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Risk of morbidity attributed to ambient PM$_{10}$ in the western cities of Iran

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ABSTRACT

The incidence of hospitalizations due to cardiovascular (HACVD) and respiratory diseases (HARD) associated with PM$_{10}$ was assessed with AirQ2.2.3. Daily PM$_{10}$ data were used to this purpose. The results showed that 8.2% (95% CI: 5.6–11.4%), 7.2% (95% CI: 4.9–10.1%), and 4.4% (95% CI: 3.0–6.3%) of HACVD and 7.3% (95% CI: 4.5–10%), 6.4 (95% CI: 4.0–8.8%), and 3.9% (95% CI: 2.4–5.4%) of HACVD in the cities of Ahvaz, Khorramabad and Ilam were attributed to PM$_{10}$ respectively. Governmental authorities need to act to control the dust hazard by spreading mulch and developing green space using vegetation amenable to the local climate.

1. Introduction

Air pollution due to industrialization and urbanization is one of the major environmental issues in the current century (Guo et al. 2010, Goudie 2014, Nourmoradi et al. 2016, Khaniabadi et al. 2017b, 2017e). Epidemiological studies have shown that chronic and acute health problems attributed to outdoor air pollution include hospitalizations for respiratory, cardiopulmonary, and cardiovascular diseases and related mortality (Khaniabadi et al. 2017a, 2017d).

Among the ambient atmospheric pollutants, particulate matter (PM) produces the most harmful effects on human health (Mentese et al. 2012). Many studies have reported strong statistical associations between PM and respiratory diseases, pulmonary damage, and mortality.

Particulate matter with an aerodynamic diameter equal to or less than 10 $\mu$m is PM$_{10}$ (Menetrez et al. 2009, Mirhosseini et al. 2013, Geravandi et al. 2017, Goudarzi et al. 2017). Short-term exposure to PM$_{10}$ can irritate the lungs and possibly cause immune responses, lung constriction, shortness of breath and cough. Long-term exposure to PM$_{10}$ may result in cancer and premature mortality (Goudie and Middleton 1992, 2001, Khaniabadi et al. 2017c). In addition to the health outcomes resulting from increase pollution from industrialization and urbanization, increasingly frequent natural dust events have affected various geographical areas in recent years, especially in the Middle East (Goudie 2014, Khaniabadi et al. 2017c). The regions of south, west, and southwest of Iran have been exposed to Middle Eastern Dust (MED) storms, especially those storms coming from the Arabian Peninsula, Kuwait, and Iraq. Ahvaz, Khorramabad, and Ilam cities are located in western Iran, and these cities have been exposed to high PM$_{10}$ concentrations as a result of these MED events. The dust events have caused thousands of hospitalizations due to cardiovascular and respiratory diseases (Goudie and Middleton 1992, 2001, Guo et al. 2010, Neisi et al. 2017a,
Nourmoradi et al. (2016), Khaniabadi et al. (2017a, 2017c, 2017d). Shahsavani et al. (2012) found that high concentrations of PM were related to adverse human health outcomes during dust event days in Ahvaz, Iran (Shahsavani et al. 2012). Kwon et al. (2002) argued that there is a statistically significant correlation between dust storms and death associated with cardiovascular and respiratory diseases in Seoul, Korea (Kwon et al. 2002), while (Meng and Lu 2007) evaluated the relationship between dust events and hospital admissions due to respiratory and cardiovascular diseases, pneumonia, and hypertension in China.

The objective of this study was to estimate the health effects of MED storms on hospital admissions due to cardiovascular and respiratory diseases in Ahvaz, Khorramabad, and Ilam using the AirQ2.2.3 model in 2016.

2. Materials and methods

2.1. Study area

Ahvaz (31°20′N, 48°40′E), Khorramabad (33°29′N, 48°21′E), and Ilam (33°36′N, 46°36′E) are the capital cities of Khuzestan, Lorestan, and Ilam provinces situated in western Iran (see Figure 1) (Khaniabadi et al. 2017a, 2017b, Mohammadi et al. 2017, Neisi et al. 2017b). They have a total population of 1,300,000, 540,000, and 172,000 persons, respectively. Goudie reported that Khorramabad is the nineteenth most polluted city in the world in terms of annual average PM10 concentrations (Goudie 2014).

2.2. Air sampling

Air pollution-monitoring sites established by the Environmental Protection Agencies (KEPA) of Ahvaz, Khorramabad, and Ilam, and they maintained and operated them. PM10 concentrations were measured using beta attenuation monitors (BAMs). One-year data of PM10 concentrations from January to December 2016 were measured. Hourly PM10 concentrations were measured and 24-h PM10 concentrations were processed to provide the input for the health effects model. We estimated hospital admissions resulting from cardiovascular and respiratory diseases caused by exposure to particulate matter (PM10) using the Air Quality Health Impact Assessment model (AirQ2.2.3). AirQ was developed by the WHO European Center for Environment and Health based on multiple peer-reviewed studies (Atkinson and Anderson 1997, Burret and Doles 1997, Touloumi 1997, Khaefi et al. 2017). AirQ is a tool, used in many previous studies (Geravandi et al. 2017, Khaniabadi et al. 2017a, 2017b, 2017d, 2017e), to assess the relationship between air pollutants concentration and health outcomes in a defined area during a given period using ambient monitoring data. The model uses dose–response function based on epidemiological studies (Khaniabadi et al. 2017a, 2017d).
Table 1. Relative risk (95% CI) and baseline incidence used for investigating the health effects of PM$_{10}$.

<table>
<thead>
<tr>
<th>Health effect</th>
<th>BI*</th>
<th>RRs (95% CI) per 10 µg/m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HACVD$^a$</td>
<td>1260</td>
<td>1.008 (1.005–1.011)</td>
</tr>
<tr>
<td>HARD$^e$</td>
<td>436</td>
<td>1.009 (1.006–1.013)</td>
</tr>
</tbody>
</table>


2.3. Health impacts

The PM$_{10}$ concentration data from January to December 2016 (12 months) were obtained from the environment protection agencies of each city. In epidemiological studies, particularly in AirQ, the input parameters related to health are relative risk (RR) and baseline incidence (BI). The RR is the possibility of developing an illness resulting from exposure to a pollutant. The RR and BI per 100,000 individuals associated with different types of mortality and morbidity are presented in Table 1. The RR and BI values were obtained from the data provided with the AirQ2.2.3 software. In this software, the health impact assessment of air pollutants is achieved by calculation of the attributable proportion (AP), which explains the portion of health impacts that occur for certain people due to contact with air pollutants (Khaniabadi et al. 2017c, 2017f). The AP was calculated using the following equation:

$$AP = \frac{\sum (\text{RR}(c) - 1) \times P(c))}{\sum \text{RR}(c) \times P(c)}$$

where AP and RR(c) are the AP of the health impact and RR for a certain health impact in the group c of exposure. Also, P(c) is the fraction of the target population in group c of exposure. The amount attributable to the population exposure was calculated using Equation (2) assuming that the baseline frequency of the specific health effect in the studied population is known.

$$IE = I \times AP$$

where IE and I are the rate of the health impact attributable to the contact and the baseline frequency of the health impact in the population, respectively. Then, given a population size, the total number of excess cases attributable to the exposure is specified by Equation (3).

$$NE = IE \times N$$

Table 2 shows the annual and seasonal average 2016 PM$_{10}$ concentrations. The maximum seasonal PM$_{10}$ concentrations in Ahvaz, Khorramabad, and Ilam (6041, 476, and 688 µg/m$^3$, respectively) were observed during the winter. Shahsavani et al. (2012) reported that the maximum PM$_{10}$ concentration was highest in the summer in Ahvaz.

The maximum average seasonal PM$_{10}$ concentration in Ahvaz was 901.9 µg/m$^3$ and occurred in winter. For Khorramabad (102.9 µg/m$^3$) and Ilam (62.5 µg/m$^3$), the highest seasonal averages occurred in summer. The annual average PM$_{10}$ concentration in Ahvaz exceeded the National Ambient Air Quality Standard (NAAQS) (150 µg/m$^3$). However, the annual average PM$_{10}$ values in Khorramabad and Ilam were within the air quality guideline values prescribed by the NAAQS.

Higher PM$_{10}$ values in Ahvaz were due to more frequent MED storms compared to the other cities (Shahsavani et al. 2012). MED storms are the primary cause of dust events in Ahvaz. Moreover, Ahvaz is more populous and industrialized than the other cities.
Therefore, other sources of pollution including transportation (vehicles) and industries also may also contributed to its high PM$_{10}$ concentrations.

3.2. Person-days

Figure 2 illustrates the percentage of days that people in Ahvaz, Khorramabad, and Ilam were exposed to different concentrations of PM$_{10}$ from MED storms during 2016. The highest percentage of exposure to PM$_{10}$ in Ahvaz, Khorramabad, and Ilam occurred on days with concentrations in the intervals of 130–139, 60–69, and 40–49 µg/m$^3$ with percentages of 13.3, 9.5, and 20.2, respectively. In another study, the maximum person-days of exposure in Makkah, Saudi Arabia were in the PM$_{10}$ concentrations range of 200–249 µg/m$^3$ (Habeebullah 2013). The maximum percentage of the days that people in Mazzano and Rezzato (Italy) were exposed to different PM$_{10}$ levels was found to be in the concentration interval of 40–49 µg/m$^3$ (Fattore et al. 2011), which is similar to the present study for Ilam.

3.3. Health impact assessment

The results of the AirQ$_{2.2.3}$ model analysis of PM$_{10}$ concentrations with 95% confidence intervals (95% CI) are shown in Table 3.

The cumulative number of excess cases for HACVD and HARD for BI values of 1260 and 436 were estimated for Ahvaz to be 508 and 1319 cases. For the other cities, Khorramabad had 144 and 372 cases, and Ilam had 66 and 170 cases based on total populations of 1,300,000, 540,000, and 172,000 persons, respectively. For comparison, in another study by AirQ, the number of excess cases of HARD and HACD due to PM$_{10}$ exposure in Tallinn (Estonia) were estimated to be 71 and 204 persons (CI) (Orru et al. 2011).

The number of excess cases of HACVD and HARD associated with PM$_{10}$ concentrations during 2016 are presented in Figure 3. This figure illustrates diagrams based on the number of each health outcome and the number of estimated cases for the central RR (50%) versus PM$_{10}$ concentration, respectively.

In Ahvaz, Khorramabad, and Ilam, 246, 15.2, and 67.3 cases of HACVD per 10$^5$ persons and 638, 39.2, and 174.4 of HARD per 10$^5$ persons can be attributed to the PM$_{10}$ concentrations above 150 µg/m$^3$, respectively. For each increase of 10 µg/m$^3$ in concentration of PM$_{10}$, the risk of HACVD and HARD increases by about 0.8 and 0.9%, respectively. These results also show that 8.2% (95% CI: 5.6–11.4%), 7.2% (95% CI: 4.9–10.1%), and 4.4% (95% CI: 3.0–6.3%) of HACVD and 7.3% (95% CI: 4.5–10%), 6.4 (95% CI: 4.0–8.8%), and 3.9% (95% CI: 2.4–5.4%) of HACD in Ahvaz, Khorramabad, and Ilam, respectively, were related to PM$_{10}$ concentrations exceeding 10 µg/m$^3$, respectively. In addition, about 90%, 94%, and 97.6% of the HACVD

![Figure 2. Percentage of days that people in Ahvaz, Khorramabad, and Ilam were exposed to PM$_{10}$ as a result of dust storms.](image)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated AP (%)</th>
<th>Number of excess persons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ahvaz</td>
<td>Khorramabad</td>
</tr>
<tr>
<td>HACVD</td>
<td>8.2 (5.6–11.4)</td>
<td>7.2 (4.9–10.1)</td>
</tr>
<tr>
<td>HARD</td>
<td>7.3 (4.5–10.0)</td>
<td>6.4 (4.0–8.8)</td>
</tr>
</tbody>
</table>
and HARD occurred on days with PM$_{10}$ concentrations less than 200 μg/m$^3$ in Ahvaz, Khorramabad, and Ilam, respectively.

In another study, Goudarzi et al. (2017) reported that the number of HARD and HACVD decreased in Kermanshah, in 2014 to 184 and 476 persons compared with 2011 (Zallaghi 2014).

The estimated HACVD and HARD incidences due to exposure to PM$_{10}$ were in the order of Ahvaz > Khorramabad > Ilam. These differences can be attributed to the varying geographic conditions, population ratios, climates, and the rates of development of these cities. Furthermore, Ahvaz, located in a desert area and more subjected to MED storms, has great air pollution (non-attainment of NAAQS). Thus, the population was subjected to higher exposures that produce higher rates of hospitalizations than in the other cities.

4. Conclusions

A health impact assessment of particulate matter (PM$_{10}$) exposure in Ahvaz, Khorramabad, and Ilam showed that adverse health effects in these cities were likely to have resulted from higher than average PM$_{10}$ concentrations on dusty days driven by MED storms. Given the estimated cardiovascular and respiratory mortality associated with PM$_{10}$, cardiovascular mortality had a larger main role in the total mortality resulting from PM. To decrease the health impacts of PM, health training should be conducted to encourage the public, especially people with chronic lung and heart diseases, and other susceptible individuals such as the elderly and children to reduce their activities on the dusty days. Moreover, efforts should be conducted by the governments to control of dust by spreading mulch and the development of green space particularly using vegetation amenable to the local climate.

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Disclosure statement

The authors have no conflicts of interest.

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