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RESEARCH ARTICLE

# Assessment of hospitalization and mortality from exposure to $PM_{10}$ using AirQ modeling in Ilam, Iran

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**Abstract** The aims of this study were to assess the health impact of $PM_{10}$ on inhabitants and to investigate the trend of $PM_{10}$ concentrations in Ilam, Iran, from 2012 to 2015. For these aims, daily average concentration of $PM_{10}$ was obtained from continuous monitoring stations in the study area. Mortality and morbidity due to $PM_{10}$ were assessed by AirQ software developed by World Health Organization (WHO). Based on the results, the annual mean concentrations of $PM_{10}$ in all of years were more than WHO guideline and $PM_{10}$ concentration had a decreasing trend in this study period. Total mortality attributed to $PM_{10}$ was found to be 49 cases in 2012, 25 in 2013, and 33 in 2014. Hospital admission due to respiratory diseases was the most impact due to $PM_{10}$. Increase in relative risk (RR) with every 10 μg/m$^3$ increase in $PM_{10}$ from 2012 to 2015 years for total mortality, respiratory disease hospitalization, and hospital admissions were 0.6, 0.8, and 0.9%, respectively. The results of this study indicated that air pollution is one of the major problems in this urban area and AirQ model as simple tool can help to design preventive and controlling programs in order to reduce human health effects of pollutants.

**Keywords** $PM_{10}$ · Air pollution · Health impact · Mortality · Hospitalization

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## Introduction

One of the main source of airborne particulate matter in the dry and semi dry areas is the dust storm phenomena, especially in deserts where weak vegetation cover and severe winds can cause easy transformation of particles. This phenomenon can affect sunshine, urban traffic, agriculture, air precipitation, as well as photochemical and dynamic processes in the atmosphere. Therefore it causes crucial health and environmental impacts (Shahsavani et al. 2012, Miri et al. 2017). In recent decades, air pollutants caused by industries and natural phenomenon such as dust has caused thousands of mortality worldwide. Despite the fact that air pollutants in very low concentrations (even lower than standard and guideline values) may have not a certain negative effect on normal human, it can however be harmful for sensitive people (Downs et al. 2007). Nowadays, the most important concerns about the health of urban air are related to new air pollutants such as $O_3$, $NO_2$ and change in trend of distribution and size of specific particulate matters (Fattore et al. 2011).

Based on epidemiological studies which conducted in two recent decades, respiratory (such as chronic bronchitis) and cardiovascular diseases in the urban areas have close relationship to air pollution (De Meij et al. 2009). The global mortality related to air pollution was found to be 1 million cases in 2000 and it was increased to 3.1 million in 2012 and more than 50% of mortality rate was related to the Asian countries (Wong et al. 2008, Mokhtari et al. 2016). There are some biological mechanisms for the impact of air pollutants on human health which have not clearly detected. However, the most probable mechanism is potential oxidation of different organs (Glinianaia et al. 2004).

According to WHO, particles with diameter smaller than 10 μm are probable cause of respiratory and cardiovascular diseases such as asthma, bronchitis, heart attacks, reductions in lung function, and increasing mortality rate. This is in agreement with some European cities in which each 10 μg/m$^3$ increase in $PM_{10}$ concentration, 6% increase in mortality has been reported (WHO 2005). According to previous studies on air pollution in Iranian mega cities such as Tehran, Isfahan, Arak, Mashhad, and Tabriz, the air quality has dropped in recent years which can be due to industrialization, urbanization, and the development of transportation systems. In most of the studies, $PM_{10}$ is introduced as the primary cause of air pollution in these cities (Kermani et al. 2014, Nikonahad et al. 2017). Moreover, studies conducted in Dehli (India), Pecan (China), and some cities in Malaysia showed that $PM_{10}$ is responsible for 80% of the annual air pollution. These cities were more or less similar to big cities in Iran in terms of industries, transportation, and population and industrialization and urban traffic have been reported to be the main cause of air pollution in these cities (Ahmad et al. 2006, Kumar and Goyal 2011, Mohan and Kandya 2007, Mu et al. 2014).

Ilam, city in southwest of Iran (Fig. 1), with a population of 176,000 is facing dust storm originated from Iraq deserts and some health and environmental problems have been reported in this city recently (2016). With respect to occurrence of dust storm in Ilam and health and environmental problems associated with this phenomena and specially $PM_{10}$, the study was aimed to assess the health impact of $PM_{10}$ during 3-year period from 2012 to 2014 as well as to investigate the trend of $PM_{10}$ concentration in this period of time.

## Material and method

### Study area

Ilam with 60 km$^2$ area, is located in southwest of Iran in longitude of 45 41′ to 46 51′ E and latitude of 33 21′N to 33 51′N. The annual mean temperature and precipitation in Ilam city are 14.3 °C and 30 mm/yr., respectively. Its population is approximately 176,000 people with population growth rate of 2.6% (Iran 2016). By age category, 23.2% people are in range <15 years old, 72.8% are in range of 15–64 years, and 4% are >60 years. Therefore, s most of Ilam inhabitants are in the age susceptible to air pollution.

### AirQ software

In this study, according to the World Health Organization (WHO), AirQ 2.2.3 software was used to assess the health impact of $PM_{10}$ (Naddafi et al. 2012). This software was designed to estimate the effects of pollutants on human health in a specified period and place and it is accessible in the WHO website (http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/activities/20050223_5).

The calculation in this software is based on (1) risk estimation from similar studies, to estimate the long-term effect of pollutants, and (2) risk estimation from the chronological studies to estimate the mortality and diseases related to air pollutants. This software was basically designed for the environmental health of central Europe while by modifying of coefficients it can be useful all around the world. According to Table 1, relating coefficients of base incidence (BI) are calculated for the health impact of age groups. Since the age group of Iran population is younger than Europe, therefore, the quantities are smaller in Iran in comparison with Europe countries (Naddafi et al. 2012).

$$AP = SUM\ \{[RR(c) - 1]^{\times} p(c)\} / SUM\ [RR(c)^{\times} p(c)] \qquad (1)$$

Where AP is attributable proportion (related to the exposure of a special population during a special time), RR(c) is relative risk of health impact in the target group, and P(c) is the population of target group. Knowledge of the base incident (BI) in the society can help to calculate the attribution of proportion (AP) using Eq. 2 (De Meij et al.).

$$IE = I \times AP \qquad (2)$$

Where $I$ represent the baseline frequency of the health endpoint in the investigated cases and IE denotes to the rate of the health outcome attributable to the exposure.

RR reflects the amount of pollutants effects on the health and this variable is linked to exposure to air pollutants. RR is calculated by time series studies that survey the concentration variations of air pollutants as well as their impacts on health in a long-time period (Fattore et al. 2011).

Finally, using Eq. 3, knowing the number of the population, the number of cases attributable to the exposure could be calculated as:

$$NE = IE \times N \qquad (3)$$

Where $N$ refer to number of the population investigated and NE is the number of exposed cases.

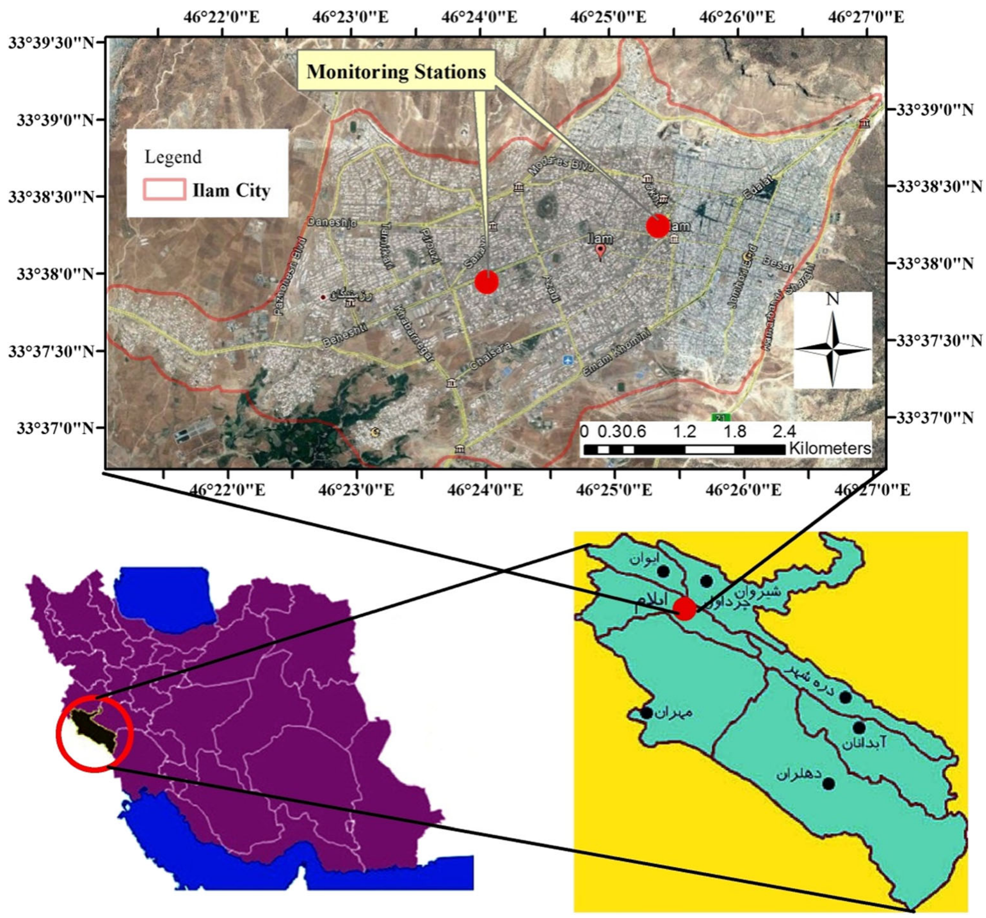


**Fig. 1** Map of study area and air quality monitoring station

## Exposure assessment

Figure 2 shows the study area and air pollution monitoring stations. The daily concentration of $PM_{10}$ from March 2012 to March 2015 was obtained from the environmental protection organization of Ilam Province. There are two continues air pollution monitoring stations in this city that measured $PM_{10}$ based on beta attenuation method. The $PM_{10}$ data, according to WHO functioning, was first processed with MS Excel software and categorized to within two levels and the annual and seasonal average, annual and seasonal maximum, and 98th percentile for every year were calculated. Finally after the classification of the collected data for each year, these data entered to AirQ software (based on 10 μg/m$^3$) to assess total mortality, cardiovascular and respiratory mortality, and hospital admission due to cardiovascular and respiratory disease.

## Result and discussion

The descriptive statistics of $PM_{10}$ concentration were shown in Table 2. The annual 24 h average concentration of $PM_{10}$ in all of years was more than the WHO guideline so that the average and maximum concentration of $PM_{10}$ in the 2012 and 2013 was

**Table 1** Relative risk (RR) with 95% confidence interval (95% CI), and rate of baseline incidence (BI)

| Outcome | Health endpoint | Incidence | Relative risk (CI 95%) per 10 μg/m$^3$ |
|---|---|---|---|
| Mortality | Total mortality | 543.5 | 1.006 (1.004–1.008) |
| | Respiratory | 48.4 | 1.013 (1.005–1.020) |
| | Cardiovascular | 231 | 1.009 (1.005–1.013) |
| Morbidity | Hospital admissions Respiratory disease | 1260 | 1.008 (1.0048–1.0112) |
| | Hospital admissions Cardiovascular disease | 436 | .009 (1.006–1.013) |

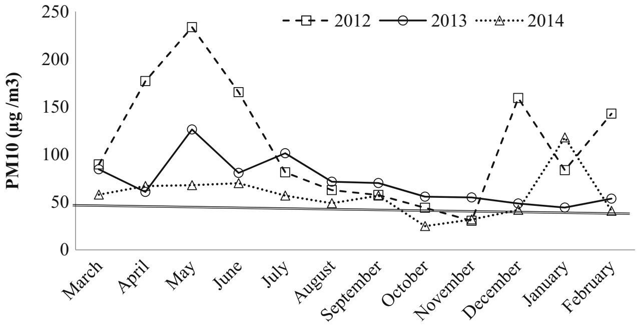


**Fig. 2** Trends of average monthly $PM_{10}$ from 2012 to 2014

almost 5.6 and 88 times more than the WHO guideline (20 µg/m$^3$) (Europe and Organization 2006), respectively. In 2014, the annual mean and maximum were 3.35 and 24 times more than WHO guideline. The maximum concentration of $PM_{10}$ was observed in summer (Fig. 2), in a way that the mean concentration of $PM_{10}$ in winter was more than summer and this result was in agreement with $PM_{10}$ concentration reported by Maleki et al. in Ahvaz city which it is close to Ilam province (Maleki et al. 2016). The main cause of high concentration of $PM_{10}$ is dust storms that occurred frequently in southeast of Iran especially in this city during summer. Because of the windy condition and the dryness of the study area, particle distribution in high concentration happens all the year, and urban and industrial activities like oil and petrochemical industries have intensified this trend.

In the other studies, the average annual $PM_{10}$ concentration in cities of Yazd (103 µg/m$^3$), Arak (78 µg/m$^3$), Tehran (90 µg/m$^3$), Tabriz (85 µg/m$^3$), Shiraz (102 µg/m$^3$), and Ahvaz (385 µg/m$^3$) were reported (Mokhtari et al. 2015, Shahsavani et al. 2012, Fazelinia et al. 2013, Gholampour et al. 2014). In two cities of Ahwaz and Yazd (Miri et al. 2017), the main source of particles were soil dusts and in Tehran (Naddafi et al. 2012), Tabriz and Shiraz the source of particles are due to the burning (Ghanbari Ghozikali et al. 2014, Gharehchahi et al. 2013).

The numbers of days that inhabitants exposed to different $PM_{10}$ concentrations were shown in Fig. 3a–c). Population

**Table 2** Summary of the concentrations of air pollutants (µg/m$^3$)

| $PM_{10}$ concentration | Year | | |
|---|---|---|---|
| | 2012–2013 | 2013–2014 | 2014–2015 |
| Average annual | 112 | 71 | 57 |
| Average summer | 88 | 54 | 53 |
| Average winter | 135 | 88 | 61 |
| 98 percentiles annual | 950 | 194 | 522 |
| Maximum annual | 1773 | 491 | 770 |
| Maximum summer | 1773 | 491 | 770 |
| Maximum winter | 561 | 221 | 195 |

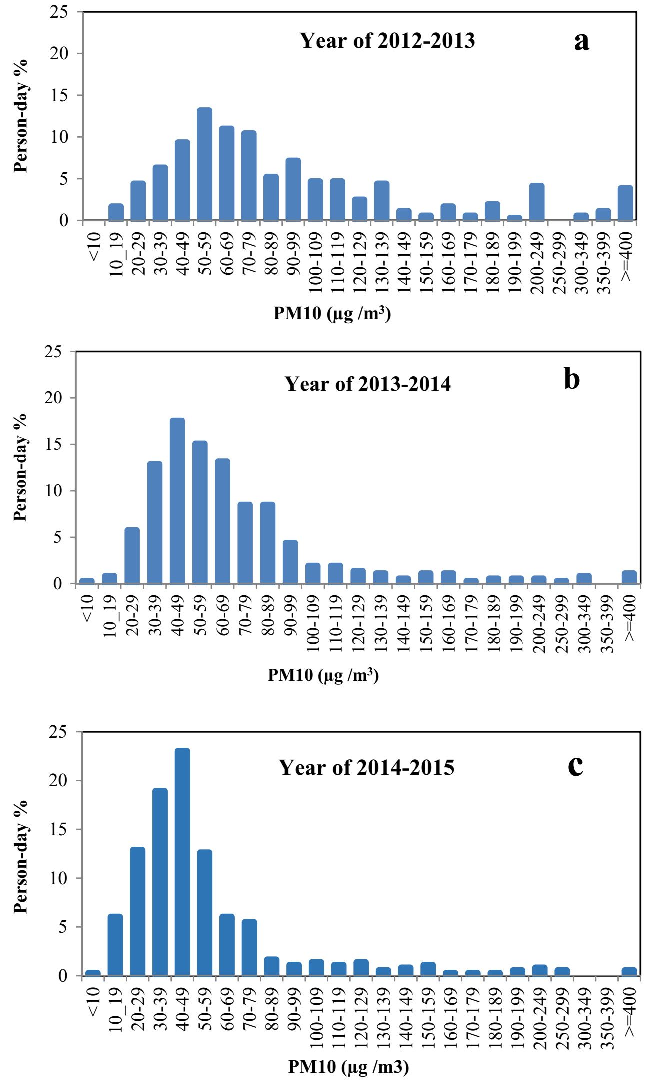


**Fig. 3** The percentage of days in which people exposed to different levels of $PM_{10}$ from 2012 to 2014

were exposed to expose to 50–59 µg/m$^3$ of $PM_{10}$ in 13.2% of days in period of 2012–2013. For period of 2013–2014 in 17.5% and for 2014–2015 in 23% of days $PM_{10}$ concentration was 40–49 µg/m$^3$.

RR reflects the increased risk originated due to exposure to a pollutants which is gained by time-series studies. It assesses the effects of air pollution on health (mortality and morbidity due to cardiovascular and respiratory diseases). With every 10 µg/m$^3$ increase in $PM_{10}$ concentrations during 2012–2015 period, RR was increased by 0.6, 0.8, and 0.9% for total mortality, hospital admissions due to respiratory disease, and hospital admissions due to cardiovascular diseases, respectively. In the other words, the effect of increased cardiovascular disease RR was more evident.

In previous study, (Miri 2016) the increase of RR was found to be 1.5% for total mortality due to every 10 µg/m$^3$ increase in $PM_{10}$ concentrations in Mashhad, Iran, with annual average (24 h) of 83 μg/m$^3$. The main reason is, maybe, difference in source of $PM_{10}$ in Mashhad with heavy traffic in most of the times and industrial activities in contrast to Ilam.

The percentage of the attributed proportion as well as the number of total premature mortality related to $PM_{10}$ is presented in Table 3 and describes the short-term impacts of exposure to $PM_{10}$ pollutants. Also, due to the high concentration of $PM_{10}$ in the year 2012–2013, the number of excess cases related to mortality in this year exceeded that of 2013–2014 and 2014–2015 (49, 33, and 25 cases, respectively). The attributable proportion (AP) related to total mortality for studied time period were 5, 4, and 3%, respectively. On the other hand, the numbers of excess cases attributable to $PM_{10}$ for hospitalization related to respiratory disease were 149, 102, and 78, respectively, during the study periods (as described earlier). In a study carried out in Tehran, AP for total mortality caused by exposure to $PM_{10}$ reported to be 4.6% (Naddafi et al. 2012). In a study was done in northern Italy, the amount of AP related to $PM_{10}$ was 2.5%. These results were in consistent with present study (Fattore et al. 2011).

According to the WHO in 2000, the mean of annual premature mortality due to airborne particulate matter in the world was 800,000 people from which 348,000 were related to Europe (Orru et al. 2009, Pascal et al. 2013). In a study conducted in Tallinn, Estonia, with a population of 390,000, about 296 premature mortality cases related to air particulate matter has been reported. In this study, the central area and crowded streets had more potential of respiratory disease and premature mortality, and also the people whose house or workplace are situated in the city center faced more health risks and had more exposure in comparison with drivers and other residence. In a study conducted in industrial areas in the north of Italy, 8 cases of premature mortality was predicted annually for the population of 24,000 people and $PM_{2.5}$ was reported as the main pollutant with high risk potential along with $O_3$ and $NO_2$ which were next in the ranking (Fattore et al. 2011). Naddafi et al. studied four indicators of air pollutants ($SO_2$, $O_3$, $NO_2$, and $PM_{10}$) in Tehran using AirQ software. Results showed that $PM_{10}$ was the most important factor affecting on total premature mortality and respiratory disease between other pollutants (Naddafi et al. 2012). Other studies in Tabriz and Shiraz reported that $PM_{10}$ have high potential to affect on inhabitants health in these cities (Ghanbari Ghozikali et al. 2014, Gharehchahi et al. 2013). The rate of mortality in Ilam in compression with mentioned studies is low. The most probable reason for this result may be the source of $PM_{10}$. In Ilam, $PM_{10}$ originated from desert storm dust, while in above studies, traffic cars and industrials activity are the main source of $PM_{10}$.

## Conclusion

In this study, the AirQ software along with estimation of central point of the relative risk (confidence interval 95%) were used to investigate the health impacts of $PM_{10}$ on Ilam inhabitants from 2012 to 2015. Results indicated that the effect of $PM_{10}$ on total mortality related to respiratory and cardiovascular disease in 2012–2013 periods with 49 cases was more than 2013–2014 (33 cases) and 2014–2015 (25 cases).

Although the concentration of PM10 was declining over the period of 2012 to 2015 in Ilam; but the concentration was still more than the WHO guideline. Since the dust storms caused by climate change is natural, therefore, extensive activities such as desertification are required to control this phenomenon that is extremely challenging. It is obvious that such activities are long-term and, therefore, some intermediate and short-term strategies should be conducted to overcome this problem.

The large amount of air particulate matter is due to dust which enters Ilam city through Iraq. Oil and petrochemical industries also produce some amounts of air particulate matter that are potentially poisonous and have bad effects on the health of residents.

**Table 3** Estimated attributable proportion (AP) expressed as percentage and number of excess cases in year 2012–2015 due to exposure $PM_{10}$

| Health endpoints in central point of RR | Estimated AP (%) | | | Estimated number of excess cases (persons) | | |
|---|---|---|---|---|---|---|
| Total mortality | 5 | 3.6 | 2.7 | 49 | 25 | 33 |
| Respiratory mortality | 10.8 | 7.5 | 5.7 | 9 | 5 | 6 |
| Cardiovascular mortality | 7.7 | 5.3 | 4 | 30 | 16 | 21 |
| Hospital admissions Respiratory disease | 7 | 4.7 | 3.6 | 149 | 78 | 102 |
| Hospital admissions Cardiovascular disease | 7.8 | 5 | 4 | 57 | 29 | 40 |
| Year | 2012–2013 | 2013–2014 | 2014–2015 | 2012–2013 | 2014–2015 | 2013–2014 |

Also it is recommended that people be sensitized on the use of personal protection materials like mask in polluted days for a short time to reduce the health effect due to $PM_{10}$.

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The most important limitations with this study were a lack of evaluation of the synergistic effects of pollutants and also the health impacts of some aggravating pollutants like particles and $SO_2$ have not been considered.

**Compliance with ethical standards**

**Conflicts of interest** All authors declare that they have no competing interests.

## References

Ahmad A., Hashim, M., Hashim, M. N., Ayof, M. N. & Budi, A. S. 2006. The use of remote sensing and GIS to estimate Air Quality Index (AQI) Over Peninsular Malaysia. GIS development, 5pp

De Meij A, Thunis P, Bessagnet B, Cuvelier C (2009) The sensitivity of the CHIMERE model to emissions reduction scenarios on air quality in Northern Italy. Atmos Environ 43:1897–1907

Downs SH, Schindler C, Liu L-JS, Keidel D, Bayer-Oglesby L, Brutsche MH, Gerbase MW, Keller R, Künzli N, Leuenberger P (2007) Reduced exposure to PM10 and attenuated age-related decline in lung function. N Engl J Med 357:2338–2347

Europe, W. H. O. R. O. F. & Organization, W. H 2006 Air quality guidelines: global update 2005: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide, World Health Organization

Fattore E, Paiano V, Borgini A, Tittarelli A, Bertoldi M, Crosignani P, Fanelli R (2011) Human health risk in relation to air quality in two municipalities in an industrialized area of Northern Italy. Environ Res 111:1321–1327

Fazelinia F, Khodabandehlou AA, Rafati L, Mahvi AH (2013) Investigation of Air Quality Index and PM10 and PM2. 5 in Arak. Iran J Health Sci 1:12–17

Ghanbari Ghozikali M, Mosaferi M, Nadafi K (2014) Quantification of the health effects of exposure to ozone in Tabriz by using AIRQ model. Urmia Med J 25:521–530

Gharehchahi E, Mahvi AH, Amini H, Nabizadeh R, Akhlaghi AA, Shamsipour M, Yunesian M (2013) Health impact assessment of air pollution in Shiraz, Iran: a two-part study. J Environ Health Sci Eng 11:11

Gholampour A, Nabizadeh R, Naseri S, Yunesian M, Taghipour H, Rastkari N, Nazmara S, Faridi S, Mahvi AH (2014) Exposure and health impacts of outdoor particulate matter in two urban and industrialized area of Tabriz, Iran. J Environ Health Sci Eng 12:10.1186

Glinianaia SV, Rankin J, Bell R, Pless-Mulloli T, Howel D (2004) Particulate air pollution and fetal health: a systematic review of the epidemiologic evidence. Epidemiology 15:36–45

Iran, S. C. O. 2016. Statistical Center of Iran Available at: https://www.amar.org.ir/english/

Kermani M, Bahrami Asl F, Aghaei M, Arfaeinia H, Karimzadeh S, Shahsavani A (2014) Comperative investigation of air quality (AQI) for six industerial cities of Iran. Urmia Med J 25:810–819

Kumar A, Goyal P (2011) Forecasting of daily air quality index in Delhi. Sci Total Environ 409:5517–5523

Maleki H, Sorooshian A, Goudarzi G, Nikfal A, Baneshi MM (2016) Temporal profile of PM 10 and associated health effects in one of the most polluted cities of the world (Ahvaz, Iran) between 2009 and 2014. Aeolian Res 22:135–140

Miri M (2016) Mortality and morbidity due to exposure to outdoor air pollution in Mashhad metropolis, Iran. The AirQ model approach. Environ Res 151:451–457

Miri M, Aval HE, Ehrampoush MH, Mohammadi A, Toolabi A, Nikonahad A, Derakhshan Z, Abdollahnejad A (2017) Human health impact assessment of exposure to particulate matter: an AirQ software modeling. Environ Sci Pollut Res:1–7

Mohan M, Kandya A (2007) An analysis of the annual and seasonal trends of air quality index of Delhi. Environ Monit Assess 131: 267–277

Mokhtari M, Miri M, Mohammadi A, Khorsandi H, Hajizadeh Y, Abdolahnejad A (2015) Assessment of air quality index and health impact of PM10, PM2.5 and SO2 in Yazd, Iran. J Mazandaran Univ Med Sci 25(131):14–23

Mokhtari M, Hajizadeh Y, Mohammadi A, Miri M, Abdollahnejad A, Niknazar H (2016) Ambient variations of benzene and toluene in Yazd, Iran, using geographic information system. J Mazandaran Univ Med Sci 26:131–139

Mu H, Otani S, Okamoto M, Yokoyama Y, Tokushima Y, Onishi K, Hosoda T, Kurozawa Y (2014) Assessment of effects of air pollution on daily outpatient visits using the air quality index. Yonago acta medica 57:133

Naddafi K, Hassanvand MS, Yunesian M, Momeniha F, Nabizadeh R, Faridi S, Gholampour A (2012) Health impact assessment of air pollution in megacity of Tehran, Iran. J Environ Health Sci Eng 9:28

Nikonahad A, Khorshidi A, Ghaffari HR, Aval HE, Miri M, Amarloei A, Nourmoradi H, Mohammadi A (2017) A time series analysis of environmental and metrological factors impact on cutaneous leishmaniasis incidence in an endemic area of Dehloran, Iran. Environ Sci Pollut Res:1–7

Orru H, Teinemaa E, Lai T, Tamm T, Kaasik M, Kimmel V, Kangur K, Merisalu E, Forsberg B (2009) Health impact assessment of particulate pollution in Tallinn using fine spatial resolution and modeling techniques. Environ Health 8:10.1186

Pascal M, Corso M, Chanel O, Declercq C, Badaloni C, Cesaroni G, Henschel S, Meister K, Haluza D, Martin-Olmedo P (2013) Assessing the public health impacts of urban air pollution in 25 European cities: results of the Aphekom project. Sci Total Environ 449:390–400

Shahsavani A, Naddafi K, Haghighifard NJ, Mesdaghinia A, Yunesian M, Nabizadeh R, Arahami M, Sowlat M, Yarahmadi M, Saki H (2012) The evaluation of PM 10, PM 2.5, and PM 1 concentrations during the Middle Eastern Dust (MED) events in Ahvaz, Iran, from April through September 2010. J Arid Environ 77:72–83

WHO 2005. Particulate matter air pollution: how it harms health. Fact sheet EURO/04/05, Berlin, Copenhagen, Rome, 4, 14

Wong C-M, Vichit-Vadakan N, Kan H, Qian Z, Teams P (2008) Public Health and Air Pollution in Asia (PAPA): a multicity study of short-term effects of air pollution on mortality. Environ Health Perspect 116:1195–1202