

Evaluation of cardiovascular and respiratory mortality attributed to atmospheric SO₂ and CO using AirQ model

Majid Kermani^{1,2}, Mohsen Dowlati^{3,4}, Sevda Fallah Jokandan³, Mina Aghaei⁵, Farshad Bahrami Asl⁶, Sima Karimzadeh^{7*}

¹Associate Professor of Environmental Health Engineering, Research Center for Environmental Health Technology, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

²Associate Professor of Environmental Health Engineering, Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

³MSc of Environmental Health Engineering, Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

⁴MSc of Environmental Health Engineering, Research Center for Environmental Health Technology, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

⁵PhD Student of Environmental Health Engineering, Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

⁶PhD Student of Environmental Health Engineering, Department of Environmental Health Engineering, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran

⁷MSc of Environmental Health Engineering, Department of Environmental Health Engineering, School of Public Health, Urmia University of Medical Sciences, Urmia, Iran

Abstract

Background: Air pollutants have multiple adverse effects on human health. In this study, the health effects of exposure to carbon monoxide (CO) and SO₂ in the air of 6 Iranian metropolises in 2011-2012 were examined.

Methods: Raw data was collected from the Iranian Department of Environment and the Iran Meteorological Organization. After validation, the required statistical indices were calculated through programming and modifying temperature and pressure in Excel software. The output of Excel was given to the AirQ model, and the results were presented as the cases of death.

Results: The annual mean concentrations of SO₂ were 2.45, 1.55, 0.6, 0.55, 1.05, and 3.8 times higher than the guidelines of the World Health Organization (WHO) (20 µg/m³) in Tehran, Mashhad, Isfahan, Shiraz, Tabriz, and Urmia, respectively. The concentrations of CO did not exceed the standard limit in any of the studied cities. The cumulative numbers of total deaths attributed to SO₂ were 744, 122, 132, 44, 37, and 107 in Tehran, Mashhad, Isfahan, Shiraz, Tabriz, and Urmia, respectively. The highest mortality rate was found in Urmia at 2.9% followed by Tehran at 1.52%; the lowest rate of 0.46% was found in Tabriz.

Conclusion: The results show that of the 6 metropolises, the highest CO mortality rate of about 2.15% belonged to Isfahan followed by Arak with about 1.38%, and the lowest rate of 0.68% belonged to Mashhad. Because of the growing trend of air pollution and its mortality rate and adverse effects, practical solutions for the control and reduction of air pollution in Iranian metropolises are necessary.

Keywords: Air pollution, Software, Iran, Cities

Citation: Kermani M, Dowlati M, Fallah Jokandan S, Aghaei M, Bahrami Asl F, Sima Karimzadeh S. Evaluation of cardiovascular and respiratory mortality attributed to atmospheric SO₂ and CO using AirQ model. Environmental Health Engineering and Management Journal 2017; 4(2): 101–108. doi: 10.15171/EHEM.2017.14.

Article History:

Received: 21 November 2016

Accepted: 6 February 2017

ePublished: 23 February 2017

*Correspondence to:

Sima Karimzadeh

Email:

sima.karimzade@yahoo.com

Introduction

The increases in technology and industrialization without consideration given to sustainable development and environmental pollution, particularly the pollution of air which is an important factor of life, need to be given more attention (1-8). Based on the annual estimates of the World Health Organization (WHO), 800 000 premature deaths occur; of that number, about 1 500 000 of these deaths occur in South Asia (9). Annually, deaths caused

by air pollution in the United States about 60 000 number. Nevertheless mortality attributable to pollution appears to be low; however, due to the large population that is exposed to air pollution and the existence of sensitive groups in society, the burden of disease attributable to pollution will increase (10,11). The effects of air pollution on human health can be categorized as chronic or acute. In determining acute effects, one examines important events that occurred in the 20th century in some cities of Europe



and America, such as Meuse Valley, Belgium; London, England; and Donora, Pennsylvania in the United States (11-13). Over the past 2 decades, studies on the health effects of air pollution have determined and demonstrated that the rate of mortality attributable to air pollution is rising (12,13). Research has shown that the global burden of air pollution-related disease estimated by the WHO is 89% of total deaths caused by heart and respiratory disease (13). In the past few decades, many studies have demonstrated that the current levels of SO₂ and carbon monoxide (CO) are associated with cardiopulmonary respiratory deaths, hospitalizations, and respiratory symptoms (14-17). CO is a colorless, odorless, poisonous, and tasteless gas. It is often mixed with other gases that do have an odor, though it has no detectable odor itself. When carbon monoxide is inhaled, it displaces oxygen in the blood and deprives the heart, brain, and other vital organs of oxygen. The six main symptoms of CO poisoning are headaches, vertigo, nausea, breathlessness, heart palpitations, and a loss of consciousness. Large amounts of CO can overcome a person in just a few minutes without prior warning, cause a loss of consciousness and eventually suffocation. Carbon monoxide is relatively stable in air and is one of the major pollutants related to the burning of natural gas and internal combustion engines. If the appliances burning fuel are properly kept and used, the amount of CO produced is not usually dangerous. About 85%-90% of CO comes from automobile exhaust (18-20). When fossil fuels which contain sulfur, like coal, are burned, sulfur dioxide is released. Generally, there are 2 reasons why SO₂ is hazardous to humans: first, it is in gaseous form, and second, it oxidizes to form sulfate. Aerosol SO₂, in comparison with other pollutants, is more soluble in water, and when it is combined with suspended solids and moisture, it creates harmful effects that are relayed by air pollution. Many studies have shown that the number of hospitalizations increase on days with high levels of SO₂ in the air. Asthmatics are generally considered the group most sensitive to high concentrations of SO₂. Another sensitive group comprises those who exercise regularly. This is due to the fact that SO₂ is highly reactive; consequently, the distribution of SO₂ along the conductive airways of the respiratory tract is non-uniform, depending on breathing volumes and types (21,22). Information on the effects of exposure for long periods (e.g., 24 hours) is obtained from epidemiological studies, which are indicative of the relationships among contaminants such as SO₂ and the health impacts on communities. To evaluate the evidence of effects on health related to SO₂ exposure for the New Zealand ambient air quality guideline values, Dennison et al studied the correlations between SO₂ and other contaminants in the air. They determined that it would be quite difficult to confidently attribute the impacts observed in epidemiological studies to SO₂ alone (23). Experimental studies were therefore applied to derive the dose-response relationships underpinning the ambient air quality guideline values for SO₂ in New Zealand (24). In a study during the years 1996-2000 in

15 cities of Italy, with increasing concentrations of CO and SO₂, the number of mortalities due to cardiovascular disease rose 0.93% and 1.11%, respectively (24). In the 8 Iranian metropolises studied in the current research, several pollutants are discharged from motor vehicles, industries, and commercial and domestic resources, and the concentrations of most of these pollutants rise above standards levels during different hours of the day. The situation has attracted the attention of a group of officials and people. Therefore, to reduce air pollution and aid decision-making in this regard, there is a significant need to quantify the health effects of pollution. The main purpose of this study was to quantify the short-term health effects of air pollution, specifically regarding the pollutants CO and SO₂, in 2011-2012 in 6 cities of Iran (Isfahan, Shiraz, Tabriz, Mashhad, Tehran, and Urmia). This study employed the software AirQ2.2.3.

Materials and Methods

Data related to air pollution were taken from the Environmental Protection Department of 6 large cities in Iran (Figure 1).

There are 21 valid, general monitoring stations for SO₂ and 25 valid, general monitoring stations for CO in the 6 Iranian cities investigated in this study. All stations monitor SO₂ and other gaseous pollutants (NO₂, PM₁₀, PM_{2.5}, O₃, and CO) hourly. The data related to pressure and temperature were obtained from the cities' metrological offices. Data regarding the cities' populations were obtained for use in statistical analysis. The population static over 65 years



Figure 1. Map of Iran in world and location of study metropolises.

old were used for population that faced with CO. The data provided for consideration was volumetric base and needed to be gravimetric-based for entry into the selected software. Thus, by writing a program in Excel, new files were created with the model's required units. First, the raw data was changed based on temperature and measurement points. The following equation was used to correct the concentrations expressed in units.

$$P_1 V_1 / T_1 = P_2 V_2 / T_2$$

Then, the raw data was analyzed and valid data was selected based on WHO, European, and European Union (EU) criteria. Zero values meant that disturbances were removed from calculating average that conducted with moving average. Data on SO₂ and CO was placed on separate sheets, because the files for entry into the software for SO₂ were daily averages and that for CO was based on an hourly average. Initial and secondary filtering was done in Excel. In this part, the required statistical parameters were

calculated and prepared for entry into AirQ software. For the quantification of both pollutants in the air, the software AirQ2.2.3 presented by the European Environment Office and the WHO was employed. It was also used to quantify the health effects of air pollution. Using this model, a kind of statistical and epidemiological method, the health outcomes were estimated using pollutant concentration and epidemiological parameters like baseline incidence, relative risk, and exposed population of the studied cities. The results were shown as attributable proportion (AP) and the number of excess cases of mortality. Finally, the results were presented as tables and charts of base line incidence (BI) and relative risk (RR) with 95% CI for estimated health endpoints attributable to SO₂ and CO in the present study (Table 1). The populations of the studied cities are shown in Table 2 (25,26).

Results

Table 1. Baseline incidence and relative risk with 95% CI for health endpoints

Health endpoint		Baseline Incidence (per 105 inhabitants)	RR (95% CI) per 10 µg/m ³	
			SO ₂	CO
Mortality	Total	543.5	1.004 (1.003-1.0048)	-
	Cardiovascular	231	1.008 (1.002-1.012)	BI:497; 1.007 (1.002-1.012)
	Respiratory	48.4	1.01 (1.006-1.014)	-

Abbreviations: BI, baseline incidence; RR, relative risk; CO, carbon monoxide.
Source: AirQ 2.2. 3 software

Table 2. Population of studied cities from the census reports on Iran

City	Exposed population	The population used in the software	Population over 65 years	Latitude	Longitude
Mashhad	2749374	2750 × 1000	200 × 1000	36.31	59.58
Tabriz	1494998	1495 × 1000	143 × 1000	38.08	46.28
Isfahan	1987168	1987 × 1000	135 × 1000	32.68	51.64
Shiraz	1549453	1540 × 1000	90 × 1000	29.62	52.52
Tehran	9000000	9000 × 1000	550 × 1000	35.34	51.25
Urmia	1615000	680 × 1000	40 × 1000	37.55	45.07

Table 3. Statistical parameters required for import into the program- CO (mg/m³) in 6 megacities

Parameter	Mashhad	Tabriz	Isfahan	Shiraz	Tehran	Urmia
Annual mean	2	2	2	2	2	2
Winter mean	2	3	2	2	2	2
Summer mean	2	2	2	2	2	2
Annual 98 Percentile (P ₉₈)	4	5	10	5	5	7
No. of station	8	6	4	2	10	1

Table 4. Statistical parameters required for import into the program- SO₂ (µg/m³) in six Megacities

Parameter	Mashhad	Tabriz	Isfahan	Shiraz	Tehran	Urmia
Annual mean	31	21	12	11	49	76
Winter mean	34	29	10	9	54	82
Summer mean	28	13	13	14	43	71
Annual 98 Percentile (P ₉₈)	48	66	19	25	94	159
Annual maximum	61	118	26	33	118	188
Winter maximum	61	18	26	34	118	176
Summer maximum	41	34	20	32	88	188
No. of station	7	5	4	2	9	1

Table 5. Comparison annual average concentration of SO₂ with the Iran national standard in 6 metropolis of Iran

City	The average annual concentration Iran national standard (µg/m ³)	The ratio annual average concentration SO ₂ (µg/m ³)
Mashhad	20	1.55
Tabriz	20	1.05
Isfahan	20	0.6
Shiraz	20	0.55
Tehran	20	2.45
Urmia	20	3.8

Based on the WHO's criteria, the data related to SO₂ and CO pollutants was studied. The required statistical parameters (annual and seasonal means and annual 98th percentiles) for CO and SO₂ were obtained from each city and are shown in Tables 3 and 4, respectively.

Table 3 shows the results that indicate the 1-hour average concentration of CO in 6 metropolitan cities was not higher than the standard level, and the highest annual concentration of CO was related to the (mg/m³) concentration of Tehran city. Table 4 shows that the annual mean concentrations of SO₂ were higher than the standard level (20 µg/m³) in Mashhad, Tehran, and Urmia with the highest annual SO₂ concentration being related to Urmia (76 µg/m³). The annual mean concentration of SO₂ was compared with Iran's national standard for average annual concentration in six metropolises of Iran, and the results are given in Table 5.

As indicated in Table 5, the annual mean concentrations of SO₂ were higher in Tehran and Urmia than in the other cities; their average ratios were 2.45 and 3.8 times greater than the average standard concentration. The province of West Azerbaijan is located in western Iran and is affected by wet weather from the Atlantic Ocean

and Mediterranean Sea. In Urmia, the capital city of the province, there are approximately 300 vehicles for every 1000 people. That is about 1.5 times the average of the country. In Urmia, the number of vehicles and expansion grows with no regard to environmental issues, and this is the main factor threatening the quality of Urmia's air in view of the quickly increasing population. In most months of the year, Mashhad has a great number of pilgrims. Thus, air pollution in this city is caused by the heavy traffic and increasing use of necessary fuels. Table 6 shows the number of times the SO₂ concentration of each city exceeds standard level in a 24-hour period and the comparison of SO₂ levels in these cities with the standard level.

Based on the results presented in Table 6, the city experiencing largest number of 24-hour periods that the SO₂ concentration was higher than that recommended by the WHO is Mashhad, where levels were higher 365 days. According to the National Quality Standards of the EPA (Environmental Protection Agency) and the National Standard of Clean Air of Iran, the standard assigned to CO for an 8-hour average is 9 ppm. CO concentrations did not exceed this standard level in any of the studied cities. Based on indicators of estimated relative risk shown in Table 7, the highest death rate is related to respiratory mortality due to contact with SO₂ in Urmia. According to the results, the total number of respiratory deaths compared to all deaths in the study period for the 6 studied cities was 365 out of 10 641 persons per year. Based on indicators of estimated relative risk shown in Table 8, the highest number of deaths is related to cardiovascular mortality due to contact with CO in Isfahan. According to the results, the estimated number of cardiovascular cases resulting in death compared to all deaths in the 6 studied cities during the study period was 64 out of 64 64 persons

Table 6. Comparison the average SO₂ concentration of 24 hours with guidelines and standards values in 6 metropolises

City	Guidelines and standards	Average 24-h	The No. of times that the SO ₂ concentration of 24 h in each city is compared to a high standard
Mashhad	WHO Guidelines	20	365
	Iran national standard	100	0
	European standards	125	0
Tabriz	WHO Guidelines	20	128
	Iran national standard	100	1
	European standards	125	0
Isfahan	WHO Guidelines	20	267
	Iran national standard	100	17
	European standards	125	3
Shiraz	WHO Guidelines	20	153
	Iran national standard	100	0
	European standards	125	0
Tehran	WHO Guidelines	20	346
	Iran national standard	100	4
	European standards	125	0
Urmia	WHO Guidelines	20	351
	Iran national standard	100	109
	European standards	125	76

Table 7. Estimated attributable proportion expressed as percentage and number of excess cases in a year due to short-term exposure above 10 $\mu\text{g}/\text{m}^3$ for SO_2

Health endpoints	Study city	AP (uncertainty range)*	No. of excess cases (uncertainty range)
Total mortality	Mashhad	0.81 (0.61-0.997)	122 (92-146)
	Tabriz	0.46 (0.34-0.55)	37 (28-45)
	Isfahan	1.21 (0.92-1.45)	132 (99-158)
	Shiraz	0.55 (0.41-0.66)	44 (33-53)
	Tehran	1.52 (1.14-1.81)	744 (560-890)
	Urmia	2.19 (2.90-3.46)	107 (81-128)
Cardiovascular mortality	Mashhad	1.61 (0.40-2.40)	103 (26-153)
	Tabriz	0.91 (0.23-1.37)	32 (8-47)
	Isfahan	2.4 (0.61-3.56)	111 (28-164)
	Shiraz	1.10 (0.28-1.65)	37 (9-55)
	Tehran	2.99 (0.76-4.42)	623 (159-920)
	Urmia	5.64 (1.47-8.23)	89 (23-129)
Respiratory mortality	Mashhad	2.01 (1.22-2.8)	27 (16-38)
	Tabriz	1.14 (0.69-1.6)	8 (5-12)
	Isfahan	2.99 (1.8-4.13)	29 (18-40)
	Shiraz	1.38 (0.83-1.92)	10 (6-14)
	Tehran	3.72 (2.26-5.12)	162 (99-223)
	Urmia	6.95 (4.29-9.47)	23 (14-31)

Table 8. Estimated attributable proportion expressed as percentage and number of excess cases in a year due to short-term exposure above 10 $\mu\text{g}/\text{m}^3$ for CO

Health endpoints	Study city	AP (uncertainty range)	No. of excess cases (uncertainty range)
Cardiovascular mortality	Mashhad	0.68 (0.19-1.17)	9 (2-12)
	Tabriz	0.83 (0.24-1.42)	6 (2-10)
	Isfahan	2.15 (0.62-3.63)	14 (4-24)
	Shiraz	0.69 (0.19-1.17)	3 (1-5)
	Tehran	1.09 (0.31-1.86)	28 (8-48)
	Urmia	1.04 (0.3-1.77)	2 (1-4)

per year. According to the output charts obtained from the software, almost 50% of deaths attributed to contact with CO occurred in concentrations of less than 4 mg/m^3 . The results from the AirQ software are shown in graph form in Figure 2. These figures show the cumulative excess cases of cardiovascular mortality due to CO concentration in the 6 studied cities in Iran: a) Mashhad; b) Tabriz; c) Isfahan; d) Shiraz; e) Urmia; f) Tehran.

Discussion

The results shown in Tables 4 and 5 indicate that the 2011 concentrations of SO_2 were 49, 31, 12, 11, 21, and 76 in Tehran, Mashhad, Isfahan, Shiraz, Tabriz, and Urmia, respectively. Those figures are 2.45, 1.55, 0.6, 0.55, 1.05, and 3.8 times higher than those set out in the WHO guidelines (20 $\mu\text{g}/\text{m}^3$). Therefore, the mean annual concentrations of SO_2 in Tehran, Mashhad, Tabriz, and Urmia were higher than the Iranian national standard and the EU standard, while it was reported as lower than the mentioned standards in Isfahan and Shiraz. As seen in Table 6, the mean annual concentration of SO_2 in Urmia was higher than the WHO standard for 96% of the days in a year. This rate was higher than the Iranian standard for 30% of days in a year (100 $\mu\text{g}/\text{m}^3$) and higher than the EU

standard on 20% of days in a year (125 $\mu\text{g}/\text{m}^3$). In Tehran, the rates were 95% higher than the WHO standards, while it was only 2% higher than the Iranian standard and never exceeded the EU standard; this result indicates the deterioration of the situation of SO_2 in these cities. It should be noted that concentrations of SO_2 in Mashhad, Isfahan, Shiraz, and Tabriz were higher than the WHO standard on 100%, 73%, 42% and 35% of days in 2011, respectively. The results indicate that the status of SO_2 is critical in Urmia and Tehran. According to 2011 reports, there were about 300 cars for every 1000 individuals in Urmia; this rate is about 1.5 times the country's average (27). It seems that the high number of cars, the increased population, and the subsequent increased use of fossil fuels can be the causes for the increase in pollutants in the above-mentioned cities. On most days of the year in the studied cities, the distribution of the SO_2 concentration is in the range of 40-49 $\mu\text{g}/\text{m}^3$ in the studied cities. As seen in Figure 2, the highest percentage of exposure to the pollutant occurred in Shiraz, Isfahan, and Tabriz with concentration intervals of 10-19 $\mu\text{g}/\text{m}^3$, in Mashhad with 20-29 $\mu\text{g}/\text{m}^3$, in Urmia with 30-39 $\mu\text{g}/\text{m}^3$, and in Tehran with 40-49 $\mu\text{g}/\text{m}^3$. Based on these figures, it becomes clear that the largest number of mortalities from cardiovascular

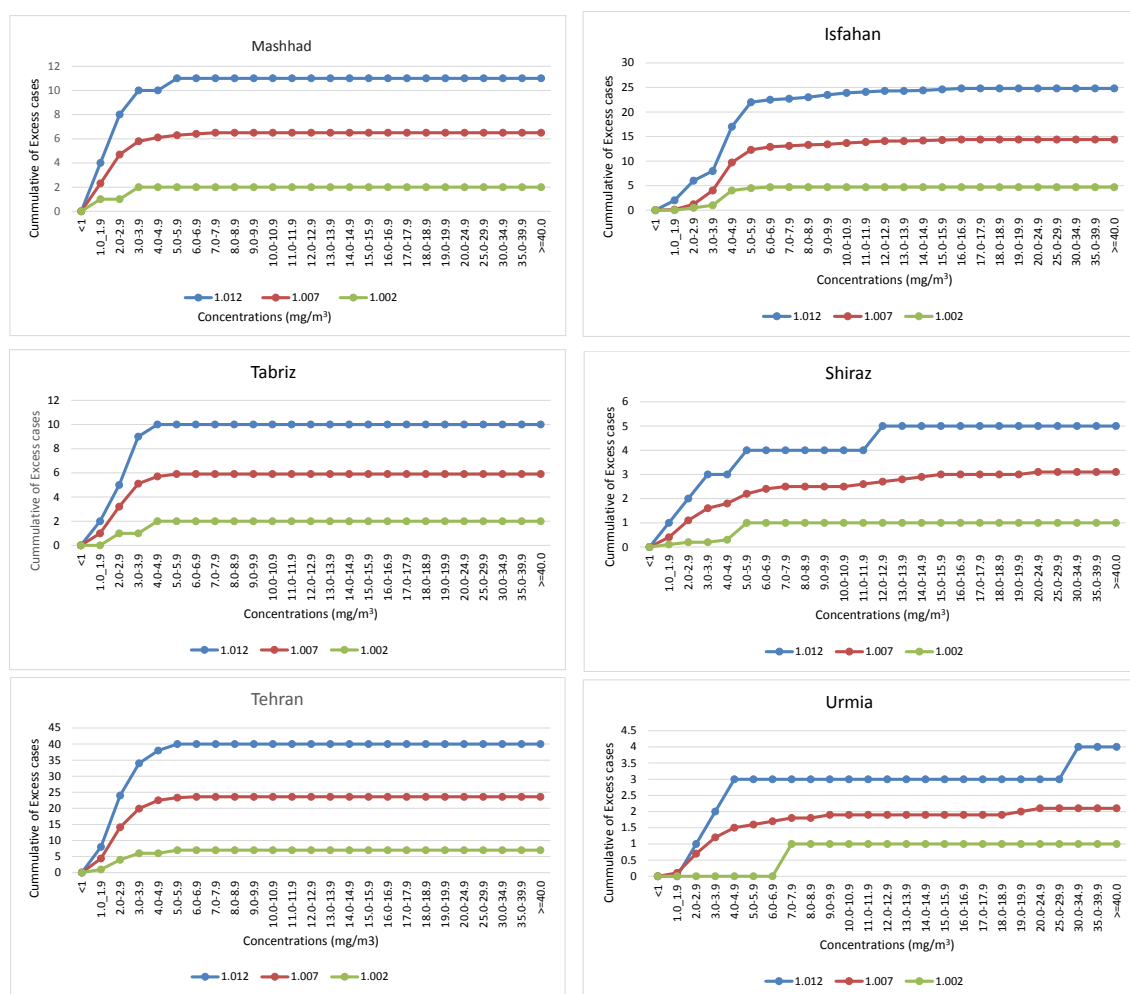


Figure 2. Cumulative of Excess cases for cardiovascular mortality of CO concentration in the six Iranian cities.

diseases have occurred at the same rate of concentration. In the case of CO, it was revealed that the concentration of the pollutant did not exceed the standard limits in any of the studied cities. According to Table 1 and considering RR and BI indices per 1000 population, the risk of cardiovascular deaths attributable to SO₂ and CO will increase 0.8% and 0.7% for each 10 µg/m³ concentration of SO₂ and 1 µg/m³ concentration of CO, respectively. Furthermore, it will increase the death rate 0.4% for each 10 µg/m³ increase in SO₂ concentration. In a study conducted in 8 cities of North America, it was found that per one unit of increase in concentration of carbon monoxide, a 2.79% increase in the number of cardiovascular patients was seen (28). As observed in Table 7, the cumulative total number of deaths attributed to SO₂ were 744, 122, 132, 44, 37, and 107 cases in Tehran, Mashhad, Isfahan, Shiraz, Tabriz, and Urmia, respectively. The results suggest that among the six studied metropolises, air pollution has caused the highest mortality rates in Urmia (about 2.19%) and Tehran (about 1.52%) and the lowest rate in Tabriz (0.46%). As is evident in Table 8, the cumulative numbers of cardiovascular deaths attributed to CO were 24, 7, 14, 3, 6, and 2 individuals in Tehran, Mashhad, Isfahan, Shiraz, Tabriz, and Urmia, respectively. The results suggest that

among the six studied metropolises, air pollution caused the highest mortality rate in Isfahan (about 2.15%) and the lowest in Mashhad (0.68%). In a study examining 15 cities in Italy during the years 1996 to 2000, it was observed that the mortality rate caused by cardiovascular diseases increased with coefficients of 0.4%, 0.93%, 1.11%, and 0.54% in the concentration of NO₂, CO, SO₂ and PM₁₀, respectively (29). According to Figure 2, the largest and smallest cumulative numbers of deaths due to cardiovascular disease were 5.64% in Urmia and 0.9% in Tabriz for SO₂. For CO, the largest cumulative number was 2.15% in Isfahan. In a study carried out in Tucson (US) air pollutants, particles and carbon monoxide had significant and strong relationships with the referral rate of cardiovascular patients with coefficients of 2.75% and 2.79%, respectively, whereas other pollutants such as SO₂, NO₂, and O₃ had weaker relationships with the referral rate of cardiovascular patients with coefficients of 0.14%, 0.69%, and 0.54%, respectively.

Conclusion

The current study, like other similar studies (30-41), showed that air pollution has a health effect on people. The results showed that in all calculated results attributed

to SO₂, Tabriz had the lowest mortality rate, while Tehran and Urmia had the highest mortality rates attributable to SO₂. Since the concentration of CO was not higher than the standard levels in the surveyed cities, the number of deaths from heart disease attributable to this pollutant was not high, while examination of the relationship between pollutant concentration and the number of deaths indicated that with increases in concentration, the number of deaths also increased. In general, statistics associated with the cumulative number of all deaths from cardiovascular disease extracted from the software clearly reflect the impacts of air pollution on human health. Thus, correct and effective planning is obviously required to control and reduce the harmful effects of air pollutants, especially SO₂ and CO. Thus, the adoption of effective methods to improve the quality of air and reduce the number of people exposed to air pollution should be considered by politicians.

Acknowledgments

The authors express their gratitude to the Environmental Protection Agency of all studied cities for their cooperation in data collection and to the Vice-Chancellery for Research of Iran University of Medical Sciences for its financial support of this study with grant No. 24221.

Ethical issues

The authors certify that all data collected during the study is presented in this manuscript, and no data from the study has been or will be published separately.

Competing interests

The authors hereby declare that in conducting this study, they had no competing interests.

Authors' contributions

All the authors contributed and participated equally in the collection, analysis, and interpretation of the data in this study. All authors critically reviewed, refined, and approved the manuscript.

References

1. Khorsandi H, Karimzade S, Aghaei M, Kargar H, Mousavi Moghanjooghi S. Estimation and quantification of health effects attributed to NO₂ pollutant in the air of Urmia, Iran. *J Urmia Univ Med Sci* 2016; 26(12): 1054-62. [In Persian].
2. Larsen B. Cost assessment of environmental degradation in the Middle East and North Africa region. *The Economic Research Forum*; 2011.
3. World Health Organization (WHO). Training package for the health sector. Outdoor air pollution. WHO; 2008.
4. Wong CM. Public health and air pollution in Asia (PAPA): coordinated studies of short term exposure to air pollution and dairy mortality in four cities. Boston: Health Effects Institute; 2010. p. 377-80.
5. Hirota K. Comparative studies on vehicle related policies for air pollution reduction in ten Asian countries. *Sustainability* 2010; 2(1): 145-62. doi: 10.3390/su2010145.
6. Bahrami Asl F, Kermani M, Aghaei M, Karimzadeh S, Salahshour Arian S, Shahsavani A, et al. Estimation of diseases and mortality attributed to NO₂ pollutant in five metropolises of Iran using AirQ model in 2011-2012. *J Mazandaran Univ Med Sci* 2015; 24(121): 239-49. [In Persian].
7. Arfaeinia H, Kermani M, Aghaei M, Bahrami Asl F, Karimzadeh S. Comparative investigation of health quality of air in Tehran, Isfahan and Shiraz metropolises in 2011-2012. *Journal of Health in the Field* 2014;1(4):36-44. [In Persian].
8. Kermani M, Bahrami Asl F, Aghaei M, Arfaeinia H, Karimzadeh S, Shahsavani A. Comparative investigation of air quality index (AQI) for six industrial cities of Iran. *Urmia Med J* 2014; 25(9): 810-9. [In Persian].
9. Cohen AJ, Ross Anderson H, Ostro B, Pandey KD, Krzyzanowski M, Künzli N, et al. The global burden of disease due to outdoor air pollution. *J Toxicol Environ Health A* 2005; 68(13-14): 1301-7. doi: 10.1080/15287390590936166.
10. Krzyzanowski M, Cohen A, Anderson R; WHO Working Group. Quantification of health effects of exposure to air pollution. *Occup Environ Med* 2002; 59(12): 791-3. doi: 10.1136/oem.59.12.791
11. Reed MD, Gigliotti AP, McDonald JD, Seagrave JC, Seilkop SK, Mauderly JL. Health effects of subchronic exposure to environment levels of diesel exhaust. *Inhal Toxicol*; 2004. 16(4): 93-177.
12. Samet JM1, Dominici F, Zeger SL, Schwartz J, Dockery DW. The national morbidity, mortality, and air pollution study. Part I: methods and methodologic issues. *Res Rep Health Eff Inst* 2000; (94 Pt 1): 5-14.
13. Ciocco A, Thompson DJ. A follow-up of Donora ten years after: methodology and findings. *Am J Public Health Nations Health* 1961; 51: 155-64.
14. Nemery B, Hoet PH, Nemmar A. The Meuse Valley fog of 1930: an air pollution disaster. *Lancet* 2001; 357(9257): 704-8. doi: 10.1016/S0140-6736(00)04135-0
15. Walters S, Phupinyokul M, Ayres J. Hospital admission rates for asthma and respiratory disease in the West Midlands: their relationship to air pollution levels. *Thorax* 1995; 50(9): 948-54.
16. Schwartz J. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. *Thorax* 1995; 50(5): 531-8.
17. Lin H, An Q, Luo C, Pun VC, Chan CS, Tian L. Gaseous air pollution and acute myocardial infarction mortality in Hong Kong: a time-stratified case-crossover study. *Atmos Environ* 2013; 76: 68-73. doi: 10.1016/j.atmosenv.2012.08.043.
18. Health effects of outdoor air pollution. Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. *Am J Respir Crit Care Med* 1996; 153(1): 3-50. doi: 10.1164/ajrccm.153.1.8542133.
19. Shrestha K. An assessment of the contribution of micro scale activities to personal pollution exposure in commuting micro environments [dissertation]. Canterbury: University of Canterbury; 2009.
20. Han X, Anther LP. A review of traffic-related air pollution exposure assessment studies in the developing world. *Environ Int* 2005; 32(1): 106-20. doi:10.1016/j.envint.2005.05.020.
21. Abdollahi M, Zadparvar L, Ayatollahi B, Baradaran M, Nikfar S, Hastaie P, et al. Hazard from carbon monoxide poisoning for bus drivers in Tehran, Iran. *Bull Environ Contam Toxicol* 1998; 61(2): 210-5.

22. WHO. Air Quality Guidelines: Global Update 2005: Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide. Geneva: World Health Organization; 2006.
23. Ministry for the Environment. Ambient Air Quality Guidelines. Wellington: Ministry for the Environment; 2002.
24. Scoggins A, Kjellstrom T, Fisher G, Connor J, Gimson N. Spatial analysis of annual air pollution exposure and mortality. *Sci Total Environ* 2004; 321(1-3): 71-85. doi: 10.1016/j.scitotenv.2003.09.020.
25. Buggeri A, Bellini O, Terracini B. Meta-analysis of the Italian studies on short-term effects of air pollution MISA 1996-2002. *Epidemiol Prev* 2004; 28(4-5 Suppl): 4-100. [In Italian].
26. Kermani M, Bahrami Asl F, Aghaei M, Karimzadeh S, Arfaeinia H, Godarzi G, et al. Quantification of health effects attributed to ozone in five metropolises of Iran using AirQ model. *Journal of Health and Hygiene* 2015; 6(3): 260-80. [In Persian].
27. Naddafi K, Hasanvand MS, Yunesian M, Momeniha F, Nabizade R, Faridi S, et al. Health impact assessment of air pollution in megacity of Tehran, Iran. *Iran J Environ Health Sci Eng.* 2012; 9(1). doi: 10.1186/1735-2746-9-28.
28. Khorsandi H, Amini Tapok F, Cargar H, Mousavi Moughanjogi S. Study of urmia city air quality according to the air quality index (AQI). *Urmia Med J* 2013; 23 (7): 767-75. [In Persian].
29. Burnett RT, Dales RE, Brook JR, Raizenne ME, Krewski D. Association between ambient carbon monoxide levels and hospitalization for congestive heart failure in the elderly in 10 Canadian cities. *Epidemiology* 1997; 8(2): 162-7.
30. Schwartz J. Air Pollution and hospital admissions for cardiovascular disease in Tucson. *Epidemiology* 1997; 8(4): 371-7.
31. Kermani M, Aghaei M, Gholami M, Bahrami Asl F, Karimzade S, Fallah Jokandan S, et al. Estimation of mortality attributed to PM_{2.5} and CO exposure in eight industrialized cities of Iran during 2011. *Iran Occupational Health Journal* 2016; 13(4): 49-61. [In Persian].
32. Motesaddi Zarandi S, Raei Shaktaie H, Yazdani Cheratee J, Hosseinzade F, Dowlati M. Evaluation of PM_{2.5} concentration and determinant parameters on its distribution in Tehran's metro system in 2012. *Journal of Mazandaran University of Medical Sciences* 2013; 22(2): 37-46. [In Persian].
33. Kermani M, Fallah Jokandan S, Aghaei M, Dolati M. Estimation the number of mortality due to cardiovascular and respiratory disease, attributed to pollutants O₃, and NO₂ in the air of Tehran. *Journal of Health Research in Community* 2016; 1(4):1-11. [In Persian].
34. Kermani M, Dowlati M, Jonidi Jafari A, Rezaei Kalantari R, Sadat Sakhaei F. Effect of air pollution on the emergency admissions of cardiovascular and respiratory patients, using the air quality model: a study in Tehran, 2005-2014. *Health in Emergencies and Disasters Quarterly* 2016; 1(3): 137-46. doi: 10.15412/J.HDQ.09010304.
35. Kermani M, Fallah Jokandan S, Aghaei M, Bahrami Asl F, Karimzadeh S, Dowlati M. Estimation of the number of excess hospitalizations attributed to sulfur dioxide in six major cities of Iran. *Health Scope* 2016; 5(4): e38736. doi: 10.17795/jhealthscope-38736
36. Kermani M, Aghaei M, Bahramiasl F, Gholami M, Fallah Jokandan S, Dolati M et al. Estimation of cardiovascular death, myocardial infarction and chronic obstructive pulmonary disease (COPD) attributed to SO₂ exposure in six industrialized metropolises of Iran. *Razi Journal of Medical Sciences* 2016; 23(145): 12-21. [In Persian].
37. Kermani M, Dowlati M, Jonidi Jaffari A, Rezaei kalantari R. A Study on the Comparative Investigation of Air Quality Health Index (AQHI) and its application in Tehran as a Megacity since 2007 to 2014. *Journal of Research in Environmental Health* 2016; 1(4): 275-284. [In Persian].
38. Kermani M, Fallah Jokandan S, Aghaei M, Dowlati M. Estimation of cardiovascular death, myocardial infarction and chronic obstructive pulmonary disease (COPD) attributed to PM and SO₂ in the air of Tehran metropolis. *Journal of Research in Environmental Health* 2016; 2(2): 116-126. [In Persian].
39. Kermani M, Dowlati M, Jonidi Jaffari A, Rezaei Kalantari R. A Study on the comparative investigation of air quality in tehran metropolis over a five-year period using air quality index (AQI). *Journal of Health Research in Community* 2016; 2(1): 28-36. [In Persian].
40. Kermani M, Dowlati M, Jonidi Jafari A, Rezaei Kalantari R. Estimation of mortality, acute myocardial infarction and chronic obstructive pulmonary disease due to exposure to O₃, NO₂, and SO₂ in ambient air in Tehran. *Journal of Mazandaran University of Medical Sciences* 2016; 26(138): 96-107. [In Persian].
41. Soleimani Z, Parhizgari N, Dehdari Rad H, Akhoond MR, Kermani M, Bagherian Marzouni M, et al. Normal and dusty days comparison of culturable indoor airborne bacteria in Ahvaz, Iran. *Aerobiologia* 2015; 31(2): 127-41. doi: 10.1007/s10453-014-9352-4.