



## Survey on Air Pollution and Cardiopulmonary Mortality in Shiraz from 2011 to 2012: An Analytical-Descriptive Study

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### ABSTRACT

**Background:** Expanding cities with rapid economic development has resulted in increased energy consumption leading to numerous environmental problems for their residents. The aim of this study was to investigate the correlation between air pollution and mortality rate due to cardiovascular and respiratory diseases in Shiraz.

**Methods:** This is an analytical cross-sectional study in which the correlation between major air pollutants (including carbon monoxide [CO], sulfur dioxide [SO<sub>2</sub>], nitrogen dioxide [NO<sub>2</sub>] and particle matter with a diameter of less than 10 μ [PM<sub>10</sub>]) and climatic parameters (temperature and relative humidity) with the number of those whom expired from cardiopulmonary disease in Shiraz from March 2011 to January 2012 was investigated. Data regarding the concentration of air pollutants were determined by Shiraz Environmental Organization. Information about climatic parameters was collected from the database of Iran's Meteorological Organization. The number of those expired from cardiopulmonary disease in Shiraz were provided by the Department of Health, Shiraz University of Medical Sciences. We used non-parametric correlation test to analyze the relationship between these parameters.

**Results:** The results demonstrated that in all the recorded data, the average monthly pollutants standard index (PSI) values of PM<sub>10</sub> were higher than standard limits, while the average monthly PSI value of NO<sub>2</sub> were lower than standard. There was no significant relationship between the number of those expired from cardiopulmonary disease and the air pollutant ( $P > 0.05$ ).

**Conclusions:** Air pollution can aggravate chronic cardiopulmonary disease. In the current study, one of the most important air pollutants in Shiraz was the PM<sub>10</sub> component. Mechanical processes, such as wind blowing from neighboring countries, is the most important parameter increasing PM<sub>10</sub> in Shiraz to alarming conditions. The average monthly variation in PSI values of air pollutants such as NO<sub>2</sub>, CO, and SO<sub>2</sub> were lower than standard limits. Moreover, there was no significant correlation between the average monthly variation in PSI of NO<sub>2</sub>, CO, PM<sub>10</sub>, and SO<sub>2</sub> and the number of those expired from cardiopulmonary disease in Shiraz.

**Keywords:** Air pollution, cardiopulmonary disease, Shiraz

## INTRODUCTION

Rapid expansions of cities along with fast economic growth and increasing energy consumption have caused numerous environmental problems for the residents.<sup>[1]</sup> One of the most important risks caused by recent developments that have endangered human life is environmental pollution. Urban air pollution has always been a serious threat to public health and the environment. Moreover, increasing the episodes of air pollution has made many more researches in this array.<sup>[2]</sup> Nowadays air pollution in many developing countries has deteriorated significantly due to rapid industrialization, urbanization, and motorization.<sup>[3,4]</sup>

In recent years, epidemiological studies showed that there is an association between air pollution and mortality.<sup>[5-8]</sup> In addition, the clinical and epidemiological evidence showed adverse effects of air pollution on the respiratory system.<sup>[9]</sup> Many studies have linked air pollution to adverse health effects such as respiratory illness, heart disease, asthma and cancer.<sup>[10]</sup> For instance, nitrogen dioxide increases airway irritability, decreased lung function and immune system.<sup>[2]</sup> Short-term effects of outdoor air pollutions include changes in lung function, respiratory symptoms and mortality due to respiratory causes. Long-term and cumulative effects of these pollutants are impaired lung growth, chronic obstructive pulmonary disease, lung cancer, asthma, and allergies.<sup>[10]</sup>

Epidemiological studies show that in recent decades, the increasing mortality associated with air pollution was not only due to respiratory diseases but is fundamentally linked to heart diseases.<sup>[11]</sup> In the past decade, epidemiologic studies demonstrated an increase in daily cardiovascular mortality and morbidity related to acute exposures to particulate air pollution.<sup>[7,12]</sup> In general, air pollution has an adverse effects on heart rate, blood pressure, blood clotting, and atherosclerosis.<sup>[13]</sup> The epidemiological studies showed the association between air pollution, especially  $PM_{10}$ , with disability and deaths from cardiovascular disease in North America and Europe.<sup>[3]</sup> The standard limit was established by the Environmental Protection Agency (EPA) for CO,  $PM_{10}$  and  $SO_2$ , being  $10 \text{ mg/m}^3$ , 50 and  $80 \text{ mg/L}$ , respectively.<sup>[14]</sup>

The association between high levels of air pollutants and human diseases has been

confirmed for over half a century. Air pollution is a heterogeneous mixture of compounds such as ozone, carbon monoxide, sulfur dioxide, nitrogen oxides, and particulate.<sup>[15]</sup> Masjedi *et al.* studied the correlation between major air pollutants and acute heart attacks in Tehran. According to their results, there was a relationship between the number of patients suffering from asthma and  $SO_2$  and  $NO_2$  concentration, but no significant relationship was found in other cases.<sup>[2]</sup> Another survey by Mohammadi demonstrated a main correlation between air pollutants in Tehran and the number of people who died because of cardiovascular disorders during 1999-2003.<sup>[16]</sup> Künzli *et al.* showed that air pollution causes more than 6% or approximately 40,000 deaths/year in Europe.<sup>[17]</sup> A study in Taiwan showed that levels of  $PM_{10}$ ,  $NO_2$ , CO, and  $O_3$  in ambient air were significantly associated with hospital admissions due to cardiovascular diseases on warm days, but on cool days all pollutants except  $O_3$  and  $SO_2$  were significantly associated with the admissions. The results of this study also showed that higher levels of ambient pollutants increase the risk of hospital admissions for cardiovascular diseases.<sup>[18]</sup>

Shiraz is the third largest city of Iran (in terms of the area) with particular geographical conditions (surrounded by mountains). It is affected by numerous air pollution sources such as industrialization and massive traffic congestion, therefore evaluating the correlation between its air pollution and human health is absolutely essential. The objectives of our study were to (i) determine the association between climate parameters with mortality rates due to cardiovascular-respiratory diseases in Shiraz, (ii) assess the effects of air pollution on the mortality rate and (iii) compare Shiraz pollutants standard index (PSI) with the value set by EPA and propose strategies for improving the air quality and preventing emergency condition.

## METHODS

This was an analytical-descriptive study conducted in Shiraz from March 2011 to January 2012. In our study, the correlation between major air pollutants including carbon monoxide (CO), sulfur dioxide ( $SO_2$ ), ozone ( $O_3$ ), and particle matter with diameters less than  $10 \mu$  ( $PM_{10}$ ) and

mortality rates due to the cardiopulmonary disease were evaluated. The survey was performed in three phases.

In the first phase, data regarding the concentration of pollutants CO, SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub>, and PM<sub>10</sub> [Table 1] were measured daily at two stations, i.e. Imam Hossein Square station and Sibviah Blvd. station by the Environmental Organization. The locations of these stations are shown in Figure 1. In order to measure the air pollutants, the Horiba Model (USA) was used. Hourly air sampling was done 24 h/day and a 24-h mean concentration was used. Since data regarding Sibviah Blvd. station was not recorded regularly, information regarding this station was not used.

In the second phase, data regarding climatic parameters (temperature and relative humidity)



**Figure 1:** Location of stations used for collecting air pollutant samples in Shiraz

was collected from the database of Iran's Meteorological Organization<sup>[19]</sup> [Table 1]. In the third phase, data of deaths from cardiovascular and respiratory diseases were provided by the Department of Health, Shiraz University of Medical Sciences [Table 2].

Air Quality Index (AQI) is used for reporting daily air quality. AQI measured the concentration of air pollution and determined the associated health effect. AQI was used for five major pollutants recommended by clean air act. These pollutants include ozone, particulate matter of air, carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these air pollutants, the standards were set to protect the health of people and decrease the adverse effects of air pollution. An AQI range from 0 to 500 and higher than 100 is recorded as unhealthy. Data collected by Shiraz Environmental Agency is reported by PSI index. Since the difference between PSI index and AQI was not significant, PSI was used in the current study. The following formula was used to calculate PSI:

$$I_p = \frac{I_{Hi} - I_{Lo}}{Bp_{Hi} - Bp_{Lo}} (Cp - Bp_{Lo}) + I_{Lo} \quad [20]$$

$I_p$  = The index for pollutant P

$C_p$  = The rounded concentration of pollutant P

$Bp_{Hi}$  = The breakpoint that is greater than or equal to  $C_p$

$Bp_{Lo}$  = The breakpoint that is less than or equal to  $C_p$

$I_{Hi}$  = The PSI value corresponding to  $Bp_{Hi}$

$I_{Lo}$  = The PSI value corresponding to  $Bp_{Lo}$ .

**Table 1:** The monthly variation of the concentration of air pollutants (CO, SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub>) and climatic parameters (temperature, relative humidity) in Shiraz from March 2011 to January 2012

Month	CO (ppm)	PM <sub>10</sub> (ug/m <sup>3</sup> )	NO <sub>2</sub> (ppm)	SO <sub>2</sub> (ppm)	Temperature (°C)	Relative humidity (%)
March	2.08	68.5	0.017	0.004	15.5	44
April	1.66	76.43	0.016	0.002	22.1	34
May	1.48	103.32	0.015	0.003	27.35	21.5
June	1.58	106.51	0.015	0.004	29.3	24.5
July	1.42	141.45	0.015	0.004	29.45	24
August	1.4	131.54	0.017	0.005	25.85	28.5
September	1.35	132.54	0.018	0.006	21.1	30.5
October	1.55	129.28	0.016	0.005	7.45	57
November	1.53	116.03	0.013	0.005	7.25	56.5
December	1.79	79.55	0.015	0.003	6.65	54.5
January	2.38	95.04	0.017	0.006	9.2	40.5

CO=Carbon monoxide, PM=Particulate matter, NO<sub>2</sub>=Nitrogen dioxide, SO<sub>2</sub>=Sulfur dioxide

**Table 2:** The monthly variation of the number of those expired from cardiovascular and respiratory diseases in Shiraz in March 2011 till January 2012

Month	The number of those expired from cardiovascular diseases	The number of those expired from respiratory diseases
March	223	38
April	254	28
May	215	20
June	239	36
July	222	39
August	215	16
September	225	29
October	289	37
November	254	46
December	172	32
January	218	37

### Statistical analysis

We used Excel 2007 and SPSS 11.5 Version 20.0. Armonk, NY: IBM Corp. The Kendall test was used to analyze the relationship between the impacts of air pollutants on the mortality rates due to cardiopulmonary diseases. Repeated measures analysis of variance (test) was also used to compare the various air pollution indices for the time period. The *post-hoc* tests, least significant difference was used when the differences was significant.

## RESULTS

Figure 2 shows the monthly variation of PSI values of CO in Shiraz from March 2011 to January 2012. The maximum and minimum PSI values of CO in March and October were 23.64 and 15.40, respectively. The amount of monthly PSI values of carbon monoxide in March was significantly different compared with other months. Figure 3 shows the monthly variation of PSI values of SO<sub>2</sub> and the maximum and minimum PSI values for sulfur dioxide were 9.06 and 2.94 in March and May, respectively. The average PSI value of SO<sub>2</sub> in May had a significant difference compared with other months ( $P < 0.05$ ). Figure 4 shows the monthly variation of PSI value of NO<sub>2</sub> and the maximum and minimum PSI values for nitrogen dioxide were 16.68 and 12.69 in October and January, respectively. The average PSI value of NO<sub>2</sub> in January was significantly different from the other months as well ( $P < 0.05$ ). Figure 5 shows

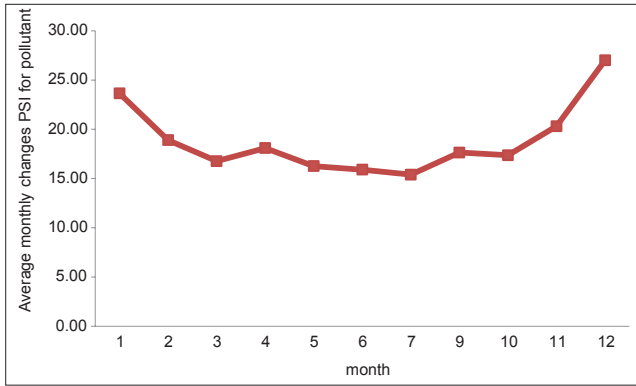
the monthly variation of PSI values of PM<sub>10</sub> and the maximum and minimum PSI value PM<sub>10</sub> were 99.04 and 56.31 in August and April, respectively. The average monthly of PSI value of PM<sub>10</sub> was higher than standard limits (0-50). The average monthly of PSI values of CO, SO<sub>2</sub>, and NO<sub>2</sub> was lower than standard limits (0-50).

Minimum temperature and humidity in Shiraz from March 2011 to January 2012 were in January and June, respectively, and the maximum temperature and humidity were in July and December, respectively. Based on the data obtained in the present study, the relationships between the average temperature and relative humidity and the mortality rate of cardiovascular and respiratory diseases were not statistically significant ( $P > 0.05$ ).

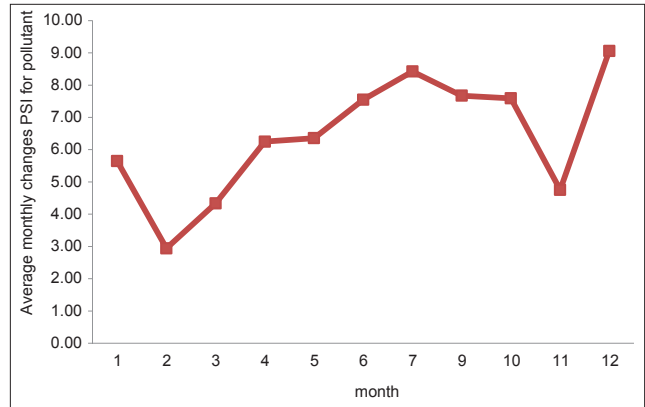
Cardiovascular disease is the leading cause of death in Iran. Latest available data from March 2011 to January 2012 shows that 2640 people in Shiraz died from cardiovascular disease and among them 48.1% were female and 51.9% male, respectively. From March 2011 to January 2012, 5.8% of deaths due to cardiovascular disease occurred before the age of 50 and 94.2% were older than 50 years. The highest and lowest rates of mortality due to cardiovascular disease was in December (10.9%) and November (4.3%), respectively. The correlation between the average monthly PSI value of air pollutants SO<sub>2</sub>, CO, PM<sub>10</sub>, and NO<sub>2</sub> with mortality from cardiovascular disease was not statistically significant as well ( $P > 0.05$ ).

Among the 387 people who died from respiratory disease, males (59.9%) were more than females (40.1%). The average age of death due to respiratory disease was 68. The highest and lowest mortality rates due to respiratory diseases were in January (11.9%) and September (4.1%), respectively. The results demonstrated that there was no correlation between the average monthly rate of PSI value of SO<sub>2</sub>, CO, PM<sub>10</sub>, and NO<sub>2</sub> and mortality from respiratory disease ( $P > 0.05$ ).

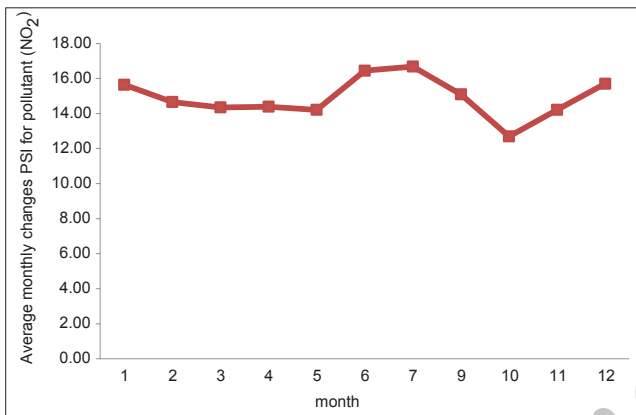
The average monthly PSI of PM<sub>10</sub> showed that the highest concentration of the pollutant occurred in August and the highest mortality rate due to respiratory diseases was in January. Statistical analysis showed that there was no significant correlation between deaths due to cardiovascular diseases and SO<sub>2</sub>, CO, PM<sub>10</sub>, and NO<sub>2</sub> emissions ( $P > 0.05$ ). In addition, there was no significant correlation between deaths from respiratory disease and SO<sub>2</sub>, CO, PM<sub>10</sub>, and NO<sub>2</sub> emissions ( $P > 0.05$ ).



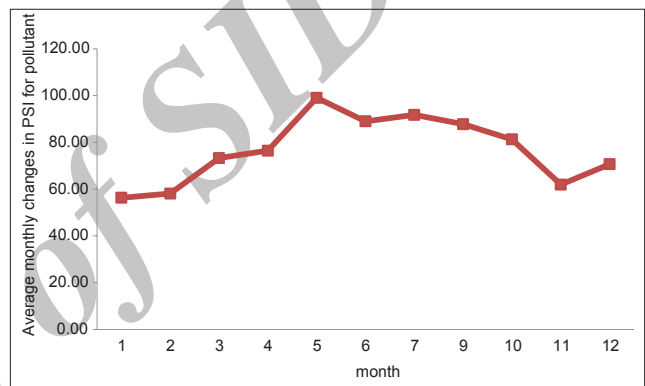
**Figure 2:** The monthly variation of pollutants standard index value of CO in Shiraz from March 2011 to January 2012



**Figure 3:** The monthly variation of pollutants standard index value of SO<sub>2</sub> in Shiraz from March 2011 to January 2012



**Figure 4:** The monthly variation of pollutants standard index values of NO<sub>2</sub> in Shiraz from March 2011 to January 2012



**Figure 5:** The monthly variation of pollutants standard index value of PM<sub>10</sub> in Shiraz from March 2011 to January 2012

## DISCUSSION

According to the results, it can be concluded that the most important air pollutant in Shiraz is PM<sub>10</sub>. PM<sub>10</sub> is produced by fossil fuels by stationary and mobile sources near urban areas. High concentrations of PM<sub>10</sub> are observed near industrial areas, roadways, and coal-fired power plants.<sup>[21-23]</sup> These particulates are also produced by natural and man-made processes, being mainly produced by industrial and mechanical processes.<sup>[22]</sup>

The monthly average of PSI value of pollutants NO<sub>2</sub>, CO and SO<sub>2</sub> in Shiraz was lower than the standard limit. Many studies in Tehran demonstrated that the air pollutants such as SO<sub>2</sub>, NO<sub>2</sub> and CO were the main cause of death from cardiovascular disease.<sup>[16]</sup> Masjedi *et al.* indicated that there was a significant relationship between levels of SO<sub>2</sub> and NO<sub>2</sub> in the air and the rate of asthma attacks recorded in Tehran.<sup>[2]</sup>

Zalghi *et al.* showed that the number of deaths occurring due to PM<sub>10</sub> in Ahwaz was 17.5%, which was actually 5.5% higher than 2009.<sup>[24]</sup> Another survey carried out by Chen *et al.* in Australia revealed that the most important causes of hospital admission due to respiratory disease were particle matter and Ozone.<sup>[25]</sup> Zhong *et al.* also showed that the major causes of hospital admission of children with asthma attack was Ozone and PM<sub>2.5</sub>.<sup>[26]</sup>

The results of the study carried out by Dehghani *et al.* in Shiraz in 2008 showed that there was a significant correlation between the average monthly variation of PSI value of sulfur dioxide and cardiovascular diseases. However, a significant correlation was not observed between the average monthly variation of PSI value of CO and cardiovascular diseases, and SO<sub>2</sub> was the main air pollutant in Shiraz.<sup>[27]</sup> However, based on data obtained in this study a significant correlation was not observed between the average monthly value of PSI of sulfur dioxide pollutant and

cardiovascular disease in Shiraz. This study also did not show a significant correlation between the average monthly variation of PSI value of CO and cardiovascular disease as well and PM<sub>10</sub> was the main air pollutant in the current study. Basically, it was expected to find a correlation between monthly variation of PSI value of CO and the mortality rate due to cardiopulmonary disease, but such a relationship was not found. This might have been caused by a lack of information due to the fact that air pollutants were only monitored in two stations and data were not recorded on some days.

### Study limitations and strengths

The main limitation of the current study is its cross-sectional nature, thus the associations documented in this study should be considered with caution.

## CONCLUSIONS

Cardiovascular diseases are caused by several factors such as age, family history, physical inactivity, overweight, smoking, high cholesterol level, high blood pressure, and unhealthy diets. Air pollution is the other important cause that can aggravate chronic heart and lung diseases. According to the results obtained in this study, PM<sub>10</sub> is the most important component of local air pollution in Shiraz. Mechanical processes such as wind blowing from neighboring countries is the most important parameter increasing PM<sub>10</sub> in Shiraz to alarming conditions. Average monthly variation of the PSI values of air pollutants such as NO<sub>2</sub>, CO and SO<sub>2</sub> are lower than standard limits. Moreover, there was no significant correlation between the average monthly variation of PSI of NO<sub>2</sub>, CO, PM<sub>10</sub> and SO<sub>2</sub> and cardiovascular and respiratory diseases in Shiraz.

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