Original article

Mortality and morbidity due to ambient air pollution in Iran

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ABSTRACT

Introduction: Air pollution is an emerging risk factor for human health like cancer and other health outcomes in developing countries, especially in Iran where air pollutants concentrations are high. However, the data on health effects of air pollution are limited.

Objective: In this study, we have estimated the mortality for all causes (TM) and for cardiovascular diseases (CM), as well as the number of hospital admissions due to cardiovascular (HA-CVD) and respiratory diseases (HA-RD), chronic obstructive pulmonary diseases (HA-COPD), and acute myocardial infarction (AMI) due to exposure to common air pollutants.

Materials and Methods: In our study, the World Health Organization (WHO) method was applied to assess the mortality and morbidity rates from published relative risk (RR) and baseline incidence (BI) values.

Results: The results showed that 4.60% (95% CI: 3.50–5.31%) TM, 4.96% (95% CI: 3.16–10.50%) CM, 4.97% (95% CI: 3.04–6.81%) HA-RD, 5.55% (95% CI: 3.77–7.82%) HA-CVD, 2.50% (95% CI: 0–4.61%) HA-COPD and 4.73% (95% CI: 1.14–4.65%) AMI, respectively can be attributed to daily PM_{10} and SO_2 concentrations exceeding 10 μg/m^3.

Conclusion: To reduce the adverse health impact of air pollution, health advices and recommendations by local health authorities should be given to general population especially for vulnerable people i.e. children, elderly or people with chronic lung and cardiac pathologies during the dusty days.

1. Introduction

Particulate matter (PM) is considered as one of the most harmful airborne pollutant emitted from biogenic and anthropogenic sources or formed from atmospheric reactions. In recent years, west Asia was influenced by desert dust storms, increasing the number of dusty days as well as the daily average of PM with an aerodynamic diameter less than 10 μm (PM_{10}). [4–7] The PM_{10} are able to deeply penetrate into the airways where they may have harmful impacts on human health. [8–12] Metals and pathogenic microorganisms can be transported by desert dust at downwind sites. Sulfur dioxide (SO_2) is a toxic gas with a pungent and irritating smell. It is released naturally by volcanic activity

and also produced as a by-product of combustion of sulfur containing fuel. [13] Inhalation of SO_2 is mainly related to respiratory and pulmonary diseases, difficulty in breathing, reduced visibility, chronic obstructive pulmonary diseases (COPD) and premature death. [14] Epidemiological studies showed that high levels of PM_{10} in the air can lead to cardiovascular diseases such as myocardial infarction, stroke, heart failure and venous thromboembolism. [8,10,15,16] Significant correlation were reported between dust events and daily hospital for respiratory diseases in Asia. [17–19] Khaniabadi et al showed that an increase in SO_2 concentration by 10 μg/m^3 increases AMI morbidity by 2.7% and HA-COPD by 2%. In Cyprus, Middleton et al found that hospital visits due to cardiovascular diseases increased after dust episodes. The aim of this
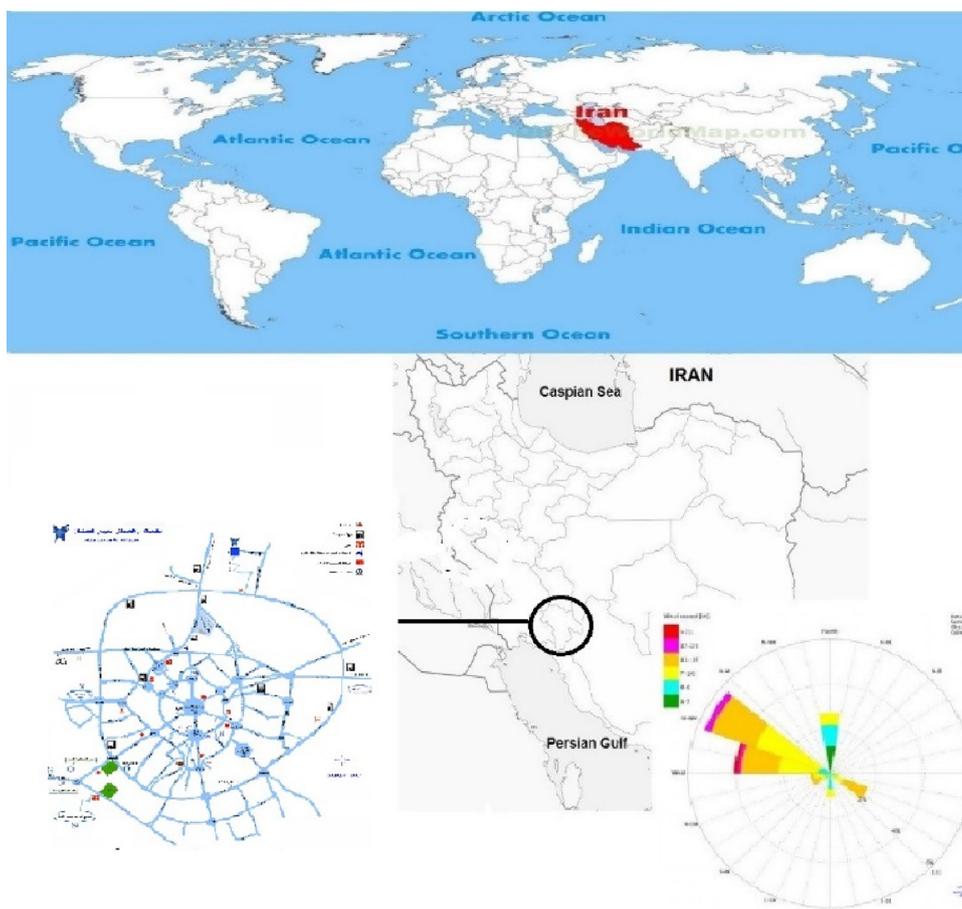
Fig. 1. The study area and sampling station.

study was to assess the mortality and morbidity due to exposure to PM_{10} and SO_2 in Hamadan (Iran).

2. Material and methods

2.1. The study area

The study area was Hamadan, the headquarters of Hamadan province, located in western Iran accounting 548,000 inhabitants (Fig. 1). The dry season occurs between June and September with the wet season extending into October, like Mediterranean climates. The most important emission source of air pollutant is dust storms events coming from the desert areas of West Asia.

2.2. AirQ software

In our study, Air Quality Health Impact Assessment (AirQ2.2.3) software proposed by the World Health organization (WHO) was used to assess the mortality and morbidity in the study area. Morbidity indices assessed were total and cardiovascular mortality, hospitalizations due to cardiovascular diseases, respiratory diseases, chronic obstructive pulmonary diseases, and acute myocardial infarction. [20] AirQ is a specialized tool that enables the user to assess the potential impact of air pollution exposure of a certain air pollutant on health of human in a defined area during a certain period of monitoring. [21–25] Attributable proportion defined as the fraction of health consequences in a public exposed to a specific air pollutant. The attributable proportion (AP) can be easily calculated by the following equation.

$$AP = \sum ([RR(c) - 1]*P(c)])/ \sum RR(c)*P(c) \qquad (1)$$

Where, AP is the attributable proportion of the health impact, RR is the relative risk for a certain health impact in category "c" of exposure taken from several epidemiological studies, and P(c) is the population proportion in category "c" of exposure.

The number of each case per population unit can be estimated when the baseline frequency of the specific health impact in the population was known as follows:

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

where IE is the number of cases attributable to air pollution per every population unit and I is the population unit. Knowing the size of population, the number of excess cases associated with the exposure can be calculated using Eq. (3):

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

where N and NE are the size of population under study and the number of excess cases, respectively.

In our study, PM_{10} and SO_2 concentrations after processing and coding mortality and morbidity as health impacts and exposed population data were imputed into the software AirQ2.2.3 for the period 2015. Furthermore, the number of excess cases of total mortality (TM), cardiovascular mortality (CM), hospitalizations for cardiovascular diseases (HA-CVD), respiratory diseases (HA-RD) and chronic obstructive pulmonary diseases, and acute myocardial infarction (AMI) in exposed inhabitants were estimated by relative risk (RR) and baseline incidence (BI) defauted by the WHO for estimation of mortality and morbidity.

2.3. Sampling

The monitoring station was located at Hamadan Environmental Protection Agency (HEPA), which was responsible for maintenance and

Table 1

Baseline incidence (BI) and relative risk (RR) for this study with 95% confidence interval.

Short-term effects	BI*	RR ** (95% CI***) per 10 µg/m³	
Total mortality	1013	1.0074 (1.0062–1.0086)	1.0040 (1.0030–1.0048)
Cardiovascular mortality	497	1.008 (1.005–1.018)	1.0080 (1.0020–1.0120)
HA-RD	1260	1.0080 (1.0048–1.0112)	–
HA-CVD	436	1.009 (1.006–1.013)	–
HA-COPD	101.4	–	1.0044 (1.000–1.011)
AMI	132	–	1.0064 (1.0026–1.0101)

operation. The hourly PM_{10} and SO_2 concentrations were continuously measured for one-year in 2015 then used to calculate the daily mean concentrations.

2.4. Relative risk and baseline incidence

In AirQ model, the main parameters related to health effect are relative risk (RR) and baseline incidence (BI). The RR is the probability of developing a disease due to exposure to a single pollutant.[26–28] The values of RR and BI (per 100,000 individuals) are attributed to different types of mortality and morbidity cases and were published by the WHO from epidemiological studies (Table 1). The required data to run AirQ include daily and annual averages, winter and summer averages, annual 98 percentile and the population. Low, high and median RR values (i.e. 95% confidence interval) were considered in this health risk assessment.

3. Results

3.1. PM_{10} and SO_2 concentrations

Table 2 illustrates the mean annual, summer and winter of PM_{10} and SO_2 concentrations. According to the National Ambient Air Quality Standards (NAAQS) guide, the daily average of air quality for PM_{10} and SO_2 are 150 and 20 µg/m³, respectively. The annual average concentrations of PM_{10} and SO_2 were 78.0 and 45.1 µg/m³, respectively. The summer PM_{10} (87.0 µg/m³) was higher than those of winter (69.0 µg/m³); while for SO_2, the winter average (48.7 µg/m³) was more than summer average (41.2 µg/m³).

3.2. Short-term health effect

Total (TM) and cardiovascular mortality (CM), daily hospitalizations due to respiratory (HA-RD) and cardiovascular diseases (HA-CVD) during Middle Eastern Dust (MED) storms, attributable to daily PM_{10} and SO_2 levels, are presented in Table 3. The number of excess cases of total and cardiovascular mortalities as result of exposure to PM_{10} and SO_2 were 51 and 22 persons, respectively. The HA-RD and HA-CVD attributed to PM_{10} were 336 and 133 persons, respectively. Also, SO_2 led to hospital admissions of 30 and 22 persons for COPD and Acute MI,

Table 2

The summer, winter and annual concentrations of PM_{10} and SO_2 of Hamadan in 2015.

Parameters	PM_{10} (µg/m³)	SO_2 (µg/m³)
Annual average	78.0	45.1
Summer average	87.0	41.2
Winter average	69.0	48.7

Table 3

Estimated attributable proportion (AP) percentage and number of excess cases in one year owing to short-term exposure above 10 µg/m³ for PM_{10} and SO_2.

Health effect	Estimated AP (%)	No of excess cases	
		PM_{10}	SO_2
Total mortality	4.61 (3.5–5.31)	253 (213–291)	51 (41–62)
Cardiovascular mortality	4.96 (3.16–10.5)	134 (85–283)	22 (15–35)
HA-RD	4.97 (3.04–6.81)	336 (207–464)	–
HA-CVD	5.55 (3.77–7.82)	133 (22–48)	–
HA-COPD	2.50 (0–4.61)	–	30 (0–54)
AMI	4.73 (1.14–4.65)	–	22 (11–33)

respectively.

3.3. Health effect

Fig. 2 shows the results of AirQ model quantification of the health risk due to exposure to PM_{10} and SO_2 in Hamadan (Iran). These figures exhibit the cumulative number of excess cases versus PM_{10} and SO_2 concentration intervals. The cumulative number of TM, CM, HA-RD and HA-CVD due to exposure to PM_{10} within median RR were 253, 134, 336 and 131 persons, respectively, while TM, CM, HA-COPD and AMI due to SO_2 exposure were estimated to 51, 22, 30, 22 persons (Fig. 2).

The results also showed that about 4.60% (95% CI: 3.50–5.31%) TM, 4.96% (95% CI: 3.16–10.50%) CM, 4.97% (95% CI: 3.04–6.81%) HA-RD, 5.55% (95% CI: 3.77–7.82%) HA-CVD, 2.50% (95% CI: 0–4.61%) HA-COPD and 4.73% (95% CI: 1.14–4.65%) AMI can be directly linked to PM_{10} and SO_2 concentrations greater than 10 µg/m³. For each 10 µg/m³ increase in the PM_{10} concentration, the risk of TM and CM increased by 0.74% and 0.80%, respectively. While for SO_2, the total and cardiovascular mortality increased by 0.48% and 1.2%, respectively. Additionally, the risk of hospitalizations for RD and CVD increased by 0.80% and 0.90%, respectively with increase in PM_{10} levels by of 10 µg/m³. Hospitalizations for COPD and Acute MI increased by 0.44% and 1.0%, respectively with increase of 10 µg/m³ in SO_2 levels.

4. Discussion

In this study, AirQ model proposed by the WHO were used to investigate the mortality and morbidity due to increased PM_{10} and SO_2 concentrations among the people. The impacts of PM_{10} and SO_2 on increased total and cardiovascular mortality, and hospital admissions due to respiratory and cardiovascular diseases, COPD and acute myocardial infarction were estimated. The mean annual, summer and winter PM_{10} concentrations were lower than the levels reported by [29] in Kermanshah (Iran). The 63-day study of Marzouni et al for the PM_{10} level was higher than the NAAQS criteria (150 µg/m³). A related study in Suwon (Korea) reported similar annual PM_{10} average of 52 µg/m³, which is 1.04 times higher than NAAQS criteria.[30] The annual maximum of PM_{10} level of 769 µg/m³ measured in summer was higher than the winter maximum value of 632 µg/m³.

The annual average and annual maximum of PM_{10} concentrations of 195.5 and 782.1 µg/m³ measured in Makkah (Saudi Arabia) by[31] were higher than those determined in this study. That higher level of PM_{10} observed during summer might probably resulted from higher temperature and wind speed that favors atmospheric turbulent and resuspension of windblown dusts. The maximum person/day exposure in Makkah (Saudi Arabia) was determined in the range of 200–249 µg/m³
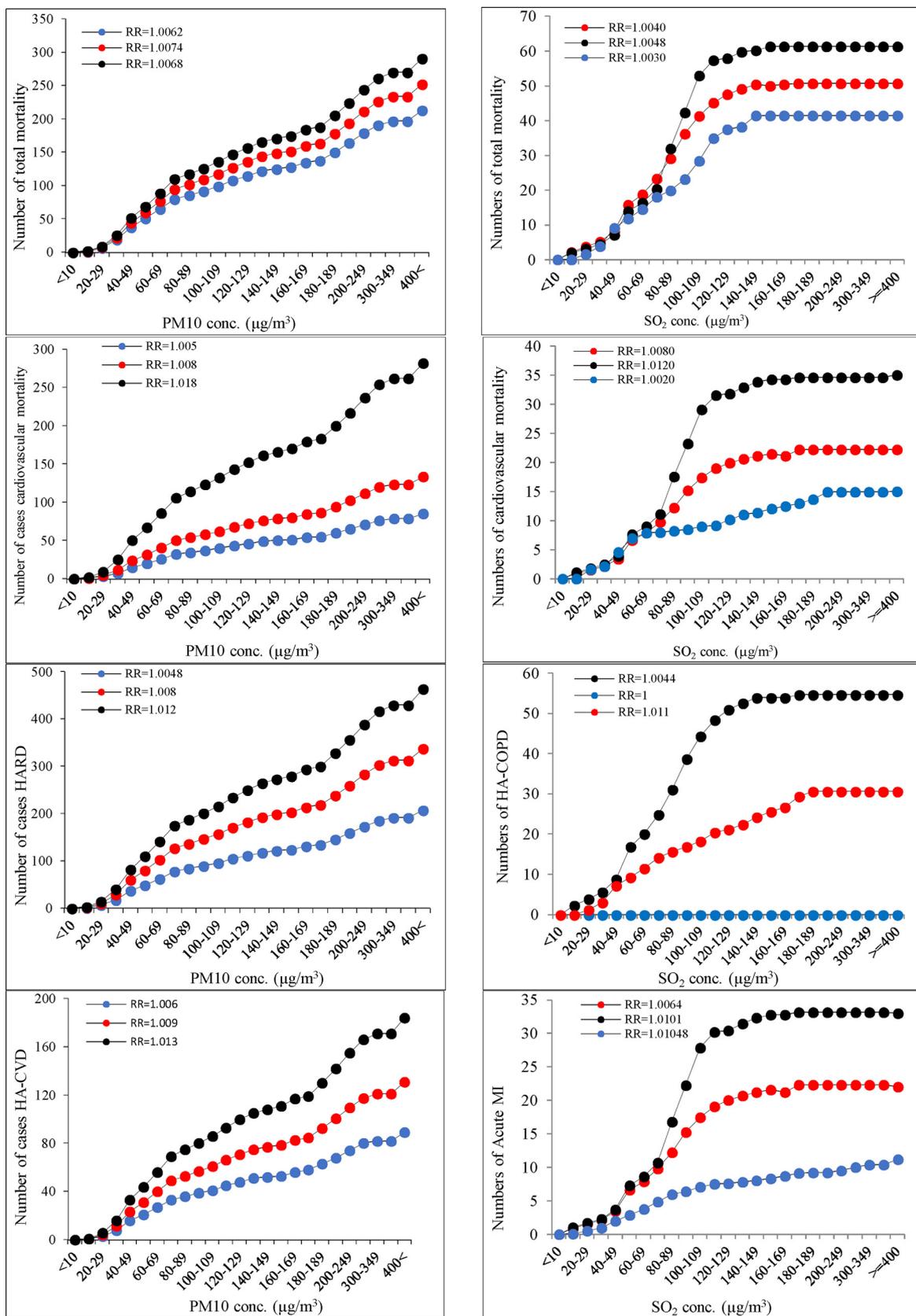
Fig. 2. Mortality and morbidity due to exposure to PM_{10} (from dust storms) and SO_2.

of PM_{10} concentrations. [31] In Italy, the maximum percentage of the days in which people in Mazzano were exposed to different PM_{10} levels was found to be in the range of 40–49 µg/m^3,[21] similar to level interval measured in the our study for PM_{10}, but 30–39 µg/m^3 for SO_2. The annual mean of SO_2 of 45.1 µg/m^3 measured in this study was higher than the NAAQS permissible level of 20 µg/m^3. In winter, the level of SO_2 (48.7 µg/m^3) was higher than the value measured in summer (41.2 µg/m^3), indicating intensive combustion of fossil fuels for heat generation at winter period.

Two time-series studies in Hong-Kong and London showed there is no evidence of a threshold for health impacts of 24-h average SO_2 levels in morbidity for cardiac diseases. [32] In the American Cancer Society study, a significant association between SO_2 and mortality was documented between 1928–1998, in which the lowest mean SO_2 concentration measured was 18 µg/m^3, while the highest average value was 85 µg/m^3.[33] The study revealed that the mortality effects decreased by 18.4% for respiratory mortality during 2015–2016 compared to 2014–2015. [34] A similar study between 1991 and 2010 indicated that PM was responsible for most of the number of excess cases of respiratory death in New-Delhi in India. [35]

In this study, the number of excess cases of HA-RD and HA-CVD due to exposure to PM_{10} were 336 and 133 persons in 2015 as well as 253 premature deaths with an annual PM_{10} mean concentration of 78 µg/m^3. The results of our study indicated that 96.8% of the health impacts including TM, CM, HA-CVD and HA-RD occurred when PM_{10} concentration was higher than 20 µg/m^3 and 97% of mortality and morbidity were attributed to PM_{10} concentrations above 200 µg/m^3.

Khaniabadi et al reported that 188 premature deaths were estimated by AirQ model during 2014–2015 in Kermanshah due to exposure to PM_{10}. [36] The TM and CM in Khorramabad (Iran) calculated by Nourmoradi et al were 235 and 136 persons in 2015. The research work also showed that MED events have an important effect on air quality as result of increase in PM_{10} concentration. In Ahvaz (Iran), 74% of the health endpoints occurred in days with SO_2 levels lower than 100 µg/m^{337} and 79.2% cases of HA-COPD occurred in days with SO_2 pollutant concentration lower than 60 µg/m^3 in Tabriz (Iran) in 2011. [38] A study in Egypt illustrated that 4.1% increase in HA-RD was related to increase in PM_{10} concentration by 10 µg/m^3. [39]

A significant correlation between PM_{10} levels and HA-RD was reported in both studies of Chen et al and Guo et al in Anshan and Beijing (China), respectively. The studies revealed more health impacts in the cold season than the warm season. The results of a cohort study in 25 cities of China indicated that 1.8% (0.8–2.9%) and 1.7% (0.3–3.2%) increase of mortality risk was relevant to 10 µg/m^3 increase in PM_{10} for cardiovascular and respiratory mortalities. [40] Another investigation was conducted by Park et al to find out the impact of Asian Dust Storm (ADS) on the hospital admissions due to the asthma and COPD. The PM_{10} levels during ADS episode reached 146.6 µg/m^3 while in normal days, the values is around 60 µg/m^3. The hospitalizations significantly increased on 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). [41] In northern China, increment of 0.036% in HA-RD and HA-CVD was observed for each 10 µg/m^3 rise in PM_{10} level. [42] In Suwon of South Korea, the number of excess cases of respiratory death attributed to exposure to air pollutants was calculated as 16.8 persons for PM_{10} and 2 persons for SO_2, respectively. [30] According to the study of Jeong in Suwon, the number of excess cases for the HA-RD and the HA-CVD were 462 and 179, respectively. The study reported higher values of HA-CVD and HA-RD for PM_{10} in comparison with the present study.

A large-scale study in Europe (Aphea-II study) showed that each 10 µg/m^3 increase in SO_2 was significantly correlated with 0.7% rise in all HA-CVD within two days. [43] A similar study in six Italian cities showed that the increase in the daily mean average of SO_2 by 10 µg/m^3 was associated with 2.8% of increase in diseases. [44] In Trieste, a city from Italy, the results indicated that 2.5% of mortality was related to PM_{10} levels over 20 µg/m^3.[45] In Estonia, the number of excess cases of

HA-RD and HA-CVD due to exposure to PM_{10} were 71 (95% CI 43–104) and 204 persons (95% CI 131–260) respectively in Tallinn in 2006 with an annual average concentration of PM_{10} of 32.2 µg/m^3. [46] The analysis indicated that the exposure above natural background corresponds to 296 (95% CI 76–528) premature deaths. [46]

In United States, Fairley demonstrated that between 1980 and 1986, each 10 µg/m^3 increase in PM_{10} level up to 150 µg/m^3 resulted to 0.12% increase in the risk rate of mortality among inhabitants of San Jose. Shumway et al showed that for PM_{10} lower than 100 µg/m^3, increase in PM_{10} level by 10 µg/m^3 caused 1.1% increase in risk of mortality in Los Angeles. In Detroit, a study of health effects showed that an increase in daily SO_2 level by 10 µg/m^3 was linked to a rise in 2% risk of mortality. [47] Increase in SO_2 was also connected to 11% rise in diurnal hospitalizations. [48] In Sao Paulo (Brazil), SO_2 had a significant correlation with increased cases of HA-COPD. [49] In Sydney (Australia), a study revealed that there was a significant association between respiratory diseases (95% CI: 1.15–1.26) and dust event. [50]

The assessment of effect of air pollution on human health is an important topic because air pollution continues to be a risk factor, especially in Iran where air pollutant concentrations continue to rise. Local analyses of the health effects of air pollution are limited, thus the use of AirQ model is necessary to provide estimates of the potential health outcomes. Our study also has limitations:

In quantitative assessment of health impacts of air pollution, the interactions between different contaminants are not evaluated and this information is not available. In the approach used here, the health impacts are focused on single pollutant without considering the simultaneous exposure to the multiple pollutants to which the public is actually exposed. Another limitation is the RR estimates that were derived in studies of different populations in comparison to that under investigation. A further limitation is potential exposure misclassification. This approach assumes that concentrations measured at the central monitoring point are representative of the exposure of all people living in a city.

5. Conclusion

AirQ model proposed by the WHO had been adopted to investigate the mortality and morbidity due to increased common air pollutants concentrations.

Since the geographic, demographic and climate characteristics are different and not well evaluated, further studies are recommended for quantification of other health impacts and assessment the health impacts of exposure to other air pollutants in urban areas. Although the findings from this study agreed with other reported studies around the world, there is still need to acquire more data on specific relative risk and baseline incidence values according to climate, geographical, and statistical features. To fully protect human health from the adverse effects of air pollution, studies are needed of the long-term health impacts of these pollutants in developing countries like Iran.

To diminish the harmful effects, public education, application of technical methods for decreasing sulfur emissions from different sources such as oil and petrochemical industries, reduction diesel and fossil fuels consumption, and careful monitoring of air pollution will have an important role as strategies control. To reduce the adverse health impact of air pollution, health advices by local health authorities should be given to general population, especially the vulnerable persons with chronic lung and heart pathologies, the elderly and children. Furthermore, preventive risk mitigation measures at governmental scale should be taken for the control of dust entering to the country such as spreading mulch, washing streets, management of water bodies, and planting some new species of plants to intercept airborne dust. Other actions should focus on eco-friendly transport systems, formidable measures necessary to reduce the high traffic density and proper management traffic systems that will reduce the negative impacts of air pollution.

Acknowledgments

References

4. Khaefi M, Geravandi S, Hassani G, et al. Association of particulate matter impact on prevalence of chronic obstructive pulmonary disease in Ahvaz, southwest Iran during 2009–2013. *Aerosol Air Qual Res.* 2017;17:230–237.

5. Khaniabadi YO, Goudarzi G, Daryanoosh SM, Borgini A, Tittarelli A, De Marco A. Exposure to PM 10, NO 2, and O 3 and impacts on human health. *Environ Sci Pollut Res.* 2017;24:2781–2789.

6. Biglari H, Geravandi S, Mohammadi MJ, et al. Relationship between air particulate matter and meteorological parameters. *Fresenius Environ Bull.* 2017;26:4047–4056.

7. Momtazan M, Geravandi S, Rastegarimehr B, et al. An investigation of particulate matter and relevant cardiovascular risks in Abadan and Khorramshahr in 2014–2016. *Toxin Rev.* 2018:1–8.

8. Martinelli N, Olivieri O, Girelli D. Air particulate matter and cardiovascular disease: a narrative review. *Eur J Internal Med.* 2013;24:295–302.

9. Zhou M, Liu Y, Wang L, Kuang X, Xu X, Kan H. Particulate air pollution and mortality in a cohort of Chinese men. *Environ Pollut.* 2014;186:1–6.

10. Khaniabadi YO, Hopke PK, Goudarzi G, Daryanoosh SM, Jourvand M, Basiri H. Cardiopulmonary mortality and COPD attributed to ambient ozone. *Environ Res.* 2017;152:336–341.

11. Daryanoosh M, Goudarzi G, Rashidi R, et al. Risk of morbidity attributed to ambient PM10 in the western cities of Iran. *Toxin Rev.* 2017:1–6.

12. Neisi A, Vosoughi M, Idani E, et al. Comparison of normal and dusty day impacts on fractional exhaled nitric oxide and lung function in healthy children in Ahvaz, Iran. *Environ Sci Pollut Res.* 2017;24:12360–12371.

13. Khaniabadi YO, Daryanoosh SM, Hopke PK, et al. Acute myocardial infarction and COPD attributed to ambient SO2 in Iran. *Environ Res.* 2017;156:683–687.

14. Khaniabadi YO, Polosa R, Chuturkova RZ, et al. Human health risk assessment due to ambient PM10 and SO2 by an air quality modeling technique. *Process Saf Environ Prot.* 2017;111:346–354.

15. Khaniabadi YO, Daryanoosh SM, Amrane A, et al. Impact of Middle Eastern dust storms on human health. *Atmos Pollut Res.* 2017;8:606–613.

16. Sicard P, Lesne O, Alexandre N, Mangin A, Collomp R. Air quality trends and potential health effects–development of an aggregate risk index. *Atmos Environ.* 2011;45:1145–1153.

17. Chien L, Yang C, Yu HL E. Estimated effects of Asian dust storms on spatiotemporal distributions of clinic visits for respiratory diseases in Taipei children (Taiwan). *Environ Health Perspect.* 2012;120:1215–1220.

18. Khaniabadi Yusef Omidi, Daryanoosh Mohammad, Sicard Pierre, Takdastan Afshin, Hopke Philip K, Esmaeili Shirin, De Marco Alessandra, Rashidi Rajab. Chronic obstructive pulmonary diseases related to outdoor PM10, O3, SO2, and NO2 in a heavily polluted megacity of Iran. *Environ Sci Pollut Res.* 2018. http://dx.doi.org/10.1007/s11356-018-1902-9.

19. Khaniabadi Yusef Omidi, Sicard Pierre, Khaniabadi Arash Omidi, Mohammadinejad Shabnam, Keishams Fariba, Takdastan Afshin, Najafi Abdolreza, De Marco Alessandra, Goudarzi Gholamreza, Daryanoosh Seyed Mohammad. Air quality modeling for health risk assessment of ambient PM10, PM2.5 and SO2 in Iran. *Hum Ecol Risk Assess: Int J.* 2018. http://dx.doi.org/10.1080/10807039.2018.1487277.

20. Javanmardi P, Morovati P, Farhadi M, et al. Monitoring the impact of ambient ozone on human health using time series analysis and air quality model approaches. *Fresenius Environ Bull.* 2018;27:533–544.

21. Fattore E, Paiano V, Borgini A, et al. Human health risk in relation to air quality in two municipalities in an industrialized area of Northern Italy. *Environ Res.* 2011;111:1321–1327.

22. Omidi Y, Goudarzi G, Heidari AM, Daryanoosh SM. Health impact assessment of short-term exposure to NO2 in Kermanshah, Iran using AirQ model. *Environ Health Eng Manage J.* 2016;3:91–97.

23. Yari AR, Goudarzi G, Geravandi S, et al. Study of ground-level ozone and its health risk assessment in residents in Ahvaz City, Iran during 2013. *Toxin Rev.* 2016;35:201–206.

24. Dobaradaran S, Geravandi S, Goudarzi G, et al. Determination of cardiovascular and respiratory diseases caused by PM10 exposure in Bushehr, 2013. *J Mazandaran Univ Med Sci.* 2016;26:42–52.

25. Geravandi S, Sicard P, Khaniabadi YO, et al. A comparative study of hospital admissions for respiratory diseases during normal and dusty days in Iran. *Environ Sci Pollut Res.* 2017;24:18152–18159.

26. Sicard P, Mangin A, Hebel P, Malléa P. Detection and estimation trends linked to air quality and mortality on French Riviera over the 1990–2005 period. *Sci Total Environ.* 2010;408:1943–1950.

27. Sicard P, Talbot C, Lesne O, Mangin A, Alexandre N, Collomp R. The aggregate risk index: an intuitive tool providing the health risks of air pollution to health care community and public. *Atmos Environ.* 2012;46:11–16.

28. Lefohn AS, Malley CS, Smith L, et al. Tropospheric ozone assessment report: global ozone metrics for climate change, human health, and crop/ecosystem research. *Elem Sci Anth.* 2018:6.

29. Marzouni MB, Alizadeh T, Banafsheh MR, et al. A comparison of health impacts assessment for PM10 during two successive years in the ambient air of Kermanshah, Iran. *Atmos Pollut Res.* 2016:1–7. http://dx.doi.org/10.1016/j.apr.2016.04.004.

30. Jeong S. The impact of air pollution on human health in Suwon City. *Asian J Atmos Environ.* 2013;7:227–233.

31. Habeebullah T. Health impacts of PM10 using AirQ2.2.3 model in Makkah. *J Basic Appl Sci.* 2013;9:259–268.

32. Wong C, Atkinson R, Anderson H, et al. A tale of two cities: effects of air pollution on hospital admissions in Hong Kong and London compared. *Environ Health Perspect.* 2002;110:67–77.

33. Pope C, Burnett R, Thun M, Calle EE, Krewski D, Thurston G. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *J Am Med Assoc.* 2002;287:1132–1141.

34. Nourmoradi H, Khaniabadi YO, Goudarzi G, et al. Air quality and health risks associated with exposure to particulate matter: a cross-sectional study in Khorramabad. *Iran. Health Scope.* 2016;5:e31766. http://dx.doi.org/10.17795/jhealthscope-31766.

35. Nagpure AS, Gurjar BR, Martel J. Human health risks in national capital territory of Delhi due to air pollution. *Atmos Pollut Res.* 2014;5:371–380.

36. Khaniabadi Y, Goudarzi G, Daryanoosh S, Borgini A, Tittarelli A, De Marco A. Exposure to PM10,NO2, and O3and impacts on human health. *Environ Sci Pollut Res.* 2016. http://dx.doi.org/10.1007/s11356-016-8038-6.

37. Goudarzi G, Geravandi S, Salmanzadeh S, Mohammadi MJ, Zallaghi E. The number of myocardial infarction and cardiovascular death cases associated with sulfur dioxide exposure in Ahvaz, Iran. *Arch Hyg Sci.* 2014;3:112–119.

38. Ghozikali MG, Heibati B, Naddafi K, et al. Evaluation of chronic obstructive pulmonary disease (COPD) attributed to atmospheric O3, NO2, and SO2 using AirQ model (2011–2012 year). *Environ Res.* 2016;144:99–105.

39. Shakour A, El-Shahat M, El-Taieb N, Hassanein M, Mohamed A. Health impacts of particulate matter in greater Cairo. *Egypt J Am Sci.* 2011;7:840–848.

40. Zhou M, Liu Y, Wang L, Kuang X, Xu X, Kan H. Particulate air pollution and mortality in a cohort of Chinese men. *Environ Pollut.* 2014;186:1–6.

41. Park J, Nam L, Myoung H, Yoonki K, Woo J. The influence of asian dust, haze, mist, and fog on hospital visits for airway diseases. *Tuberc Respir Dis.* 2015;78:326–335.

42. Chen R, Pan G, Kan H, Tan J, Song W, Wu Z. Ambient air pollution and daily mortality in Anshan, China: a time-stratified case-crossover analysis. *Sci Total Environ.* 2010;408:6086–6091.

43. Sunyer Ballester F, Tertre A, Atkinson R, Ayres J, Forastiere F, Forsberg B. The association of daily sulfur dioxide air pollution levels with hospital admissions for cardiovascular diseases in Europe (The Aphea-II study). *Eur Heart J.* 2003;24:752–760.

44. Biggeri A, Bellini P, Terracini B. Meta analysis of the Italian studies on short-term effects of air pollution. *J Epidemiol.* 2001;4:25–27.

45. Tominz R, Mazzoleni B, Daris F. Estimate of potential health benefits of the reduction of air pollution with PM10 in Trieste, Italy. *Epidemiol Prev.* 2005;29:149–155.

46. Orru H, Maasikmets M, Lai T, et al. Health impacts of particulate matter in five major Estonian towns: main sources of exposure and local differences. *Air Qual Atmos Health.* 2011;4:247–258.

47. Lippmann M, Ito K, Nadas A, Burnett R. Association of particulate matter components with daily mortality and morbidity in urban populations. *Res Rep Health Eff Inst.* 2000;95:5–72.

48. Burnett RT, Cakmak S, Brook JR, Krewski D. The role of particulate size and chemistry in the association between summer time ambient air pollution and hospitalization for cardiorespiratory diseases. *Environ Health Perspect.* 1997;105:614–620.

49. Gouveia N, deFreitas C, Martins L, et al. Respiratory and cardiovascular hospitalizations associated with air pollution in the city of Sao Paulo, Brazil. *Cad De Saude Publica.* 2006;22:2669–2677.

50. Merrifield A, Schindeler S, Jalaludin B, Smith W. Health effects of the September 2009 dust storm in Sydney, Australia: did emergency department visits and hospital admissions increase? *Environ Health.* 2013;12.