_{10} annual average value from 70 to 20 μg/m^3 can reduce mortality rate by 15%.[5]

The highest percentage of exposure days was for the concentration range of 100–109 μg/m^3 of PM_{10}. About 48% of total annual days the people have exposed with PM_{10} concentrations more than 100 μg/m^3. Almost in all days of the year, the people have exposed with PM_{10} concentrations upper than the WHO recommended guideline (20 μg/m^3). About 16% and 23% of people exposed to concentrations of 40–49 and 50–59 μg/m^{3}of $PM_{2.5}$, respectively. In other words, each person of Isfahan on all days of the year was exposure of $PM_{2.5}$ concentrations more than the WHO guidelines.

A weakness of the AirQ model is that it is not take into consideration the health effects caused by exposure to mixtures of several pollutants or their synergistic effects, but only the effect of pollutants is investigated individually.

Table 2: Summary of air pollutants and meteorological variables in Isfahan city (2013-2014)

Parameters	Spring	Summer	Autumn	Winter
Relative humidity (%)				
Minimum	4	3	6	4
Maximum	100	56	97.5	98
Precipitation (mm)				
Minimum	2.1	0	0	0.35
Maximum	16.4	3.4	14.1	12
Temperature (°C)				
Minimum	−1	11.5	−4.4	−9.6
Maximum	34	41.5	33.3	21.7

Conclusion

The results of present study showed that almost all days of the year people have exposed with $PM_{2.5}$ and PM_{10} concentrations upper than the WHO recommended guidelines in Isfahan. During 2013–2014, premature deaths caused by $PM_{2.5}$ and PM_{10} with average RR were about 6.35% and 6.76% of the total deaths, respectively. Deaths due to PM_{10} attributable cardiovascular and respiratory diseases accounted for 44.3% and 9.55% of the total deaths due to PM_{10} exposure. Therefore, the best available and applicable controlling strategies should be

Table 3: Estimated baseline incidence of relative risk, total number, and particulate matter 2.5 and particulate matter 10 attributable deaths and hospital admissions

Health endpoints	BI (10^5)	Air pollutants	RR*	AP (uncertainty range)**	Number of excess cases (uncertainty range)**
Total mortality	598.3	$PM_{2.5}$	1.015	6.3668	670
		PM_{10}	1.0074	6.7701	713
Cardiovascular mortality	247.1	PM_{10}	1.008	7.2791	316
Respiratory mortality	37	PM_{10}	1.012	10.5352	68
Hospital admissions due to respiratory disease	1260	PM_{10}	1.008	7.2791	1614
Hospital admissions due to cardiovascular disease	436	PM_{10}	1.009	8.1152	623

Crude rate per 100,000 inhabitants. *Crude rate per 100,000 inhabitants. **Obtained using the lower and upper RR values. BI=Baseline incidence, RR=Relative risk, AP=Attributable proportion, PM=Particulate matter

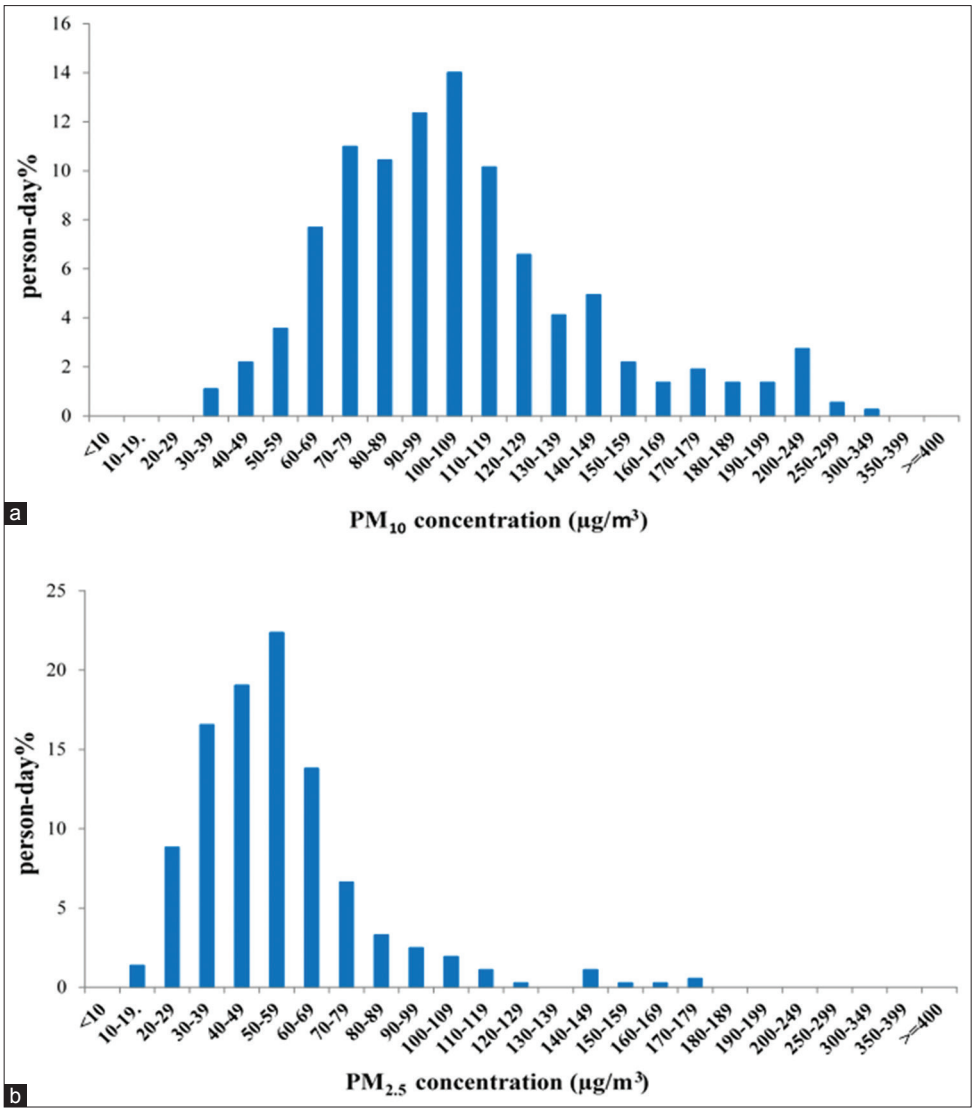

Figure 2: Percentage of days that people were exposed to different concentrations of PM_{10} (a) and $PM_{2.5}$(b) in Isfahan

carried out by authorities to protect the citizen's health and to reduce the health outcome of exposure to this kind of PMs.

Acknowledgments

The collaboration of the Isfahan Department of Environment and Health Centre of Isfahan province in providing required information is greatly acknowledged.

Financial support and sponsorship

Nil. There is no sponsorship for this work

Conflicts of interest

There are no conflicts of interest.

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