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

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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 (PM10) 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 PM10 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 PM10 concentrations in the range of 40 to 49 μg/m3, i.e., lower than the daily (50 μg/m3) 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 PM10 concentrations above 10 μg/m3. 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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Introduction

Air pollution includes particles and gaseous pollutants, but particles are of paramount 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\textsubscript{10}) is particularly important for human health because PM\textsubscript{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\textsubscript{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\textsubscript{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. 2011). 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\textsubscript{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\textsubscript{10} concentrations were 894, 798, 5338, 2998, and 378 μg/m\textsuperscript{3}, respectively. In some areas, measured hourly PM\textsubscript{10} concentrations were greater than 6000 μg/m\textsuperscript{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 hypertension in China (Meng and Lu 2007). In addition, significant correlations were found between the PM\textsubscript{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\textsubscript{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\textsubscript{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 (Mirdosseini et al. 2013).

Particulate matter sampling

PM\textsubscript{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\textsubscript{10} concentrations using a β-ray absorption monitor (MetOne Model BAM-1020-Continuous Beta, USA). The hourly PM\textsubscript{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\textsubscript{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,
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/m³ 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 PM₁₀ 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:

\[
AP = \sum \left( \frac{RR(c) - 1}{RR(c)} \right) \sum \left[ RR(c) \times P(c) \right] \]

Table 1  Relative risk (95% confidence interval) and baseline incidence per 100,000 individuals, used for investigating the PM₁₀ health effects

<table>
<thead>
<tr>
<th>Health effect</th>
<th>Baseline incidence</th>
<th>Relative risk per 10 μg/m³ increase (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HACD&lt;sup&gt;a&lt;/sup&gt;</td>
<td>436</td>
<td>1.009 (1.006–1.013)</td>
</tr>
<tr>
<td>HARD&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1260</td>
<td>1.008 (1.0048–1.0112)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Hospital admission for cardiovascular diseases

<sup>b</sup> 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:

\[
IE = I \times AP
\]

(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:

\[
NE = IE \times N
\]

(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\(^3\).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PM(_{10}) (( \mu )g/m(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual average</td>
<td>67.3</td>
</tr>
<tr>
<td>Summer average</td>
<td>68.3</td>
</tr>
<tr>
<td>Winter average</td>
<td>65.9</td>
</tr>
<tr>
<td>Annual maximum</td>
<td>621.0</td>
</tr>
<tr>
<td>Summer maximum</td>
<td>621.0</td>
</tr>
<tr>
<td>Winter maximum</td>
<td>535.0</td>
</tr>
<tr>
<td>98th percentile</td>
<td>287.1</td>
</tr>
</tbody>
</table>

Table 2 PM\(_{10}\) concentrations in Khorramabad in 2015

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.
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/m³, 31.8 and 82.3 HACD and HARD cases can be attributed to PM₁₀, respectively. For each increase of 10 μg/m³ in PM₁₀ 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 PM₁₀ concentrations lower than 200 μg/m³ 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 (PM₁₀) on the health of people living in Khorramabad (Iran). The impact of PM₁₀ was estimated as the increase in cardiovascular and respiratory morbidity for short-term PM₁₀ exposure. The AirQ2.2.3 program was used in epidemiological studies worldwide to assess the short-term health impacts of PM₁₀ 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 PM₁₀ concentrations were 67.3, 68.2, 621, and 287 μg/m³, respectively, in 2015. Previous Iranian studies reported that, e.g., in Ilam city (180Km west from Khorramabad), the annual PM₁₀ mean concentration was 78 μg/m³ in 2015 (Khaniabadi et al. 2017a). The PM₁₀ average in summer (87 μg/m³) was higher than the winter (69 μg/m³). The annual maximum PM₁₀ was observed in summer with 769 μg/m³ and the 98th percentile was 273 μg/m³. An annual mean of 116 μg/m³ was observed in Kermanshah (150Km North) in 2012 (Marzouni et al. 2016) as well as a summer mean, annual maximum and 98th percentile of PM₁₀ concentrations were 126, 624, and 376 μg/m³, respectively. A mean PM₁₀ concentration during stormy days of 187 μg/m³ was found in 2010 in Sanandaj (250 km North) as well as an annual maximum 24-h concentrations of PM₁₀ equal to 600 μg/m³ (Ebrahimi et al. 2014). Higher annual mean (195.5 μg/m³) and annual maximum (782.1 μg/m³) of PM₁₀ 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., PM₁₀ > 50 μg/m³) was lower than the number of dusty days in Kermanshah in 2012 (322 days). Higher PM₁₀ 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 PM₁₀ levels exceeding 200 μg/m³, 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 PM₁₀ concentrations range of 40-49 μg/m³ in Khorramabad, i.e., lower than the daily limit value (50 μg/m³) established by the WHO guideline while the annual limit value (20 μg/m³) was largely

![Fig. 2](image-url) Exposition time (in %) for people living in Khorramabad during normal, dusty, and MED events.
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 $\mu$g/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 $\mu$g/m$^3$, and 97% of these impacts was attributed to PM$_{10}$ concentrations less than 200 $\mu$g/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 $\mu$g/m$^3$ (Tominz et al. 2005). The greater number of people admitted to hospital, for concentrations exceeding 200 $\mu$g/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,

<table>
<thead>
<tr>
<th>Disease</th>
<th>AP (%)</th>
<th>Cases in normal (&lt;50 $\mu$g/m$^3$)</th>
<th>Cases in dusty (50–200 $\mu$g/m$^3$)</th>
<th>Due to MED (&gt;200 $\mu$g/m$^3$)</th>
<th>Subtotal</th>
<th>D/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>HACD</td>
<td>4.74 (3.21–6.70)</td>
<td>19.8 (13–28)</td>
<td>71.6 (49–101)</td>
<td>20.2 (14–29)</td>
<td>112 (76–158)</td>
<td>4.63</td>
</tr>
<tr>
<td>HARD</td>
<td>4.23 (2.58–5.83)</td>
<td>51.2 (31–70)</td>
<td>184.8 (32–72)</td>
<td>53 (176–397)</td>
<td>289 (14–29)</td>
<td>4.65</td>
</tr>
</tbody>
</table>

*a Estimated value for the central relative risk
*b Estimated values for the low-high relative risk values

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/m³ increase in PM₁₀ 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/m³ increase in the PM₁₀ 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/m³ in PM₁₀ 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/m³ increments of PM₁₀ for cardiovascular mortality and respiratory mortality, respectively (Zhou et al. 2014). Older references showed that, e.g., in the USA, each 10 μg/m³ increase of PM₁₀ concentration up to 150 μg/m³ caused 0.12% increase in the risk rate of mortality among inhabitants of San Jose during 1980–1986 (Fairley 1990). For each 100 μg/m³ increase in the PM₁₀ 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 PM₁₀ lower than 100 μg/m³, each 10 μg/m³ increase of PM₁₀ level led to 1.1% increase in mortality risk in Los Angeles, USA (Shumway et al. 1988).

A significant correlation between PM₁₀ 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 PM₁₀ in Athens (Moustris et al. 2017). The annual mean PM₁₀ concentrations ranged from 30 to 65 μg/m³ over time. The AirQ2.2.3 software was used to evaluate adverse health effects by PM₁₀ 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 PM₁₀ threshold value (40 μg/m³) was found (Moustris et al. 2017). When the mean annual PM₁₀ concentration exceeds the threshold value, the number of HARD associated with PM₁₀ 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 PM₁₀ concentration): 32 people in Volos, Greece (41 μg/m³) over the time period 2007–2011 (Moustris et al. 2016), 39 in Suwon, South Korea (52 μg/m³) in 2011 (Jeong 2013), 77 in Tehran, Iran (91 μg/m³) in 2010 (Naddaf et al. 2012), 2504 in Makkah, Saudi Arabia (196 μg/m³) in 2012–2013 (Habeebullah et al. 2013), and 4919–5002 in Cairo, Egypt (306–441 μg/m³) 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 PM₁₀ concentrations during ADS events reach 147 μg/m³ whereas the concentrations are around 62 μg/m³ 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 Khorraramabad, which is manifested primarily as a range of respiratory and cardiovascular problems. The results have strongly suggested the importance of the Middle Eastern Dust (MED) events in Khorraramabad on increases of health outcomes attributable to PM₁₀. 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.
References


WHO (2004) Meta-analysis of time-series studies and panel studies of particulate matter (PM) and ozone (O3). WHO task group. WHO/EURO 04/5042688


WMO, World Meteorological Organization (2013) Establishing a WMO Sand and Dust Storm Warning Advisory and Assessment System Regional Node for West Asia: current capabilities and needs

