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Estimation of the Number of Excess Hospitalizations Attributed to Sulfur Dioxide in Six Major Cities of Iran

Majid Kermani,[1,2] Sevda Fallah Jokandan,[2] Mina Aghaei,[3,4,*] Farshad Bahrami Asl,[5] Sima Karimzadeh,[6] and Mohsen Dowlati[1]

[1]Research Center for Environmental Health Technology, Iran University of Medical Sciences, Tehran, IR Iran
[2]Environmental Health Engineering Department, School of Public Health, Iran University of Medical Sciences, Tehran, IR Iran
[3]Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, IR Iran
[4]Center for Air Pollution Research (SAPR), Institute for Environmental Research (IER), Tehran University of Medical Sciences, Tehran, IR Iran
[5]Department of Environmental Health Engineering, School of Public Health, Hamadan University of Medical Sciences, Hamadan, IR Iran
[6]Department of Environmental Health Engineering, School of Public Health, Urmia University of Medical Sciences, Urmia, IR Iran

[*]*Corresponding author*: Mina Aghaei, Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, IR Iran, E-mail: Aghaei.mina11@yahoo.com

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Abstract

Background: Air pollution is an important issue and public concern throughout the world. Sulfur dioxide is one of the pollutants that can lead to many adverse effects on human health, animal and plant life.
Objectives: Our study aimed to estimate excess hospitalization cases due to chronic obstructive pulmonary disease (COPD) and acute myocardial infarction (AMI) disease due to short-term exposure to SO_2 during years 2011 to 2012, in six major cities of Iran including Tehran, Mashhad, Tabriz, Isfahan, Shiraz and Urmia.
Methods: First, hourly air pollution data related to SO_2 were obtained from the department of environmental in six major cities of Iran. Next, required parameters were calculated and imported to AirQ software after data analysis and processing. Finally, output results of the number of excess hospitalizations attributed to SO_2 was presented in the form of tables and graphs.
Results: The total cumulative numbers of hospital admissions due to COPD (HA-COPD) were estimated in six Iranian major cities, which were 243 in central relative risk in a year. For hospital admission due to Acute Myocardial Infraction (HA-AMI), the highest impact of SO2 exposure was for Urmia with attributable proportion (AP) of 4.56%, corresponding to 41 excess cases in this city.
Conclusions: Although relative risk per 10 $\mu g/m^3$ is low and sometimes mortality and morbidity attributable to pollutant seems slight because of sensitive and large population exposed to air pollutants, burden of disease associated with air pollution will be great. Therefore, authorities should apply necessary actions and efforts based on comprehensive scientific researches in order to control air pollutants and abate their negative effects on human health.

Keywords: Air Pollution, Sulfur Dioxide, Hospital Admission, Iran

1. Background

Air pollution is an important issue and public concern throughout the world. It is responsible for many adverse health effects on human health and the environment (1, 2). Sulfur dioxide is one of the pollutants that come from combustion of fuels containing sulfur (such as oil, coal, gas and petroleum), refineries and vehicle emissions (3). This pollutant is a severe irritant and reactive gas, which can be absorbed through nose and lower respiratory tract at inhalation exposure (4). Sulfur dioxide causes inflammation, constriction and creates mucus by reducing the diameter of airways (3). At various concentrations of SO_2, pollutant has effects on different systems and organs and exposure can lead to a wide range of side effects from bronchospasm to coughing, eye irritation, edema and vascular changes (4, 5).

Sulfur dioxide and particulate matters (PM) are pollutants co-existing in coal-smoke air pollution that account for the main portion of the pollutant burden in many cities of the world (5-7). They can affect the respiratory system because of their synergistic impacts (8). Emission of sulfur dioxide can contribute to the acidification of surface water, crops, forests and ecosystem that can be considered as a cause of deforestation (9). Some epidemiological studies reported that exposure to elevated air pollutants such sulfur dioxide can contribute to an increase in mortality due to respiratory and cardiovascular causes (10, 11) and daily hospital admissions due to chronic obstructive pulmonary disease (COPD) (12, 13), asthma (14) and respiratory disease (15, 16) in short and long term exposure to ambient air pollution. A multi-center study on air pollution and mortality in Spain by Ballester claimed that SO_2 concentrations higher than daily average were related to mortality

(17). An Italian meta-analysis of short-term effects of air pollution reported that an increase of 2.8% in cardiovascular diseases was observed due to an increase in sulfur dioxide pollutant levels of 10 $\mu g/m^3$ of daily average (18).

In addition, according to a time-stratified case-crossover study conducted by Lin et al. in Hong Kong, SO_2 pollutant had a significant association with increasing acute myocardial infarction (AMI) mortality (19). According to the findings of a study conducted in Shiraz, air quality exceeded standards in 85 days and in another study by Gharechahi et al., significant relationship between sulfur dioxide pollutant and hospitalizations due to respiratory diseases in elderly group and COPD ($P < 0.001$) (20, 21) was indicated. In many cases sulfur compounds are the main causes of damage to materials (22). Although SO_2 and other sulfur oxides have been studied, many questions about their impacts on human health have remained unclear.

2. Objectives

Our study aimed to estimate excess hospitalization cases due to chronic obstructive pulmonary disease and acute myocardial infarction disease as a result of short-term exposure to SO_2 during years 2011 and 2012 in six major cities of Iran.

3. Methods

This study was conducted in six major cities of Iran. We used the AirQ software to assess and evaluate the health impact of SO_2 exposure on human health in six major cities of Iran. Hourly air pollution data related to SO_2 were obtained from department of environmental (DOE) of six study cities, from March 2011 to March 2012. Thereafter, 24-hour means were calculated. Map and location of studied cities is shown in Figure 1.

Gathered data were in volumetric base but the AirQ software was designed on gravimetric base, so we obtained data of pressure and temperature from Islamic Republic of Iran meteorological organization and used the following equation (22) to convert ppb unit (DOE data) to $\mu g/m^3$ unit (model required):

$$\frac{\mu g}{m^3} = \frac{P\left(mmHg\right) \times MW \times PPM}{62.4 \times T\left(K\right)} \times 1000$$

Where, MW is molecular weight of pollutant, T is temperature as Kelvin degree and P is pressure (22). To quantify the health impact due to exposure to SO_2, annual mean, winter and summer mean, annual 98 percentile, annual maximum and winter and summer maximum were calculated in all cities and their stations.

All of these corrections, processing and required statistical parameters calculation were performed using microsoft office excel spread sheet. We calculated hospital admission due to acute myocardial infarction and chronic obstructive pulmonary disease (COPD) attributed to SO_2 by AirQ2.2.3 tool.

The air quality health impact assessment tool (AirQ) was proposed by the world health organization (WHO) in 2004 and developed by the WHO European centre for environment health, Bilthoven division (23, 24). This tool is based on epidemiological studies and statistical equations. Four-screen input of this model are AirQ user screen, location screen, air quality data and parameter screen (25). Outputs of model, present results in tables and graphs. Estimation is based on the attributable proportion (AP), defined as the fraction of the health outcome in a specific population attributable to exposure to specific pollutant during the period of time in a certain area. Attributable proportion is calculated using the following equation (26);

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

Where, p(c) is the population of the city and RR is the relative risk of health endpoints in category "C" of exposure that is obtained from an epidemiological study and exposure-response functions.

Relative risk (RR) is defined as a ratio of the probability of the event when people exposure to probability of the event when people non-exposed. Rate of health outcome attributable to the exposure (IE) was calculated as follows:

$IE = I \times AP$ (27)

Where, I is the baseline frequency of the health outcome in the population under investigation. Number of cases attributable to the exposure to pollutant (NE) with known size of population (N) can be calculated as follows:

$NE = IE \times N$ (27)

Baseline incidence (BI) is multiplied at population size and attributable proportion (AP) then divided by 10^5 to obtain number of excess cases (28):

$$\left(\frac{Baseline \quad incidence \times Population}{10^5}\right) \times Attributable \quad proportion = No.of \quad excess \quad cases$$

Finally, after importing prepared data to the AirQ tool, results were presented as the excess cases of hospital admission attributed to sulfur dioxide pollutant in each city (28).

4. Results

Table 1 shows some calculated parameters of environmental data required for quantification by the model in six

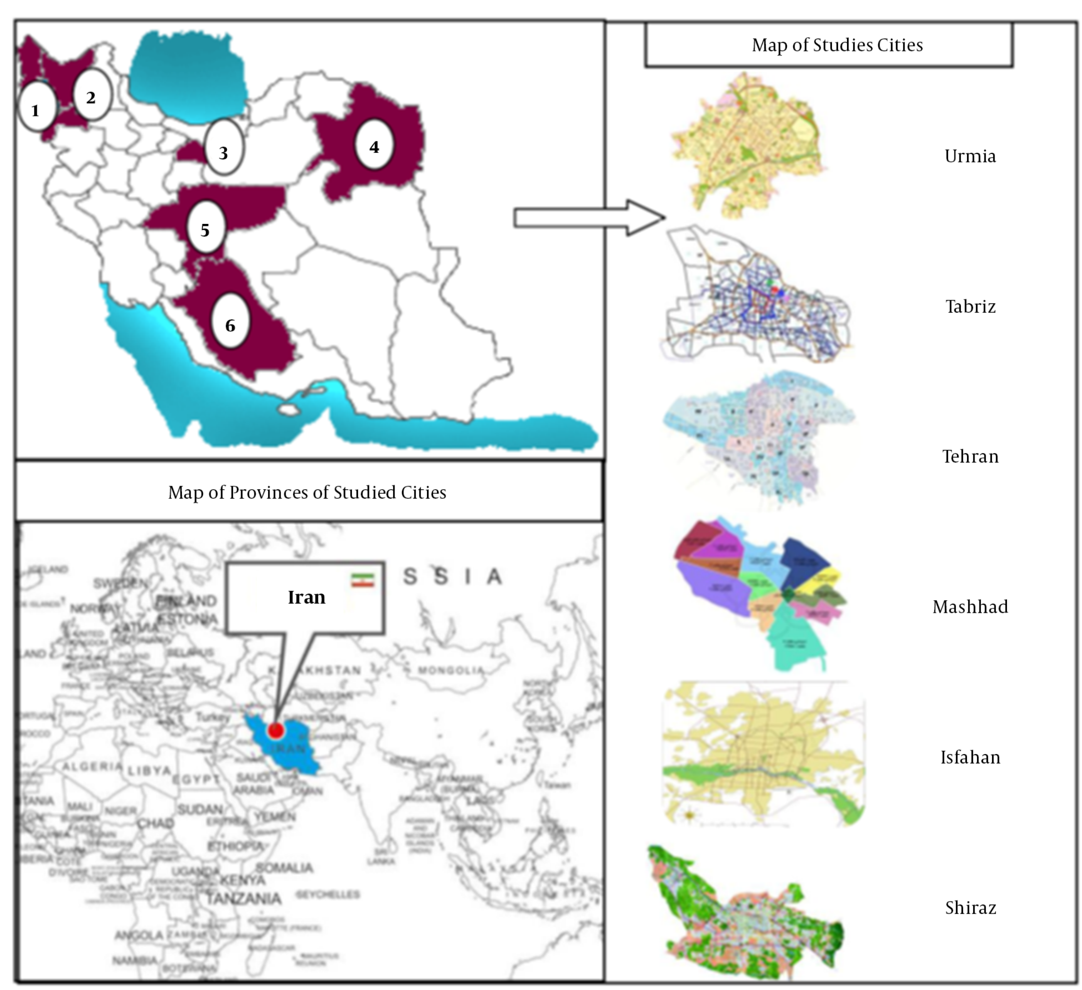

Figure 1. Map of Six Major Cities in Iran and Their Location

cities of Iran. Since SO_2 data obtained from DOE were expressed on an hourly basis, we computed daily average values. We applied census data reported by statistical centre of Iran (SCI) in 2010 to determine the exposed population.

As it can be seen in Table 1, highest annual concentrations of sulfur dioxide ($\mu g/m^3$) were recorded in Urmia and Tehran, with mean values of 76 and 49 $\mu g/m^3$, respectively. Overall, 20 $\mu g/m^3$ was determined based on the Iranian national standards as annual average of SO_2. According to these standards, in all of the studied cities except Shiraz and Isfahan SO_2 exceeded the national standards. During the study period, annual mean concentrations of SO_2 in Tabriz and Mashhad were approximately 1.05 and 1.55 times higher than national standards, respectively.

Baseline incidence (BI) and relative risks (RR) with 95% confidence intervals (95% CI) used for the health effect estimation in this study are shown in Table 2. Relative risks and BI used for SO_2 based on other studies conducted in Iran and these parameters calculate in Iranian cities (9, 29).

Days (%) which people in these six cities were exposed to different levels of SO_2 are shown in Table 3. In the AirQ, it was assumed that measured concentrations show average exposure of people (30). According to the results, highest percentages of person-day for Urmia, Shiraz, Tabriz, Isfahan, Tehran and Mashhad were 12.5% (at 30 - 39 $\mu g/m^3$ concentration interval), 49.86% (at 10-19 $\mu g/m^3$ concentration interval), 47.95% (at 10 - 19 $\mu g/m^3$ concentration interval), 21.64 (at 40 - 49 $\mu g/m^3$ concentration interval) and 31.78% (at 40 - 49 $\mu g/m^3$ concentration interval), 55.62% (at 20 - 29 $\mu g/m^3$ concentration interval), respectively (Table 3).

Number of excess cases of hospital admissions due to COPD and AMI, as a result of short-term exposure to SO_2

Table 1. Summary of Required Statistical Parameters, SO_2, Annual 24-hour ($\mu g/m^3$) in Six Cities of Iran (2011 - 2012)

Cities	Average	Winter Maximum	Summer Minimum	98%	Exposed Population
Mashhad	31	61	41	48	2750000
Tehran	49	118	88	94	9000000
Isfahan	12	26	20	19	1987000
Tabriz	21	18	34	66	1495000
Shiraz	11	34	32	25	1540000
Urmia	76	176	188	159	680000

Table 2. Baseline Incidence and Relative Risks for Health Endpoints of SO_2 in the Study

Indicators	HA- COPD, CI 95%	HA-Acute myocardial infraction, CI 95%
Relative risk (95% CI) per 10 $\mu g/m^3$	1.0044 (1 - 1.011)	1.0064 (1.0026 - 1.0101)
Baseline incidence (per 10^5 inhabitants)	101.4	132

concentrations above 10 $\mu g/m^3$ in six cities was estimated (Tables 4 and 5).

According to Table 4, maximum number of excess hospital admissions due to COPD in investigated cities is related to Urmia considering the AP and exposed population.

Results indicate that risks of HA-COPD and HA-AMI increase by 0.44% and 0.64% with every 10 $\mu g/m^3$ increase in SO_2 concentration, respectively. Output results of AirQ are shown by graphs (Figures 2 and 3).

Since the number of excess HA-AMI and HA-COPD for Tehran is much higher than other cities we preferred to show this city in a different scale (Figure 4).

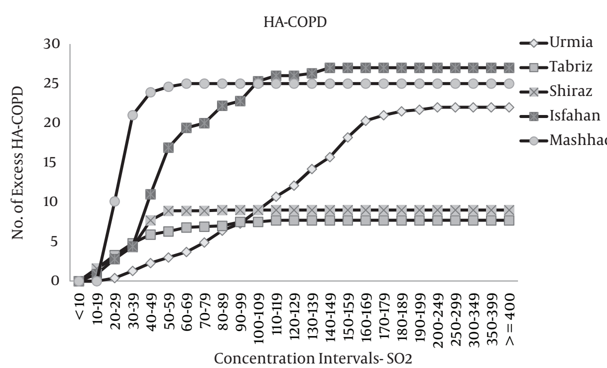

Figure 3. Estimation of Cumulative Number of Hospital Admissions Due to Chronic Obstructive Pulmonary Disease Attributable to Sulfur Dioxide Compared to Concentration Intervals by the AirQ Tool in Studied Cities of Iran

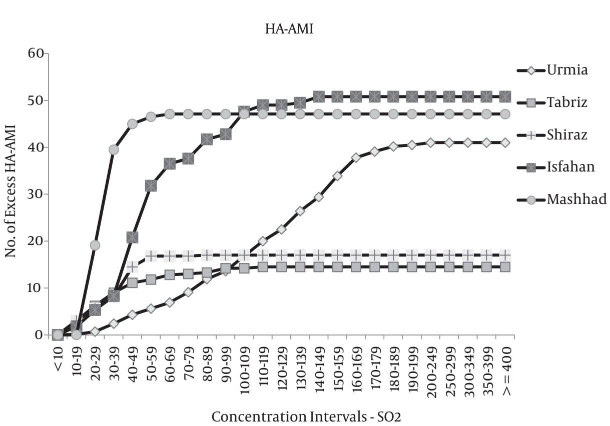

Figure 2. Estimation of Cumulative Number of Hospital Admissions due to Acute Myocardial Infraction Attributable to Sulfur Dioxide Compared to Concentration Intervals by the AirQ Tool in Studied Cities of Iran

5. Discussion

In this study estimation of excess hospitalization due to chronic obstructive pulmonary disease (HA-COPD) and acute myocardial infarction disease (HA-AMI) due to short-term exposure to SO2 pollutants during years 2011 and 2012 was performed using a model in six major cities of Iran.

According to Table 3, the highest exposure to SO_2 in mentioned cities occurred at different concentration levels as follows: 10 - 19 $\mu g/m^3$ in Shiraz, Isfahan and Tabriz, 20 - 29$\mu g/m^3$ in Mashhad, 30 - 39$\mu g/m^3$ in Urmia and 40 - 49 $\mu g/m^3$ in Tehran. Based on Table 1, annual concentration of SO_2 in Tehran, Mashhad, Isfahan, Shiraz, Tabriz and Urmia was 2.45, 1.55, 0.6, 0.55, 1.05 and 3.8 times higher than the WHO standards (20 $\mu g/m^3$), respectively. Therefore, all of the studied cities exceeded the SO_2 national standards ex-

Table 3. Percentage of Days That People in the Six Cities are Exposed to Different Levels of SO^2

Concentration intervals, $\mu g/m^3$	Urmia	Tabriz	Tehran	Shiraz	Isfahan	Mashhad
< 10	2.14	16.99	0.27	8.22	5.48	0
10 - 19	2.86	47.95	4.93	49.86	21.37	0
20 - 29	7.5	16.99	6.3	14.25	14.25	55.62
30 - 39	12.5	9.04	16.44	8.22	7.4	35.62
40 - 49	10	4.66	31.78	15.07	21.64	6.85
50 - 59	5	1.37	20.82	4.11	14.79	1.37
60 - 69	4.29	1.37	9.59	0	5.21	0.55
70 - 79	6.43	0.27	3.84	0	1.1	0
80 - 89	6.79	0.27	2.47	0.27	3.29	0
90 - 99	3.57	0.82	2.47	0	0.82	0
100 - 109	6.07	0	0.55	0	3.01	0
110 - 119	5.71	0.27	0.55	0	0.82	0
120 - 129	3.93	0	0	0	0	0
130 - 139	5.71	0	0	0	0.27	0
140 - 149	3.93	0	0	0	0.55	0
150 - 159	5.71	0	0	0	0	0
160 - 169	4.64	0	0	0	0	0
170 - 179	1.43	0	0	0	0	0
180 - 189	1.07	0	0	0	0	0
190 - 199	0.36	0	0	0	0	0
200 - 249	0.36	0	0	0	0	0
250 - 299	0	0	0	0	0	0
300 - 349	0	0	0	0	0	0
350 - 399	0	0	0	0	0	0
≥ 400	0	0	0	0	0	0

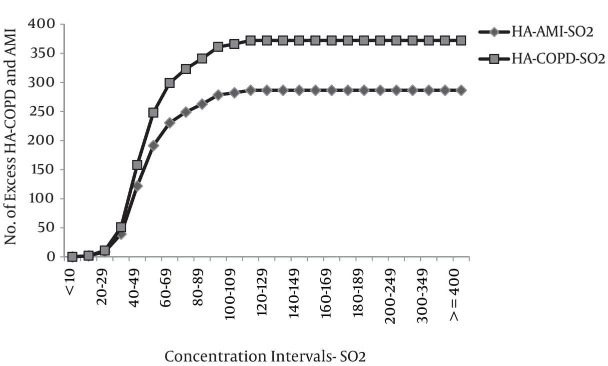

Figure 4. Estimation of Cumulative Number of Hospital Admissions Due to Chronic Obstructive Pulmonary Disease Attributable to Sulfur Dioxide Compared to Concentration Intervals by the AirQ tool in Tehran

cept Shiraz and Isfahan.

The total cumulative number of hospital admissions due to COPD (HA-COPD) was estimated in six Iranian major cities, which was 243 cases in central relative risk in a year. For hospital admission due to acute myocardial infraction (AMI), the highest impact of SO_2 exposure was for Urmia with attributable proportion (AP) of 4.56%, corresponding to 41 excess cases in this city. Overall, 225 AMI hospital admission cases attributed to SO_2 were reported in Tehran city by Kermani et al. (2014) (31).

In a study conducted in Korea (from January 2011 to December 2011), number of excess cases of HA COPD and HA AMI was 32.1 and 6 in central RR, respectively (26). In our study total number of excess hospitalization cases due to COPD and AMI as a result of short-term exposure to SO_2 was 690 in all studied cities. Geravandi et al. (2015) studied the incidence of health endpoint in Ahvaz and recorded 173

Table 4. Number of Hospital Admissions due to Chronic Obstructive Pulmonary Disease (COPD)

Health End Point (Hospitalization)	City	RR	AP	No. of Excess Cases, Uncertainty Range
Hospital admission due to chronic obstructive pulmonary (HA- COPD)	Mashhad	Central	0.89	25
		Lower	0	0
		Upper	2.21	62
	Tehran	Central	1.67	152
		Lower	0	0
		Upper	4.07	371.7
	Shiraz	Central	0.61	9
		Lower	0	0
		Upper	1.51	22
	Isfahan	Central	1.33	27
		Lower	0	0
		Upper	3.28	66
	Tabriz	Central	0.5	8
		Lower	0	0
		Upper	1.25	19
	Urmia	Central	3.18	22
		Lower	0	0
		Upper	7.59	52

Abbreviations: AP, Attributable Proportion; RP, Relative Risk.

Table 5. Estimated Attributable Proportion (AP) Expressed as Percentages and Number of Excess Cases in a Year Due to Short-Term Exposure Above 10 $\mu g/m^3$ for SO_2

Health End Point, Hospitalization		AP, Attributable Proportion	No. of Excess Cases, Uncertainty Range
HA-Acute myocardial infraction	Mashhad	1.29 (0.53-2.03)	47 (19-74)
	Tehran	2.41 (0.99- 3.75)	286 (118-446)
	Shiraz	0.89 (0.39-1.39)	17 (7-27)
	Isfahan	1.93 (0.79-3.02)	51 (21-79)
	Tabriz	0.73 (0.3-1.15)	15 (6-23)
	Urmia	4.56(1.9-7.01)	41 (17-63)

$\mu g/m^3$ for maximum annual concentration of SO_2, which was observed during winter of 2012. Their study also reported that about 5.6% of COPD cases attributed to SO_2 occurred at higher than 20 $\mu g/m^3$ concentrations (26). In another study in Ahvaz (2014), the number of myocardial infarction and cardiovascular death cases associated with sulfur dioxide exposure was estimated to be 37 and 165, respectively (32).

Results implied that sulfur dioxide with highest and lowest AP was reported in Urmia and Tabriz, respectively, indicating the highest and lowest health end points (hospitalizations). The status of SO_2 is more critical in Urmia and Tehran compared with other areas.

In a study conducted in six cities of Harvard, increased death rates in cities were reported with higher SO_2 levels (33). Overall, studies carried out on this issue showed convincing evidences on the role of pollutants in the incidence of disease and death. Some other studies have shown that pollutants are a growing concern for public health (34).

Despite the fact that there is positive and direct relationship between sulfur dioxide and the total daily number of mortality, ranges of impacts attributable to exposure to SO_2 or a mixture of pollutants are yet unclear. According to Dennison et al. (2002), since there are correlations between SO_2 and other pollutants in the air, attributing the observed effects just to SO2 is difficult (35).

Although relative risk per 10 $\mu g/m^3$ is low and sometimes mortality and morbidity attributable to pollutant seems slight because of sensitive and large population exposed to air pollutants, burden of disease associated with air pollution will be great. Sulfur compounds are the main cause of damage to materials in many cases (22). Although SO_2 and other sulfur oxides have been studied, many questions about their impacts on human health have remained unanswered.

Some possible measures proposed to reduce sulfur dioxide emissions are as follows: use of low-sulfur heavy fuel oils, diminution in coal consumption, reducing the sulfur content of fuels and desulphurization of flue gas, etc. Thus, authorities should apply necessary actions and efforts based on comprehensive scientific researches in order to control air pollutants and abate their negative effects on human health. Adopting effective methods to improve air quality and to reduce people's exposure to air pollution can be considered by policy makers.

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Footnote

Authors' Contribution: Study concept and design, Majid Kermani; acquisition of data, Sima Karimzadeh and Farshad Bahrami Asl; analysis and interpretation of data, Mina Aghaei, Sevda Fallah Jokandan and Mohsen Dowlati; drafting of the manuscript, Mina Aghaei; critical revision of the manuscript for important intellectual content, Majid Kermani.

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