Health impacts of particulate matter in air by AirQ model in Khorramabad city, Iran

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Abstract

Introduction: Air pollution due to particulate matter is a major environmental and health issue in all regions of the world. The aim of this study was to investigate the health impacts of PM_{10} (particulate matter with an aerodynamic diameter ≤10μm) in Khorramabad city, Iran in 2014.

Materials and methods: In this study, PM_{10} sampling was conducted by a high-volume sampler at flow rate of 1.1-1.4 m^3/min. The annual mortality and morbidity to cardiovascular and respiratory diseases attributable to PM_{10} exposure were estimated by AirQ software model. This model has been proposed to health impact assessment of atmospheric pollutants by World Health Organization (WHO).

Results: The annual, winter and summer averages of PM_{10} were 80.59, 58.28, and 80.59μg/m3, respectively. The total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to respiratory diseases and hospital admissions due to cardiovascular diseases were estimated 320, 304, 72, 507 and 201 cases, respectively.

Conclusion: In order to diminish the adverse health effects of particulate matter in Khorramabad city, health training by healthcare centers should be conducted to public people especially persons with chronic lung and heart diseases, elderly and children. Moreover, the efforts should be conducted in the governmental scale in order to control the Middle East dust storms (MED) sources.

Keywords: Air Pollution, Health Impact Assessment, PM_{10}, Mortality, Morbidity, AirQ

Introduction

Air pollution due to industrialization, urbanization and increasing of population is one of the important problems in the world, especially in developing countries. Air pollution is a serious issue that can be harmful for human health and welfare (1, 2). Approximately 80% of persons with 65 years and over have one or more chronic diseases and more than 50% of them have activity limitations (2). Among air pollutants, particulate matter (PM) is the pollutant with the most undesired adverse effects on human health (3, 4). Many studies have reported that there are a strong correlation between PM concentrations and hospital admissions due to the respiratory and cardiovascular diseases (5). Among particulate matter in

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the atmosphere, particulate matter with aerodynamic diameter less than or equal to10μm (PM_{10}) has the great adverse effects on human health. PM_{10} has the potential to penetrate into the respiratory system (6). Epidemiological studies have reported that more than 500,000 Americans dies are occurred each year due to cardiovascular diseases associated with PM_{10} (7). Respiratory diseases are also hazardously associated with PM_{10} (8-10). In the last decade, because of the Middle East Dust storms (MED), south, west and southwest of Iran have been affected to exposure with PM_{10}. Khorramabad city is capital of Lorestan province, located in the southwest of Iran, and is in counter with high amounts of PM_{10} as results of MED events. The AirQ software model has been applied by many researchers to assess the human health impact of PM_{10} (1, 3, 11-13). Results of other studies illustrated that particulate matter is the pollutant with the biggest health impacts on the human. The aim of this study was to survey the short-term health impacts of exposure to PM_{10} using Air Quality Health Impact Assessment (AirQ 2.2.3) software in Khorramabad city, Iran in 2014.

Materials and methods

Study location: Khorramabad (with coordinates of 33°29′16″N and 48°21′21″E) is a capital city of Lorestan province in southwest of Iran (Figure 1). Based on the latest census report on 2014, the population of Khorramabad city is 540,000 persons.

Air sampling: The sampling of PM_{10} was carried out by a high-volume sampler (Anderson Model) at flow rate of 1.1-1.4 m^3/min that located at 3 meters above the ground level. 6 samples were collected in every week for a period of one year in 2014. On all the measurement days, the concentrations of PM_{10} were recorded every 30 min during a 24-h period.

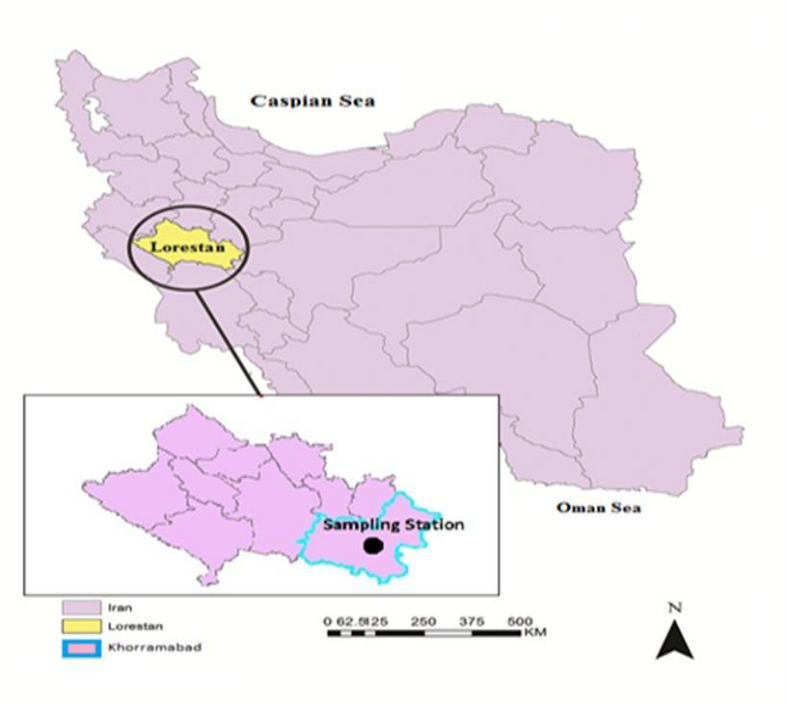


Figure 1. Location of Khorramabad city and sampling station.

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AirQ software model: The AirQ software model developed by the World Health Organization (WHO) European Center for Environment and Health, Bilthoven Division was used for this study (11). This model was used to approximate the effect of exposure to definite air pollutant on the people existing in a certain time and region. The model assumes that the first 6 months of the year are summer and other 6 months are winter (1). The evaluation is based on the attributable proportion (AP), which is described as the portion of the health result in a certain residents attributable to contact to a given air pollutant (12, 14). The Eq. (1) is used for calculation of AP.

$$AP = \frac{\sum\{(RR\ (c) - 1)\ \times P\ (c)\}}{\sum[RR\ (c) \times P\ (c)]} \quad \text{Eq. (1)}$$

Where AP is the attributable proportion of the health effect and RR is relative risk for a certain health effect. P (c) is the population to contact to a pollutant (15). The rate attributable to the contact is determined by Eq. (2), if the baseline frequency of the health effect in the studied population is identified.

$$IE = I \times AP \quad \text{Eq. (2)}$$

Where; IE and I are the rate of the health effect attributable to the contact and the baseline frequency of the health effect in the population, respectively. Finally, the total number of persons attributable to the exposure is specified by Eq. (3).

$$NE = IE \times N \quad \text{Eq. (3)}$$

Where NE and N are the number of persons attributed to the exposure and the total number of investigated residents (15).

Inputs adjustment: HIA (health impact assessment) using AirQ needs to data of PM_{10} concentration in the standard conditions (STP). For non-standard temperatures and pressures, Eq (4) can be used.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{Eq. (4)}$$

Where; P_1, V_1, and T_1 are the initial pressure, volume and absolute temperature in the non-standard conditions, respectively. Also P_2, V_2, and T_2 are the pressure; volume and absolute temperature in the standard conditions, respectively. The mean daily concentrations of PM_{10} were applied in the study. The mortality and morbidity rates related to the PM_{10} were estimated using AirQ software (Version: 2.2.3). The AirQ software supposes that the concentrations of pollutant are representative of the average contact of the people. Subsequently, the numbers of persons for total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases and hospital admissions because of respiratory diseases were estimated by relative risk and baseline incidence of WHO (2, 16).

Results

Table 1 shows data of the seasonal average of PM_{10} concentrations measured in the sampling station. The maximum PM_{10} concentration with an average of 102.90µg/m^3 was occurred during the summer. Table 2 shows the relationship of PM_{10} with the percentage of attributed proportion, relative risk and number of persons suffering from total mortality, cardiovascular mortality, respiratory mortality and hospital admissions.

Table 1. Seasonal average of PM_{10} concentrations measured in the station sampling.

Season	Average ± SD (µg/m^3)	Maximum (µg/m^3)	Minimum (µg/m^3)
Summer	102.90 ± 60.41	376	1
Winter	58.28 ± 39.42	422	2
Annual	80.59 ± 49.91	422	1

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Table 2. Relative risk, attributable proportion and number of excess cases estimated due to PM_{10} exposure.

Health effect	Indicator estimate	Relative risk	Estimated AP (%)	Estimated number of excess cases (persons)
Total mortality	Lower	1.0062	5.0556	235.0
	Mean	1.0074	5.9767	278.0
	Upper	1.0086	6.8794	320.0
Cardiovascular mortality	Lower	1.0050	4.1182	146.4
	Mean	1.0080	6.4303	93.7
	Upper	1.0180	13.3918	304.8
Respiratory mortality	Lower	1.0080	6.4303	19.4
	Mean	1.0120	9.3450	28.2
	Upper	1.0370	24.1182	72.9
Hospital admissions for respiratory diseases	Lower	1.0048	3.9621	229.0
	Mean	1.0080	6.4302	372.0
	Upper	1.0112	8.7714	507.0
Hospital admissions for cardiovascular diseases	Lower	1.0060	4.9015	98.0
	Mean	1.0090	7.1764	14.4
	Upper	1.0130	10.0955	201.0

Cumulative cases of total mortality attributed to PM_{10} concentrations are illustrated in Fig 2 with three ranges of relative risk (lower, mean and upper). As seen, the number of 320 persons was estimated by the model as total mortality within one year due to the exposure with PM_{10}. Cardiovascular mortality because of PM_{10} concentration is shown in Figure 3. The estimated cases which attributed to PM_{10} for cardiovascular mortality (Figure 4) at lower, average and higher of RR were 93, 146 and 304 persons, respectively. Also, the estimated cases for respiratory mortality are presented in Figure 4. As seen, 72 persons were died because of exposure to PM_{10} concentration in Khorramabad city during 2014. Hospital admissions for respiratory diseases versus PM_{10} concentration is shown in Figure 5. The estimated cases which attributed to PM_{10} for hospital admissions for respiratory diseases at lower, average and higher of relative risk (RR) were 229, 372 and 507 persons, respectively. Also, hospital admissions for cardiovascular diseases due to PM_{10} concentration were approximated and the results are illustrated in Figure 6. The approximated cases which attributed to PM_{10} for hospital admissions for cardiovascular diseases were 201 persons during 2014.

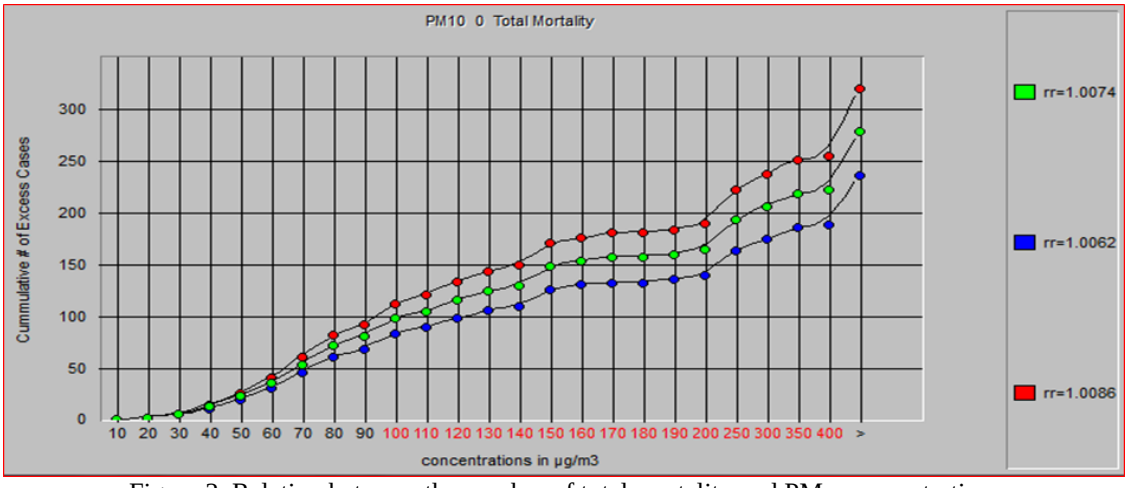


Figure 2. Relation between the number of total mortality and PM_{10} concentration.

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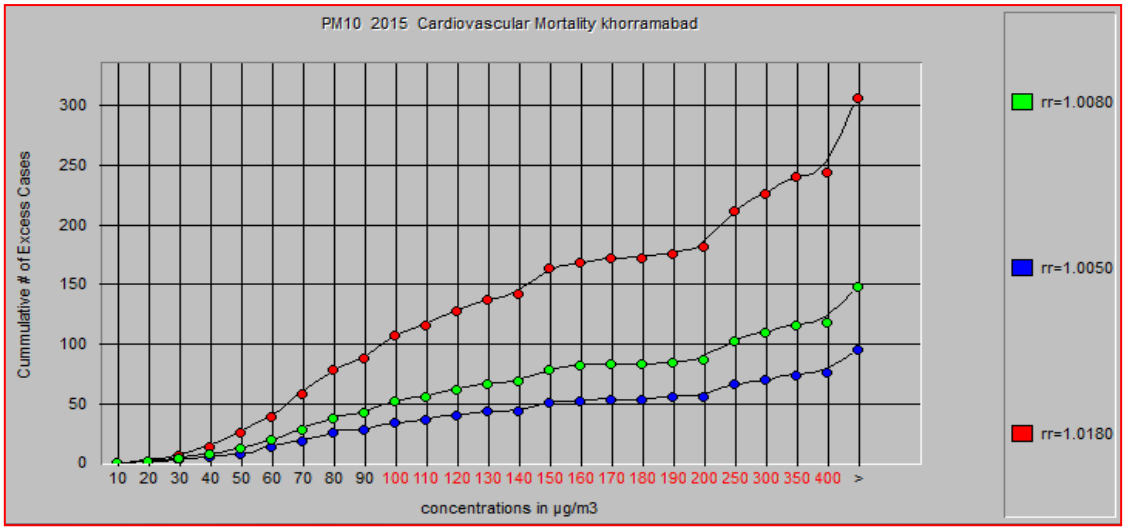


Figure 3. Relation between the number of cardiovascular mortality and PM_{10} concentration.

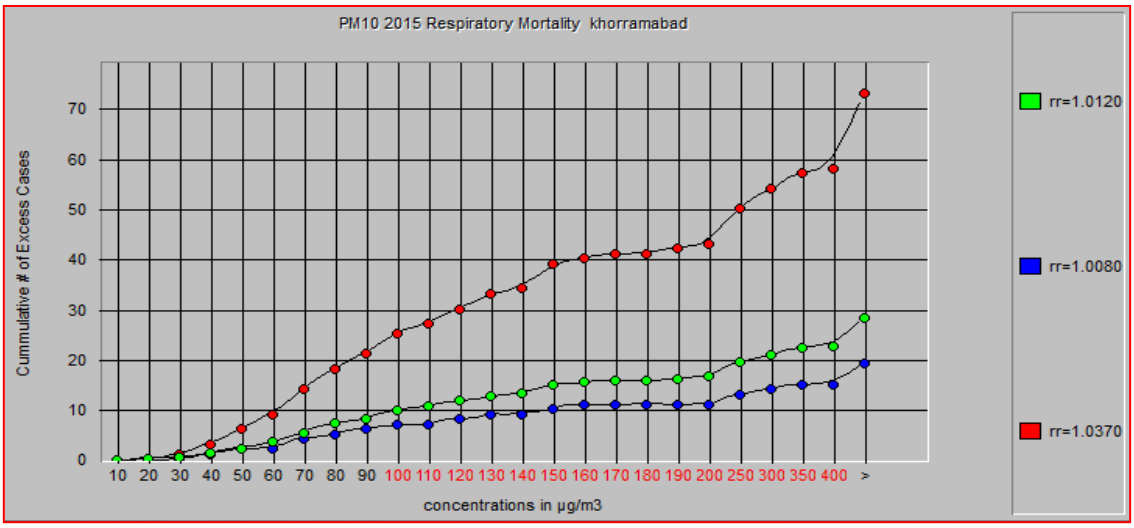


Figure 4. Relation between the number of respiratory mortality and PM_{10} concentration.

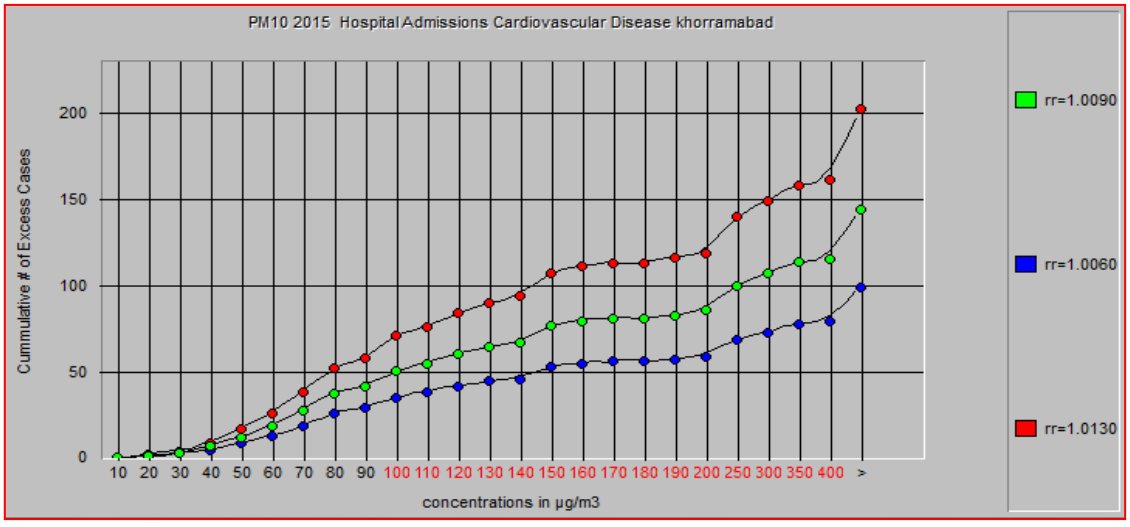


Figure 5. Relation between the number of hospital admissions for respiratory diseases and PM_{10} .

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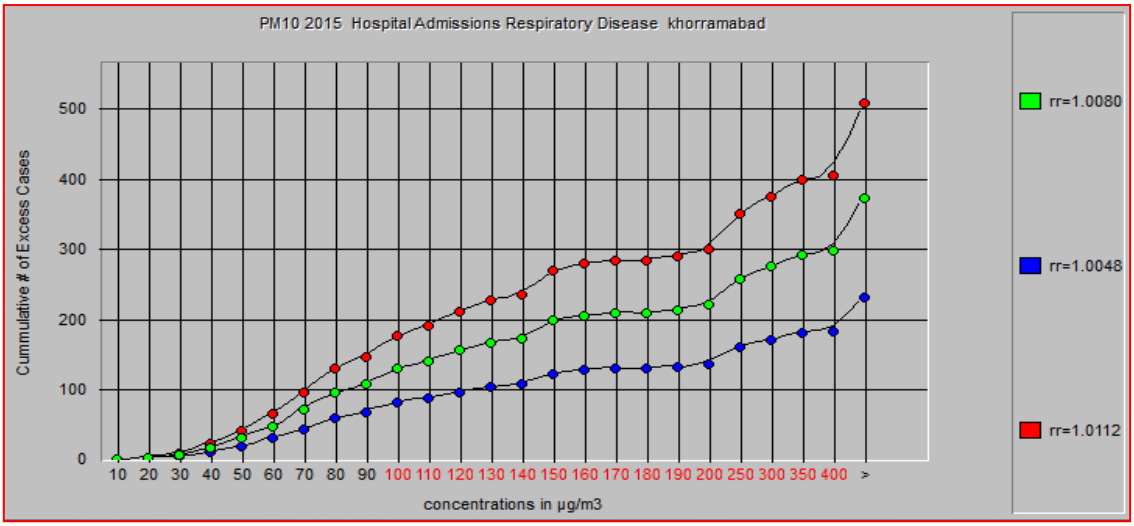


Figure 6. Relation between the number of hospital admissions for cardiovascular diseases and PM_{10}.

Discussion

Cardiovascular and respiratory mortality and hospital admissions for cardiovascular and respiratory diseases are occurred as a result of PM_{10} exposure. The average concentration of annual, winter and summer of PM_{10} was obtained 58.28, 102.90, and 80.59µg/m^3, respectively. The maximum of annual, summer and winter concentrations of PM_{10} in this study were 422, 376, and 422µg/m^3, respectively. Increase in PM_{10} concentration over the summer season in Khorramabad city, can be in relation to Middle-East Dust (MED) storms from arid areas of Iraq, Kuwait and Saudi Arabia. Middle-East Dust (MED) storms are the main cause of dust events in the west and southwest of Iran (17). The Air Quality Guidance of WHO (AQG WHO) has recommended that the annual average of exposure to PM_{10} should be lower than 50µg/m^3 (12). Therefore, based on Table 1, the annual average of PM_{10} in Khorramabad city was obtained 80.59µg/m^3 which is higher than of AQG WHO. Shahsavani et al. (2012) demonstrated that the mean and maximum annual of PM_{10} concentration in Ahvaz city on April and September 2010 were obtained 319.6µg/m^3 and 2028.0µg/m^3, respectively (18). Goudarzi et al. (2014) reported that the annual average concentration of PM_{10} in Ahvaz city (Iran) in 2012 was 321µg/m^3 (12). Nourmoradi et al. (2015) also reported that the average of PM_{10} concentration on April to September 2012 in Sanandaj city (Iran) were 116.68µg/m^3 (19). According to Zallaghi et al. (2011) study, the average concentration of PM_{10} in the summer 2011 in Kermanshah city (Iran) was higher than the winter. Zallaghi et al. (2011) reported that the average concentrations of annual, summer and winter of PM_{10} were measured 89.54, 117.91 and 60.06µg/m^3, respectively (20). Based on Table 2, the number of excess cases for total mortality was calculated 278 persons at centerline of relative risk (RR=1.0074 and AP=5.9767%). Fig 2 illustrate that 89.4% of total mortality occurred in days with PM_{10} concentrations not exceeding 200µg/m^3. The estimated number of excess cases for total mortality was 278 persons for this study. Martuzzi et al. (2002) reported that total mortality as a result of exposure to PM_{10} concentration above 20µg/m^3 was 677 persons in Milan, Italy (21). Goudarzi et al. (2008) showed that 4% of the total mortality occurred in Tehran city (Iran) was related to PM_{10} concentrations above 20µg/m^3 (22). Based on Fig 3 (RR=1.012 and AP=6.43), 84.38% of the cardiovascular mortality occurred in days with PM_{10} levels less than

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200μg/m^3 and as a result of it, 93 persons were died. Goudarzi et al. (2014) estimated that 1055 persons were died due to the cardiovascular diseases in Ahvaz city, Iran in 2012 (12). Fig 4 showed that 10.6% of respiratory mortality (RR=1.012 and AP=9.3450) occurred in days with PM_{10} levels exceeding 200μg/m^3 and the number of excess cases because of the respiratory mortality were estimated 28 persons. Hosseini et al. (2014) presented that the number of excess cases due to the respiratory mortality were calculated 23 persons in Sanandaj, Iran from January 2013 to January 2014 (1). Relative risk (RR) and estimated attributable proportion percentage (AP) for hospital admissions for respiratory diseases were estimated 1.008 and 6.4302, respectively. Based on Fig 5, 10.6% of hospital admissions for respiratory diseases occurred in days with PM_{10} levels less than 20μg/m^3 and the numbers of excess cases, for this PM_{10} concentration, were estimated 372 persons. Gholampour et al. (2014) reported that the numbers of hospital admissions for respiratory disease due to exposure with PM_{10} were 1107 cases in Tabriz city, Iran from September 2012 to June 2013 (8). Fig 6 also showed the number of hospital admissions for cardiovascular diseases because of PM_{10}. As seen, 6.3% of hospital admissions for respiratory diseases estimated in days with PM_{10} levels less than 20μg/m^3 and the numbers of excess cases for this concentration were estimated 14 persons. Hosseini et al. (2014) reported that the numbers of excess cases for hospital admissions due to respiratory diseases were 118 persons in Sanandaj city from January 2013 to January 2014 (1). Tominz et al. (2005) reported that 1.8% of natural mortality, 2.2% of cardiovascular mortality and 2.5% of respiratory mortality in Trieste, Italy, in 2005 were due to exposure with PM_{10} concentrations of exceeding than 20μg/m^3 (23). Yavari et al. (2007) demonstrated that about 13% of the total number of cardiovascular and respiratory diseases was associated with PM_{10} concentration of higher than 20μg/m^3 (24). Zhou et al. (2014) also showed that every 10μg/m^3 increase in PM_{10} concentration was connected to 1.8% and 1.7% increased risks of cardiovascular and respiratory mortalities, respectively in china in 2006 (25). A comparison between the results of our study with other studies showed that higher mortality rate in Khorramabad city was resulted to higher average PM_{10} levels or higher number of exposure days.

Conclusion

In this study, health impacts of exposure to particulate matter (PM_{10}) were assessed on the people living in the Khorramabad city (Iran) using the AirQ software in 2014. This study was the first attempt to evaluate the health impacts of particulate matter (PM_{10}) in Khorramabad city. The results revealed that 5.66% of natural mortality in Khorramabad city was associated with concentrations of PM_{10} above 20μg/m^3. In order to diminish the health effects of particulate matter in Khorramabad city, health training by healthcare systems should be conducted to public people especially persons with chronic lung and heart diseases, elderly and children. Moreover, the efforts should be conducted in the governmental scale in order to control the Middle East dust storms (MED) sources.

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