

The Number of Myocardial Infarction and Cardiovascular Death Cases Associated with Sulfur Dioxide Exposure in Ahvaz, Iran

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Background & Aims of the Study: Sulfur dioxide is a component of greatest concern and is used as an indicator for the larger group of gaseous sulfur oxides (SO_x). Sulfur dioxide can be absorbed into your body through the nose and lungs, its reaction with the moisture in the nose and nasal cavity, and entering the circulatory system directly through the airways. The aim of this study is to assess health-effects of exposure Sulfur dioxide in Ahvaz city during 2012.

Materials & Methods: The Sulfur dioxide data was taken from Ahvaz Department of Environment and Meteorological Organization. The different health endpoints of sulfur dioxide in Ahvaz in 2012 were calculated by a model. We utilized the relative risk values and baseline incidence measures by the WHO (Middle East) drawn from health effects association of sulfur dioxide. To use these raw data, we processed the data by Excel software, and then the impact of meteorological parameters was converted as input file to Air Q model. Finally, health-effects of exposure to sulfur dioxide were calculated

Results: According to the findings, the highest and the lowest sulfur dioxide concentrations during 2012 were observed in Downtown "Naderi" and Bureau of Meteorology "Havashenasi", respectively. The average annual concentration of measured sulfur dioxide was 160 µg/m³. Total numbers of myocardial infarction and cardiovascular death attributed to sulfur dioxide were respectively 37 and 165 in 2012.

Conclusions: This could be due to higher gasoline consumption of vehicles, oil industry, steel, and heavy industries in Ahvaz. Prevention and control measures to reduce people's exposure to sulfur dioxide pollution can very useful.

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Background

In recent years, epidemiological studies of air pollution have demonstrated that air pollution is responsible for endangering human health and

other living organisms such as agricultural crops and increasing the death rate (1-5). Air pollution is a major environmental risk to health. Lower air pollution levels mean better cardiovascular and respiratory health of population both in long- and short-terms (6,7). Several studies have demonstrated the relation between short and long term effects of exposure to air pollutants and human health. Studies also show a connection between short term exposure and increased emergency departments visits and hospital admissions for respiratory illnesses, particularly at risk populations such as children, the elderly, and asthmatics (8). United States National Ambient Air Quality Standards (NAAQS) list air pollutants as carbon monoxide, ozone, particulate matter, sulfur dioxide, nitrogen dioxide, and lead (8). The exposure to sulfur dioxide is extremely risky for people health because these compounds enter the circulatory system directly through the airways. Sulfur dioxide is produced by volcanoes and various industrial processes. Coal and petroleum often contain sulfur compounds, and their combustion generate sulfur dioxide. Sulfur dioxide is a colorless gas and a pungent odor with a characteristic and irritating smell that is released from the burning of fossil fuels (coal, oil) such as power plants and high sulfur diesel fuel (9-11).

Sulfur dioxide is the component of greatest cause of concern and is used as an indicator for larger group of gaseous sulfur oxides (SO_x) (8, 10). Sulfur dioxide is one of the major portion of pollutant load in many cities. It can cause irritation, corneal haze, reduction of visibility, and some respiratory diseases (9-11). Sulfur dioxide can be absorbed into your body through your nose and lungs. Sulfur dioxide can easily and rapidly enter your bloodstream through your lungs. Short-term exposures to high levels of sulfur dioxide can be life threatening. The most important effects of SO₂ air pollution on human include: breathing difficulty, hospital admission rates increase, pulmonary edema, asthma attacks, eye irritation, cardiopulmonary

disease, morbidity, and mortality increase in old people and infants (12-20). Sulfur dioxide can be dangerous to the respiratory system and lungs' functions and can also cause eyes' irritation.

Ahvaz is generally known for its industrial community as well as environmental pollution. In the last decade, air pollution (industrial and dust storm) has been added to the region's other environmental problems (21, 22). Social consequences of air pollution on the citizens were also evaluated (21, 22). With the rapid economic growth in Ahvaz, air pollution level resulting from motor vehicles and industrial emissions has drastically increased. Furthermore, health effects of air pollution in terms of sulfur dioxide, ozone, and particulate matter in most of megacities, particularly Ahvaz, were reported. Previous studies have shown associations between ambient air pollution and birth defects (23, 24).

One study found no relationship between spontaneous abortion and exposure to sulfur dioxide among women living in an industrial community in Finland. Another study in Croatia showed a relationship between the ground-level concentrations of sulfur dioxide and met? hemoglobin concentrations in pregnant women when a coal-powered thermoelectric power plant was in operation ("dirty" period) and when it was closed ("clean" period) (25). Another study, in the Czech Republic, showed that 18-year-old males who were exposed to high levels of sulfur dioxide had sperm with more abnormalities and reduced abilities to move (26).

Lin et al found a correlation between maternal exposure to elevated ambient sulfur dioxide during pregnancy and low birth weight in Taiwan (27). In another study in Canada, Liu et al reported meaningful association between gaseous ambient air pollutants and adverse pregnancy outcomes in Vancouver, Canada (28). In another study, Maisonet et al showed a relation between ambient air pollution and low birth weight in the Northeastern United States

(29). Pooled estimates on 12 European cities' daily mortality data showed that 50 $\mu\text{g}/\text{m}^3$ increase in concentrations of sulfur dioxide and particulates increased the death rate to 3% and 2%, respectively (30). In Spokane where sulfur dioxide concentrations were even lower, Schwartz reported similar significant findings on health effect of particulates independent of sulfur dioxide (31).

Aims of the study: The aim of this study is designed to evaluate the relationship between fluctuations in ambient sulfur dioxide concentrations and myocardial infarction and cardiovascular death in Ahvaz (located in the south-western Iran), during 2012.

Materials & Methods

The present study is an epidemiological and used model study. In this study, the health effects of exposure to sulfur dioxide is assessed in Ahvaz (located in south-western Iran) during 2012. Data were collected through Ahvaz Meteorological Organization and Department of Environment (2). Data analysis process encompassed temperature and pressure modifications, primary processing (the deletion, spreadsheet, and synchronization), secondary processing (writing code and condition correction), formulation, and filtering. We calculated myocardial infarction and cardiovascular death related to sulfur dioxide by AirQ_{2.2.3} based on the relative risk, attributable proportion, and baseline incidence from WHO data (2). WHO is a valid and reliable tool to estimate the potential short term effects of air pollution. This model includes four screen inputs (supplier, AQ data, location, and parameter) and two output screens (table and graph) (12). For estimation of health impact attributable to the exposure of air pollution on the target population, AirQ model estimates the impacts of specific air pollutants on resident population in a certain area and period. The

primary and secondary standard of sulfur dioxide according to the national ambient air quality standard (NAAQS) is 150 $\mu\text{g}/\text{m}^3$ in 24-hour (2, 8).

Ahvaz, the capital of Khuzestan Province, with about one million people, an area of 8152 km², is located at 48° to 49°29' east of Greenwich meridian and 31° 45' north of the equator (2, 12). To perform the study, data was taken from Ahvaz Department of Environment (ADoE). Stations were located Downtown "Naderi", Old School of Public Health "BehdashtGhadim", Bureau of Meteorology "Havashenasi", and Head office of ADoE "Mohitzist". The study area location and sampling station in Ahvaz are presented in Figure 1.

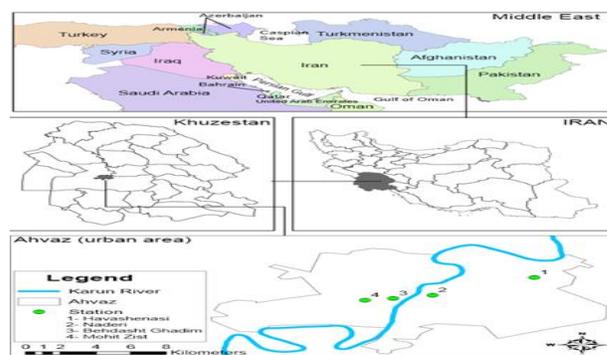


Figure 1: The study area location and sampling station in Khuzestan Province (Ahvaz), south west of Iran (22).

Results

Based on the results, the highest and the lowest stations in terms of sulfur dioxide concentrations were respectively Naderi and Havashenasi during 2012. The yearly average, summer mean, winter mean, and 98 percentile of sulfur dioxide concentrations in these stations are presented in Table 1. It shows that annual mean of sulfur dioxide in Ahvaz was 160 $\mu\text{g}/\text{m}^3$ in 2012 which is higher than NAAQS standards.

Table 1: The highest and lowest concentration of Sulfur dioxide($\mu\text{g}/\text{m}^3$) corresponding to stations for use in model.

Stations Parameter	Average Ahvaz	lowest stations (Havashenasi)	highest stations (Naderi)
Annual mean	160	75	220
Summer mean	46	37	75
Winter mean	173	81	242
98 percentile	171	96	281

Figure 2 shows average concentrations of sulfur dioxide during this year's seasons. According to the results, the maximum sulfur dioxide concentration was observed in the winter in 2012.

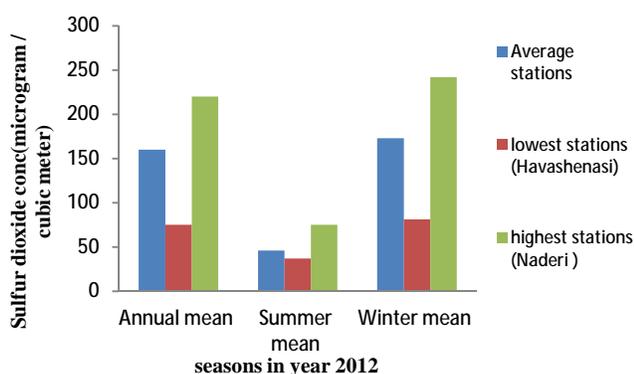


Figure 2: Relationship between sulfur dioxide concentration and the seasons in 2012

Relative risk (RR) and estimated Attributable Proportion (AP) percentage for acute

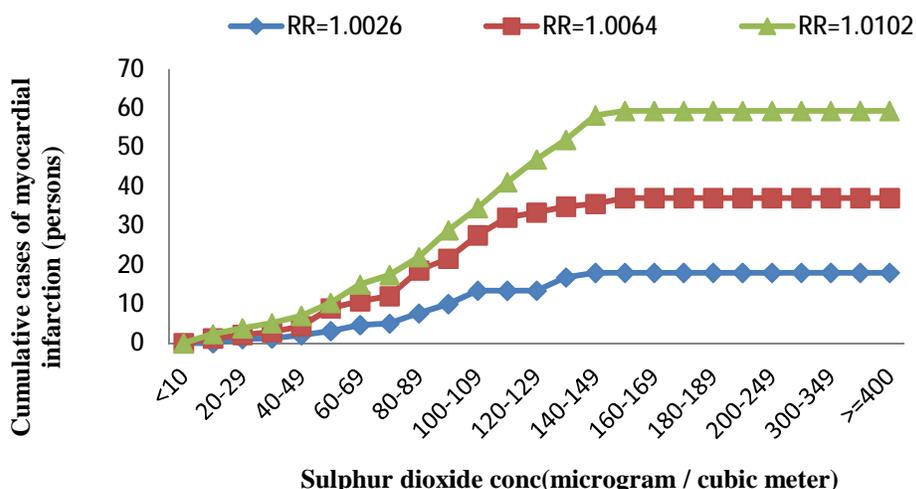


Figure 3: Relationship between cumulative number of acute myocardial infarction (MI) and sulfur dioxide concentrations

myocardial infarction (MI) and cardiovascular mortality are calculated (Table 2). According to the model's default, the baseline incidence (BI) of the health endpoint for sulfur dioxide was 497. 132 per 100,000 people, so the estimated value of excess cases was estimated 37 for myocardial infarction at centerline of relative risk (RR=1.0064 and AP=2.8652%) and 165 for cardiovascular mortality at centerline of relative risk (RR=1.008 and AP=3.3216%).

Table 2: Estimated relative risk indicators and myocardial infarction and cardiovascular death cases attributable to sulfur dioxide concentrations

Health effects attributable to sulfur dioxide	RR (relative risk)	Estimated AP (%)	Estimated number of excess cases (persons)
myocardial infarction	1.0064	2.8652	37
cardiovascular death	1.008	3.3216	165

Figure 3 shows the cumulative number of acute MI versus sulfur dioxide concentrations. It was estimated 37 for 2012. 57% of the cases occurred in days with sulfur dioxide concentrations of lower than $70\mu\text{g}/\text{m}^3$, and 74% of the cases corresponded to the days with concentrations below $100\mu\text{g}/\text{m}^3$.

Cumulative cases of cardiovascular mortality attributed to sulfur dioxide concentrations are illustrated in Figure 4 with three ranges of relative risk. Total cumulative number of cardiovascular death within one year of

exposure was estimated for 165 subjects; 63 % of the cases occurred in days which sulfur dioxide levels did not exceed $80\mu\text{g}/\text{m}^3$.

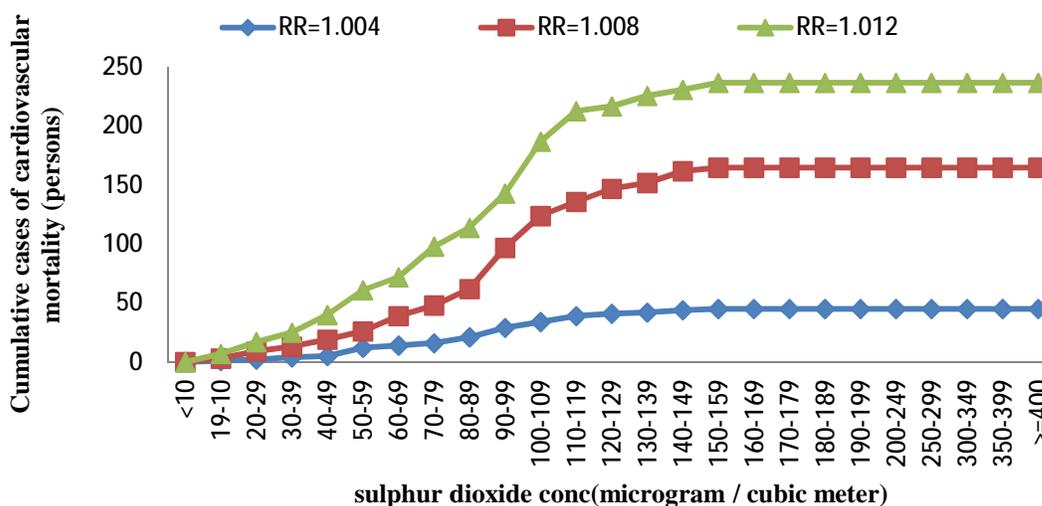


Figure 4: Relationship between cumulative number of cardiovascular mortality and sulfur dioxide concentration

Discussion

The results showed that the maximum concentration was in Naderi station and the minimum in Havashenasi station. Total number of cardiovascular mortality attributed to sulfur dioxide was 237 and acute MI cases versus sulfur dioxide in high relative risk were 60, 55% of which happened when the sulfur dioxide concentration was less than $70\mu\text{g}/\text{m}^3$. Relative risk and estimated Attributable Proportion percentage for cardiovascular death and myocardial infarction are calculated (Table 2).

Baseline incidence (BI) for health endpoints for sulfur dioxide was $497.132 \text{ per } 10^5$, so the cardiovascular mortality rate was calculated 156 (RR=1.0080 and AP=3.3216%) and myocardial infarction rate was calculated 37

(RR=1.0064 and AP=2.8652%) at centerline of relative risk. Also, 46% of myocardial infarction at relative risk centerline happened when the sulfur dioxide concentration was less than $60\mu\text{g}/\text{m}^3$. Results show that Ahvaz with 5% pollution level is almost one of the most polluted cities. The higher percentage of the death rate is perhaps due to higher sulfur dioxide average or because of its high sustained concentration days in Ahvaz.

Figures 3 to 4 illustrate sulfur dioxide concentrations versus related health endpoints and average concentrations during the year. In this study, we estimated cardiovascular death and myocardial infarction associated with short and long term fluctuations in concentrations of sulfur dioxide pollutant on people, using Air Q model in Ahvaz, Iran. Based on the findings, approximately 8.5% and 7.6 % of total cardiovascular death and

myocardial infarction were attributed to respiratory sulfur dioxide. The association of daily mortality and morbidity with short-term variations in ambient concentrations of air pollutants is evident in the literature (32); Lin et al reported that 26% increase in terms of LBW risk given maternal ambient exposure to SO₂ concentration exceeding 11.4 ppb during pregnancy compared to low exposure (<7.1 ppb) (OR=1.26, 95% CI=1.04-1.53) (27).

Liu et al reported that low birth weight was associated with exposure to SO₂ during the first month of pregnancy (OR = 1.11, 95% CI, 1.01-1.22, for a 5.0 ppb increase). Preterm birth was associated with exposure to SO₂ (OR = 1.09, 95% CI, 1.01-1.19, for a 5.0 ppb increase) during the last month of pregnancy (28). The high percentage of the observed health endpoints in this study was associated with high concentration of measured sulfur dioxide in Ahvaz. In a similar work, Goudarzi et al (2009) estimated sulfur dioxide hygienic effects in Tehran, Iran; almost 7.5 and 5.6 % of all cardiovascular death and myocardial infarction cases were attributed to sulfur dioxide (33); nonetheless, concentration of sulfur dioxide in Ahvaz was much higher compared to Tehran.

Sunyer et al studied air pollution impacts on cardiovascular and respiratory mortality; they showed that with an increase of daily sulfur dioxide levels at the same and the preceding day, a daily average increase of 10 µg/m³ of sulfur dioxide was significantly correlated with 0.7 % increase (95% confidence interval=0.1–1.3) in all cardiovascular admissions at the same and the next day (34); however, the number of health effects' cases in Ahvaz was relatively higher because of greater concentrations of sulfur dioxide. In another study by Mohamadi et al (2009) health effects of air pollutants in Ahvaz were calculated; approximately 4.35% of cardiovascular death and 2.2% of myocardial infarction were related to sulfur dioxide (35).

A study on six Italian cities demonstrated that the increase in the daily average pollutant levels of 10 µg/m³ of sulfur dioxide correlated with 2.8% increase in cardiovascular disease (36) which is not consistent with the present study due to the geographic, demographic, and climate characteristics of the region.

Zalaghi et al (2010) surveyed health effects of air pollution in Ahvaz, Bushehr and Kermanshah; approximately 4.8% of cardiovascular death in Ahvaz, 9.1% in Kermanshah, and 3.75% in Bushehr were attributed to sulfur dioxide (37). It was reported that concentration of sulfur dioxide in Ahvaz was higher compared to Kermanshah and Bushehr. Studies of Ballester et al in Valencia, Spain showed that increase in daily average pollutant levels of 10 µg/m³ of sulfur dioxide was associated with 3% increase in all circulatory diseases (38). The current study's results represent the same health endpoints for sulfur dioxide in Ahvaz because of oil, petroleum, and steel industries.

Conclusion

This study adds another outcome to the increasing body of literature on the adverse reproductive health effects of exposure to sulfur dioxide and it is the second attempt in evaluating health impacts of sulfur dioxide air pollutants in Ahvaz, Iran. Approximately 8.5 and 7.6 % of the total cardiovascular death and myocardial infarction were attributed to respiratory sulfur dioxide.

High percentage of the observed health endpoints was associated with high concentration of measured sulfur dioxide, and as it was previously mentioned, sulfur dioxide concentration was higher than NAAQS guidelines' values. Although the results of this study are in line with results of other researches around the world, the geographic, demographic, and climate characteristics being different, further studies are required to

specify local RR and BI. Pollution prevention, limiting emissions of pollutants from various sources such as changing modes of transport, reducing energy consumption, and careful monitoring of air pollution are necessary to reduce sulfur dioxide concentrations. Undertaking the actions, it is generally expected to have reduced exposures of people to all gaseous SO_x. This may have another important benefit of reducing the formation of fine sulfate particles which pose significant public health threats.

Footnotes

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Conflict of Interest:

The authors declared no conflict of interest.

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