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RESEARCH ARTICLE

Hospital admissions in Iran for cardiovascular and respiratory diseases attributed to the Middle Eastern Dust storms

Yuef Omidi Khaniabadi[1] · **Roberto Fanelli**[2] · **Alessandra De Marco**[3] · **Seyed Mohammad Daryanoosh**[4] · **Itai Kloog**[5] · **Philip K. Hopke**[6,7] · **Gea Oliveri Conti**[8] · **Margherita Ferrante**[8] · **Mohammad Javad Mohammadi**[9] · **Ali Akbar Babaei**[10] · **Hassan Basiri**[11] · **Gholamreza Goudarzi**[10,12]

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Abstract The main objective of this study was to assess the possible effects of airborne particulate matter less than 10 μm in diameter (PM_{10}) from the Middle Eastern Dust (MED) events on human health in Khorramabad (Iran) in terms of estimated hospital admissions (morbidity) for cardiovascular diseases (HACD) and for respiratory diseases (HARD) during the period of 2015 to 2016. The AirQ program developed by the World Health Organization (WHO) was used to estimate the potential health impacts to daily PM_{10} exposures. The numbers of excess cases for cardiovascular/respiratory morbidity were 20/51, 72/185, and 20/53 on normal, dusty, and MED event days, respectively. The highest number of hospital admissions was estimated for PM_{10} concentrations in the range of 40 to 49 μg/m^3, i.e, lower than the daily (50 μg/m^3) limit value established by WHO. The results also showed that 4.7% (95% CI 3.2–6.7%) and 4.2% (95% CI 2.6–5.8%) of HARD and HACD, respectively, were attributed to PM_{10} concentrations above 10 μg/m^3. The study demonstrates a significant impact of air pollution on people, which is manifested primarily as respiratory and cardiovascular problems. To reduce these effects, several immediate actions should be taken by the local authorities to control the impacts of dust storms on residents' health, e.g., developing a green beltway along the Iran-Iraq border and management of water such as irrigation of dry areas that would be effective as mitigation strategies.

Keywords AirQ model · Dust storm · Cardiovascular disease · Respiratory disease · Iran

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✉ Alessandra De Marco
alessandra.demarco@enea.it

[1] Health Care System of Karoon, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

[2] Department of Environmental Health Sciences, IRCCS, Istituto di Ricerche Farmacologiche, Mario Negri, Milan, Italy

[3] Department of Territorial and Production Systems Sustainability, ENEA, Rome, Italy

[4] Health Center of Hendijan, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

[5] Department of Environmental Health, Harvard University, 665 Huntington Avenue, Landmark Center Room 415, Boston, MA 02115, USA

[6] Department of Public Health Sciences, University of Rochester School of Medicine and Dentistry, Rochester, NY 14642, USA

[7] Center for Air Resources Engineering and Science, Clarkson University, Potsdam, NY 13699, USA

[8] Environmental and Food Hygiene Laboratories (LIAA) of Department of Medical Sciences, Surgical and Advanced Technologies "G.F. Ingrassia", Hygiene and Public Health, University of Catania, Catania, Italy

[9] Abadan School of Medical Sciences, Abadan, Iran

[10] Environmental Technologies Research Center (ETRC), Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

[11] Department of Environmental Health Engineering, School of Health, Lorestan University of Medical Sciences, Khorramabad, Iran

[12] Air Pollution and Respiratory Diseases Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

Introduction

Air pollution includes particles and gaseous pollutants, but particles are of paramount of importance with respect to health effects (e.g., Sicard et al. 2010; Jakubiak-Lasocka et al. 2015; Khaefi et al. 2017). In the twentieth century, adverse effects of air pollution on human health were demonstrated. For instance, the air pollution episodes in Europe (Meuse Valley and London) and in the USA (Donora, Pa) caused observable excess mortality and morbidity (Nemery et al. 2001; Fattore et al. 2011; Yari et al. 2016). Among common air pollutants, particulate matter with an aerodynamic diameter of less than or equal to 10 μm (PM_{10}) is particularly important for human health because PM_{10} represent the particles mass that penetrate into the respiratory tract (Schwartz et al. 1993; Wang et al. 2009; Weuve et al. 2012). The major sources of PM_{10} are anthropogenic, e.g., road traffic, combustion, power plant activities, and industrial processes or natural, e.g., sea salt and desert dust (Gharehchahi et al. 2013). Exposure to ambient PM_{10} can cause several adverse health outcomes such as lung irritation, asthma exacerbation, chronic bronchitis, cancer, increased hospital admissions, and mortality resulting from respiratory and cardiovascular diseases (e.g., Sicard et al. 2011; Jeong 2013; Neisi et al. 2016).

Dust storms occur when high wind speeds occur over low, dry vegetation and open soil areas (WMO 2013). These dust storms are associated with environmental and socioeconomic problems (Gerivani et al. 2011; Soleimani et al. 2016; Goudarzi et al. 2017). Over the past two decades, increasing frequency and intensities of dust storms transported from Iran's western neighboring countries have influenced the western and central parts of the country with high PM_{10} levels for several days at a time (Ebrahimi et al. 2014). Middle Eastern Dust (MED) storms especially from the Arabian Peninsula, Jordan, Iraq, Syria, and Kuwait affected Iran and likely resulted in the observed increased rates of morbidity and mortality for cardiovascular and respiratory disease (Shahsavani et al. 2012; Ebrahimi et al. 2014; Khaniabadi et al. 2017a). Respiratory disease hospitalizations have increased during MED events in Saudi Arabia (Habeebullah 2013). During previous dust storms for instance in Australia (Brisbane, Barnett et al. 2012), China (Beijing, Xie et al. 2005), Iran (Ahvaz city, Shahsavani et al. 2012), Mauritania (Ozer 2006), and Spain (Cabello et al. 2012), the maximum hourly PM_{10} concentrations were 894, 798, 5338, 2998, and 378 $\mu g/m^3$, respectively. In some areas, measured hourly PM_{10} concentrations were greater than 6000 $\mu g/m^3$ during dust storms (Naddafi et al. 2012). Significant correlations ($p < 0.05$) were observed between dust storms and mortality for cardiovascular and respiratory diseases in South Korea (Kwon et al. 2002) and between dust events and daily hospital admissions for respiratory and cardiovascular diseases, pneumonia, and hypertensions in China (Meng and Lu 2007). In addition, significant correlations were found between the PM_{10} levels and the number of cardiovascular emergency admissions during dust events in Sanandaj (Iran) over the time period 2009–2010 (Ebrahimi et al. 2014). Major desert dust storms have occurred in Iran since 2004 (Khaniabadi et al. 2017a; Maleki et al. 2016). The present study estimated the effects of dust storms on hospital admissions due to cardiovascular diseases (HACD) and respiratory diseases (HARD) attributed to exposure to high PM_{10} concentrations in Khorramabad.

Materials and methods

Study area

Khorramabad (33° 29′ 16″ N; 48° 12′ 21″ E) is the capital of the Iranian province of Lorestan (Fig. 1) and is located in southwestern Iran. The population of Khorramabad was estimated as 540,000 inhabitants in 2014 (Iranian statistical center). Khorramabad is exposed to MED storms and is one of the most polluted cities in the world in terms of PM_{10} (Goudie 2014). In recent years, in addition to the MED storms, the number of vehicles and new heavy industries, such as a petrochemical complex, has strongly increased local emissions and produced poor air quality. The city is enclosed by the Zagros Mountains (1170 m a.s.l.) trapping the air pollutants in the boundary layer and producing high air pollutant levels exceeding the air quality standards (Mirhosseini et al. 2013).

Particulate matter sampling

PM_{10} concentrations and air quality data were obtained from the air quality monitoring agency (Lorestan Environmental Protection Agency (LEPA)). An air pollution-monitoring site is located at the Daneshkade Behdasht station and the LEPA is responsible for its maintenance and operation. The monitoring station is fully automated and provides hourly PM_{10} concentrations using a β-ray absorption monitor (MetOne Model BAM-1020-Continuous Beta, USA). The hourly PM_{10} concentrations, from 1 January 2015 to 1 January 2016, were obtained from the LEPA and 24-h concentrations were computed for this study. For the aggregation of hourly data to longer averaging periods (i.e., 24-h) a minimum data capture rate of 75% was imposed to calculate a valid aggregated value. The number of dust event days was determined by using data from Iranian Environmental Protection Agency. Dust event days were detected based on visibility, wind speed, and PM_{10} hourly concentrations (Hoffmann et al. 2008).

Air quality health impact assessment: AirQ software

The WHO software tool AirQ (Air Quality Health Impact Assessment, AirQ2.2.3) performs calculations that allow quantification of the health effects of exposure to air pollution,

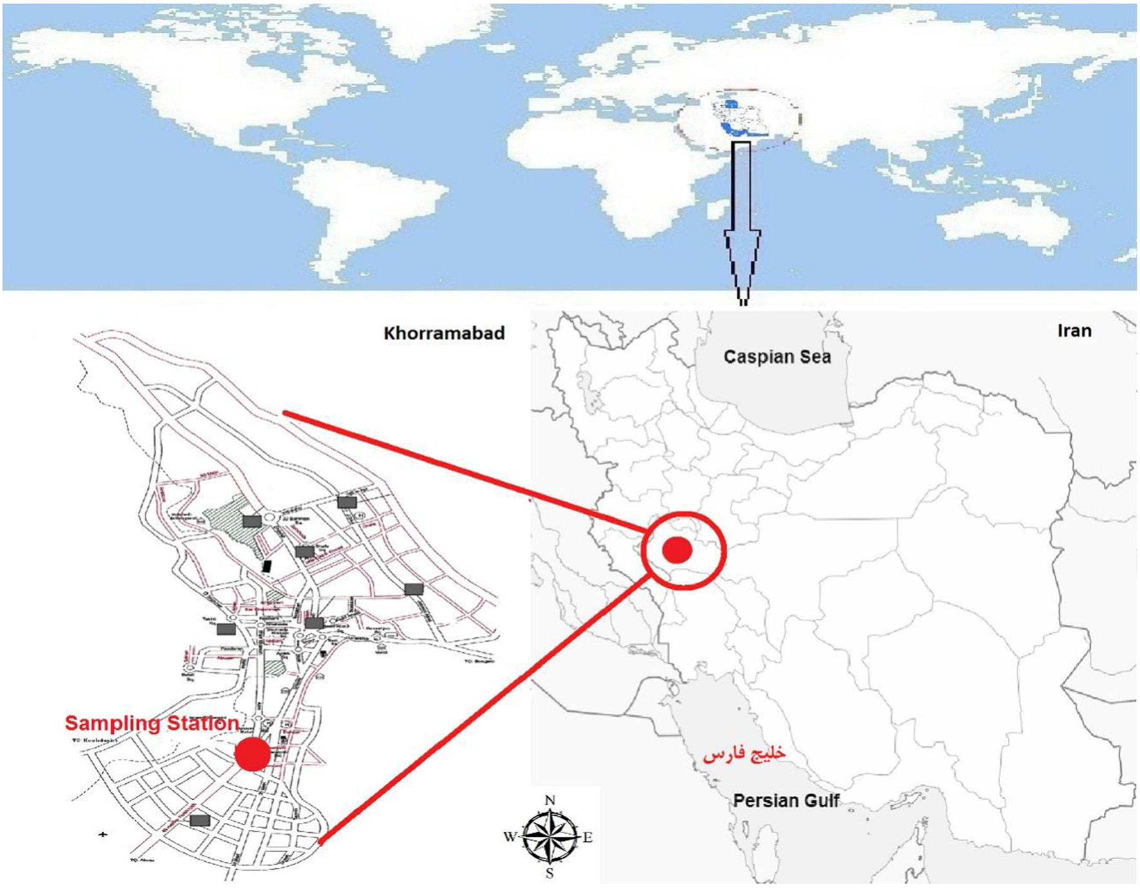

Fig. 1 Location of Khorramabad city and sampling site in Iran

including estimates of the reduction in life expectancy (Fattore et al. 2011; Shakour et al. 2011; Khaniabadi et al. 2017b). The AirQ model estimates the effects of short-term changes in air pollution (based on risk estimates from time-series studies) and the effects of long-term exposures. The AirQ model requires relative risk (RR) and baseline incidence (BI) values based on existing exposure-response relationships developed from prior epidemiological studies (Ghozikali et al. 2016; Conti et al. 2017). In epidemiology, the RR is the risk (probability) of developing a disease relative to exposure, per 10 μg/m^3 increase of the air pollutant (Sicard et al. 2011; Omidi et al. 2016; Khaniabadi et al. 2017a). A relative risk of 1 indicates that there is no increase in risk. In fact, under certain circumstances, it might be possible to have a RR value of less than 1, which would suggest that instead of being a risk factor the exposure of interest might actually be protective.

The counts of daily respiratory and cardiovascular hospitalizations due to accidents were excluded from the analysis. The values of RR and BI for HACD and HARD attributed to PM$_{10}$ exposure (Table 1) were obtained from published WHO (2004) data based on epidemiological studies and meta-analysis of time-series and panel studies such as APHEA-2 providing quantitative estimates of the short-term health effects of air pollution (e.g., Atkinson and Anderson 1997; Burret and Doles 1997; Katsouyanni et al. 1997; Touloumi 1997).

The attributable proportion (AP) is defined as the fraction of health consequences in a population exposed to a specific air pollutant (Fattore et al. 2011; Khaniabadi et al. 2017a). The AP can be related to the RR values by:

$$\mathrm{AP} = \sum\left(\left[\mathrm{RR}(c){-}1\right]{*}P(c)\right]\right)\Big/\sum\left[\mathrm{RR}(c)^{*}P(c)\right] \quad (1)$$

Table 1 Relative risk (95% confidence interval) and baseline incidence per 100,000 individuals, used for investigating the PM$_{10}$ health effects

Health effect	Baseline incidence	Relative risk per 10 μg/m^3 increase (95% CI)
HACD[a]	436	1.009 (1.006–1.013)
HARD[b]	1260	1.008 (1.0048–1.0112)

[a] Hospital admission for cardiovascular diseases

[b] Hospital admission for respiratory diseases

where AP is the attributable proportion of health outcomes and RR(c) is the relative risk for a given health outcome in category c of exposure (e.g., residential or industrial), taken from prior exposure-response functions based on epidemiological studies. $P(c)$ is the population proportion in category c. The rate of attributable proportion related to the exposure can be estimated by:

$$\mathrm{IE} = I \times \mathrm{AP} \tag{2}$$

where IE is the incidence of exposure which is the rate of the health outcomes attributable to the exposure, for a given concentration level, and I is the baseline incidence which is the baseline frequency of the given outcome in the studied population. Knowing the population size, the number of estimated excess cases associated with the exposure can be calculated by:

$$\mathrm{NE} = \mathrm{IE} \times N \tag{3}$$

where NE is the number of cases attributed to the exposure and N is the size of the population investigated.

Exposure assessment

The PM_{10} concentrations were pre-processed in Excel to convert the data to the inputs to run the AirQ program. For that, annual and seasonal averages, annual and seasonal maxima values, and 98th percentile were calculated. The PM_{10} concentrations were parsed into 10 $\mu g/m^3$ intervals, corresponding to exposure categories. The model assumes that PM_{10} concentrations are representative of the mean exposure of the population. In agreement with the dust event categories (Carsten et al. 2008), the number of excess cases for HACD and HARD was estimated for the three ranges of PM_{10} levels (<50, 50–200, and >200 $\mu g/m^3$) and three RR values (low, central, and high 95% confidence interval) using AirQ2.2.3 software.

Results

PM_{10} concentrations

The US 24-h National Ambient Air Quality Standards (NAAQS) for PM_{10} is 150 $\mu g/m^3$ (US-EPA 2006). The PM_{10} statistics such as annual average, annual maximum, summer and winter averages, summer, and winter maxima, and 98th percentile concentrations are presented in Table 2. In Khorramabad, the annual average PM_{10} concentration was 67.3 $\mu g/m^3$ in 2015 with a summer average of 68.3 $\mu g/m^3$ and a slightly lower average in winter (65.9 $\mu g/m^3$). The maximum 24-h concentration (621 $\mu g/m^3$) was observed in summer compared to a winter maximum of 535 $\mu g/m^3$. The annual 98th percentile in 2015 was 287 $\mu g/m^3$. In 2015 in Khorramabad, 22 days had PM_{10} concentrations exceeding the NAAQS criterion value (i.e., 150 $\mu g/m^3$). In 2014, a previous study reported 90 days with daily PM_{10} concentrations exceeding 150 $\mu g/m^3$ in Khorramabad, with an annual average of 80.6 $\mu g/m^3$ and an annual maximum of 422 $\mu g/m^3$ (Nourmoradi et al. 2016).

Table 2 PM_{10} concentrations in Khorramabad in 2015

Parameters	PM_{10} ($\mu g/m^3$)
Annual average	67.3
Summer average	68.3
Winter average	65.9
Annual maximum	621.0
Summer maximum	621.0
Winter maximum	535.0
98th percentile	287.1

According to the Hoffmann classification for dust storms (Table 3), the number of days for the normal, dusty, light dust storm (DS1), dust storm (DS2), strong dust storm (DS3), and serious strong dust storm (DS4) categories were 181, 175, 7, 2, 0 and 0, respectively, in Khorramabad in 2015. For the dust event categories (Carsten et al. 2008), the number of DS1 and DS2 days were 9. The number of days for dusty category (PM_{10} > 50 $\mu g/m^3$) was higher than the days with normal values (PM_{10} < 50 $\mu g/m^3$).

Person-days

Figure 2 depicts the percentage of days in which people living in Khorramabad were exposed to different ranges of PM_{10} concentrations related to normal, dusty, and MED storm days. In 2015, the exposure time to PM_{10} for normal (<50 $\mu g/m^3$), dusty (50–200 $\mu g/m^3$), and MED (>200 $\mu g/m^3$) conditions were 49.8, 47.1, and 3.0% in a year, respectively. In 2015, the highest morbidity rate (i.e., 14% of the total number) was related to the PM_{10} concentrations in the range 40–49 $\mu g/m^3$.

Short-term health effects

The cardiovascular and respiratory hospitalizations during normal, dusty, and MED storm days, produced by PM_{10} exposure, in terms of attributable proportions (AP) are presented in Table 4 for low, high, and central RR values. The number of excess of morbidity for cardiovascular diseases on normal, dusty, and MED event days for the central RR was 19.8, 71.6, and 20.2 individuals, respectively. The estimated numbers of excess respiratory diseases morbidity were 51.2, 184.8, and 53.0 persons during normal, dusty, and MED event days, respectively. The sum of excess HACD and HARD cases associated with a short-term PM_{10} exposure were 112

Table 3 Classification of normal days and dusty days and its occurrences (Carsten et al. 2008)

Category	Classification			Number of days
	Visibility (m)	Wind speed (m/s)	PM_{10} (μg/m^3)	
Normal days	–	–	<50	181
Dusty days	>2000	–	50–200	175
Light dust storm (DS1)	<2000	–	200–500	7
Dust storm (DS2)	<1000	>17	500–2000	2
Strong dust storm (DS3)	<200	>20	2000–5000	0
Serious strong dust storm (DS4)	<50	>25	>5000	0

and 289 people based on the central RR value. The ratios of number of excess cases in dusty air to normal air are similar for both HACD and HARD (ratio = 4.6). The estimated AP was 4.7% (95% CI 3.2–6.7%) for HACD and 4.2% (95% CI 2.6–5.8%) for HARD, respectively.

Figure 3 shows the cumulative number of each health outcome (number of excess cases) including the lower (lower curve), central (middle curve), and higher (upper curve) relative risks, corresponding to 5% (underestimated risk), 50% (central risk) and 95% (overestimated risk) confidence interval, respectively. For concentrations exceeding 150 μg/m^3, 31.8 and 82.3 HACD and HARD cases can be attributed to the PM_{10}, respectively. For each increase of 10 μg/m^3 in PM_{10} concentration, the risk of HACD and HARD rises by 0.60 and 0.48%, respectively. In addition, about 97% of hospitalizations for cardiovascular and respiratory diseases was associated to PM_{10} concentrations lower than 200 μg/m^3 and 3% was related to MED events in 2015.

Discussion

In this study, a WHO estimation tool was used to investigate the health effects of particulate matter (PM_{10}) on the health of people living in Khorramabad (Iran). The impact of PM_{10} was estimated as the increase in cardiovascular and respiratory morbidity for short-term PM_{10} exposure. The AirQ2.2.3 program was used in epidemiological studies worldwide to assess the short-term health impacts of PM_{10} on mortality and morbidity cases (e.g., Tominz et al. 2005; Fattore et al. 2011; Shakour et al. 2011; Habeebullah 2013; Jeong 2013; Khaniabadi et al. 2017c).

In Khorramabad, the annual average, summer average, annual maximum, and 98th percentile of PM_{10} concentrations were 67.3, 68.2, 621, and 287 μg/m^3, respectively, in 2015. Previous Iranian studies reported that, e.g., in Ilam city (180Km west from Khorramabad), the annual PM_{10} mean concentration was 78 μg/m^3 in 2015 (Khaniabadi et al. 2017a). The PM_{10} average in summer (87 μg/m^3) was higher than the winter (69 μg/m^3). The annual maximum PM_{10} was observed in summer with 769 μg/m^3 and the 98th percentile was 273 μg/m^3. An annual mean of 116 μg/m^3 was observed in Kermanshah (150Km North) in 2012 (Marzouni et al. 2016) as well as a summer mean, annual maximum and 98th percentile of PM_{10} concentrations were 126, 624, and 376 μg/m^3, respectively. A mean PM_{10} concentration during stormy days of 187 μg/m^3 was found in 2010 in Sanandaj (250 km North) as well as an annual maximum 24-h concentrations of PM_{10} equal to 600 μg/m^3 (Ebrahimi et al. 2014). Higher annual mean (195.5 μg/m^3) and annual maximum (782.1 μg/m^3) of PM_{10} was observed in Makkah (Saudi Arabia) over 1-year period (March 2012 to February 2013). In this study, the number of days (184 days) assigned as dusty (i.e., PM_{10} > 50 μg/m^3) was lower than the number of dusty days in Kermanshah in 2012 (322 days). Higher PM_{10} concentrations during summer are caused by higher temperatures and wind speeds leading to increased atmospheric turbulent and resuspension of dusts in Middle Eastern desert areas (Habeebullah 2013).

In Khorramabad and Ilam, 3% of estimated excess cases occurred during days with PM_{10} levels exceeding 200 μg/m^3, i.e., MED storms in 2015. Similar to Kermanshah in 2012, Ilam in 2015, and in Northern Italy in 2006, the highest number of hospital admissions was observed for PM_{10} concentrations range of 40–49 μg/m^3 in Khorramabad, i.e., lower than the daily limit value (50 μg/m^3 established by the WHO guideline while the annual limit value (20 μg/m^3) was largely

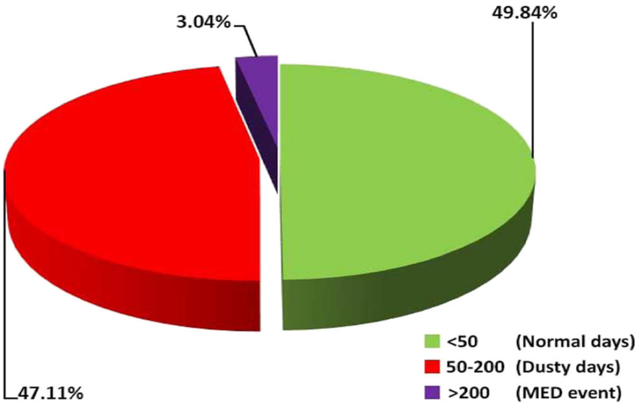

Fig. 2 Exposure time (in %) for people living in Khorramabad during normal, dusty, and MED events

Table 4 Estimated attributable proportion (AP) percentage and number of excess cases in 2015 related to short-term PM_{10} exposure calculated for three relative risk values (low, central, and high 95% confidence interval) and under different conditions (normal, dusty, and MED events)

Disease	AP (%)	Cases in normal (<50 μg/m^3)	Cases in dusty (50–200 μg/m^3)	Due to MED (>200 μg/m^3)	Subtotal	D/N
HACD	4.74	19.8	71.6	20.2	112	4.63
	(3.21–6.70)	(13–28)	(49–101)	(14–29)	(76–158)	
HARD	4.23	51.2	184.8	53	289	4.65
	(2.58–5.83)	(31–70)	113–255	(32–72)	(176–397)	

[a] Estimated value for the central relative risk

[b] Estimated values for the low-high relative risk values

exceeded (WHO 2006; Fattore et al. 2011; Marzouni et al. 2016; Khaniabadi et al. 2017a, c). In another study, the maximum number of hospital admissions was determined for the PM_{10} concentration range 200–249 μg/m^3 in Saudi Arabia (Habeebullah 2013).

The results of this study revealed that 87% of HACD and HARD occurred when PM_{10} concentrations were higher than 20 μg/m^3, and 97% of these impacts was attributed to PM_{10} concentrations less than 200 μg/m^3. In a study in Trieste, Italy, the results showed that 2.5% of respiratory deaths were related to PM_{10} concentrations greater than 20 μg/m^3 (Tominz et al. 2005). The greater number of people admitted to hospital, for concentrations exceeding 200 μg/m^3, can be attributed to the Middle Eastern Dust events.

In this study, an excess of total morbidity (HARD + HACD) of 112 and 289 people was associated with a short-term PM_{10} exposure. In Tallinn (Estonia), the number of excess cases of HARD and HACD due to exposure to PM_{10} were estimated at 71 and 204 persons in 2006–2008 (Orru et al. 2011). The study of short-term health effects of PM_{10} in Suwon (South Korea) has estimated the number of excess cases for the HARD and the HACD at 462 and 179 people,

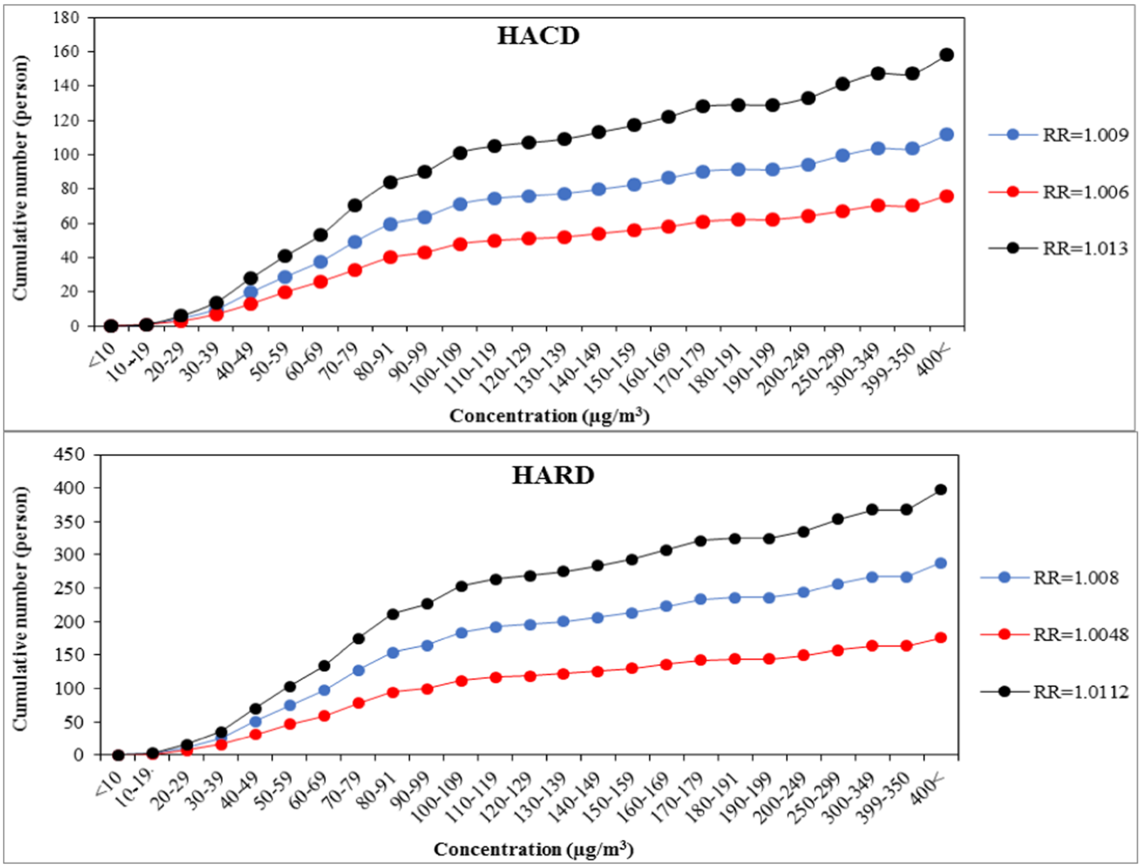

Fig. 3 Relationship between the number of HACD and HARD and ranges of PM_{10} concentrations for three relative risk values RR (low in *red*, central in *blue*, and high in *black*)

respectively, in 2011 (Jeong 2013). In this study, for each 10 µg/m^3 increase in PM_{10} level, HARD and HACD increased by 0.60 and 0.48%, respectively. In another study, in northern China, there was a 0.04% increase in HARD and HACD for each 10 µg/m^3 increase in the PM_{10} level (Chen et al. 2010). In another study in Egypt, an increase of 4.1% in the HARD was associated with an increase of 10 µg/m^3 in PM_{10} level (Shakour et al. 2011). A cohort study in 25 cities of China indicated that 1.8% (0.8–2.9%) and 1.7% (0.3–3.2%) increases (mean and 95% CI) in mortality risk was related to 10 µg/m^3 increments of PM_{10} for cardiovascular mortality and respiratory mortality, respectively (Zhou et al. 2014). Older references showed that, e.g., in the USA, each 10 µg/m^3 increase of PM_{10} concentration up to 150 µg/m^3 caused 0.12% increase in the risk rate of mortality among inhabitants of San Jose during 1980–1986 (Fairley 1990). For each 100 µg/m^3 increase in the PM_{10} concentration, 1.35 and 0.021% increase in the incidence of cardiovascular and respiratory diseases was observed respectively in Washington (Hefflin et al. 1994). For PM_{10} lower than 100 µg/m^3, each 10 µg/m^3 increase of PM_{10} level led to 1.1% increase in mortality risk in Los Angeles, USA (Shumway et al. 1988).

A significant correlation between PM_{10} levels and HARD with a central relative risk of 1.14 (1.01–1.29) was observed, with a number of cases higher during the cold season than the warm season (Chen et al. 2010; Guo et al. 2010). A recent study, carried out in Greece for a 13-year period 2001–2013, assessed the annual number of HARD due to the exposure to inhalable PM_{10} in Athens (Moustris et al. 2017). The annual mean PM_{10} concentrations ranged from 30 to 65 µg/m^3 over time. The AirQ2.2.3 software was used to evaluate adverse health effects by PM_{10} and the results show that the annual mean of HARD cases per 100,000 inhabitants ranged between 20 (suburban area) and 40 (city center area). Moreover, a strong relation between the annual number of HARD cases and the annual number of days exceeding the European Union daily PM_{10} threshold value (40 µg/m^3) was found (Moustris et al. 2017). When the mean annual PM_{10} concentration exceeds the threshold value, the number of HARD associated with PM_{10} increases by 25% on average (Moustris et al. 2016).

Different studies reported the number of HARD cases per 100,000 inhabitants (with the associated mean annual PM_{10} concentration): 32 people in Volos, Greece (41 µg/m^3) over the time period 2007–2011 (Moustris et al. 2016), 39 in Suwon, South Korea (52 µg/m^3) in 2011 (Jeong 2013), 77 in Tehran, Iran (91 µg/m^3) in 2010 (Naddafi et al. 2012), 2504 in Makkah, Saudi Arabia (196 µg/m^3) in 2012–2013 (Habeebullah et al. 2013), and 4919–5002 in Cairo, Egypt (306–441 µg/m^3) in 2008–2009 (Shakour et al. 2011).

A study in Sydney (Australia) found a significant relationship between respiratory diseases and dust events with a relative risk value of 1.2 (95% CI 1.15–1.26) for respiratory diseases (Merrifield et al. 2013). Another investigation was conducted to determine the influence of Asian Dust Storms (ADS) on the hospitalizations due to asthma and chronic obstructive pulmonary disease (COPD) over the tie period 2006–2012. The PM_{10} concentrations during ADS events reach 147 µg/m^3 whereas the concentrations are around 62 µg/m^3 during normal days. Hospital visits were significantly associated ($p < 0.05$) with the occurrence of Asian dust and increased significantly in the days with ADS for asthma (RR = 1.21; 95% CI 1.01–1.19) and COPD (RR = 1.29; 95% CI 1.05–1.59) compared with control days (Park et al. 2015). The numbers of excess cases for COPD and respiratory mortality were 336 and 26 persons, respectively, in 2015 (Khaniabadi et al. 2017a).

Conclusions

The study demonstrates a likely significant impact of air pollution on people living in Khorramabad, which is manifested primarily as a range of respiratory and cardiovascular problems. The results have strongly suggests the importance of the Middle Eastern Dust (MED) events in Khorramabad on increases of health outcomes attributable to PM_{10}. Although the findings are consistent with previous studies conducted worldwide, further investigation is required to refine the specific relative risk and baseline incidence values specific to the Iranian territory and related to variations in climate, geography, and demographic characteristics. Additional investigation is required to estimate the adverse health effects due to other pollutants, such as nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, and volatile hydrocarbons. In order to reduce the adverse health effects of particulate matter, health advisories provided by health authorities should be given to the public with particular emphasis on vulnerable people (e.g., children, elderly) with chronic lung and heart pathologies (e.g., asthmatic) to reduce their exposures during the dusty days. Furthermore, mitigation measures and strategies, as preventive risk, should be initiated by the appropriate government agencies to control air pollution and dust events in Iran. Activities such as spreading mulch, washing streets, management of water bodies, and planting some new species of plants to intercept airborne dust could reduce the dust concentrations in the ambient air.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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