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Prediction of the Impact of Air Pollution on Rates of Hospitalization for Asthma in Shiraz Based on Air Pollution Indices in 2007-2012

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Abstract

Objectives: This study was designed to determine the effects of air pollutants on emergency admissions for asthma, and to forecast the disease burden in Shiraz, Iran. Methods: The average daily concentrations of fine particles (PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3) were calculated from data reported by two air quality monitoring stations in Shiraz from the beginning of 2007 to mid-2012. Results: The numbers of patients admitted with asthma attack during this period were collected from four main university-affiliated hospitals. Admissions were correlated strongly with the levels of PM_{10}, SO_2, CO and O_3 during warm seasons ($P < 0.001$), and with NO_2 level during cold seasons ($P < 0.001$). We forecast increasing trends in air pollutants and patient admissions in the year 2015. Conclusion: Our findings are further evidence of the effects of air pollutants on asthma exacerbations.

Keywords

Air Pollution, Asthma Attack, Iran, Carbon Monoxide, Nitrogen Dioxide, Sulfur Dioxide, Ozone, Particulate Matter

1. Introduction

Asthma is a chronic respiratory disease that worsens with exposure to allergens, viral respiratory infections and

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air pollutants [1]-[3]. Numerous epidemiologic studies emphasis that air pollutants are important factors in exacerbations and hospital admissions for asthma [4]-[6]. Outdoor air contaminants consist of primary pollutants emitted directly into the atmosphere, such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter (PM), along with secondary pollutants that form in the air as a result of chemical reactions with other pollutants and gases such as ozone (O_3), nitrogen oxide species and some particles [7]. Air pollutants can be produced from point or mobile sources. Point sources emit pollutants into the air from a fixed location such as power plants, chemical plants and other industrial facilities. Mobile sources include cars, trucks and vehicles [8].

Shiraz, the capital of Fars province, has a total area 240 km^2 and a population of around 1.5 million (in 2012), making it the fifth largest city in Iran. It is located in the Zagros Mountain range in southwestern Iran at an elevation of 1486 meters above sea level. The city has a temperate climate with four distinct seasons and an average annual rainfall of about 300 mm. Industrial activities in the city include an oil refinery, a thermal power plant and a cement factory. In addition to air pollution, this city is influenced by meteorological phenomena characteristic of the Middle East, such as dust storms originating from Iraq in warm seasons.

Although air pollution is an important public health problem in large cities in Iran, few studies have centered on the effects of air pollutants on asthma admission rates. The purposes of this study were to investigate the association between air pollution and admission rates of patients with asthma attacks from 2007 to 2012, and to predictthe future asthma disease burden in Shiraz.

2. Methods

2.1. Data Collection

To retrieve the medical records of patients admitted with asthma attack, we reviewed the admissions lists of four main university-affiliated hospitals (Namazee, Faghihi, Dastghaib and Aliasghar Hospital) in Shiraz from the beginning of 2007 to mid-2012. In addition to demographic information, the date of admission and duration of the hospital stay were extracted from their files.

Data on the daily levels of PM_{10}, SO_2, NO_2, CO and O_3 were obtained from two Environmental Protection Department automatic air quality monitoring stations located near the city center and in the northern part of Shiraz. The period from April to September was considered to comprise the warm seasons, and the period October to March was considered the cold seasons.

2.2. Statistical Analysis

The average daily concentration of each pollutant was calculated from data reported by the two monitoring stations. The associations between daily, monthly, seasonal and annual mean levels of PM_{10}, SO_2, NO_2, CO and O_3 and the number of patients admitted due to asthma attack were determined by calculating Pearson correlation coefficients for each interval during the 5.5-year study period. All statistical analyses were done with SPSS version 19.0 (SPSS Inc., Chicago, IL, USA), and two-tailed P values less than 0.05 were considered statistically significant. An autoregressive integrated moving average (ARIMA) model was used to forecast monthly admission rates to 2015 of patients with asthma in relation to each of the five air pollutants studied here.

3. Results and Discussion

During the 5.5-year study period, 1939 patients (931 males and 1008 females, age range 2 to 106 years, mean age 44.22 ± 26.16 years) were admitted for asthma exacerbation to one of the four participating hospitals. About one fifth of the patients (416, 21.5%) were younger than 18 years, and 457 (23.5%) were older than 65 years. The number of daily admissions varied from zero to 13. The patients were hospitalized for periods ranging from 1 day to 1 month (average 4.7 days). **Table 1** shows the annual mean concentrations of five major air pollutants and the number of patients admitted for asthma attack. Monthly variations in air pollutant levels and the numbers of patients admitted are shown in **Figure 1**. The monthly mean concentrations of SO_2, NO_2 and O_3 correlated with admission rates during the study period ($P < 0.001$). The levels of PM_{10}, SO_2, CO and O_3 correlated strongly with admissions during the warm seasons ($P < 0.001$), whereas NO_2 levels correlated with patient admissions during the cold seasons ($P < 0.001$).

There is growing epidemiological evidence of associations between air pollution and respiratory disorders in

Table 1. Annual concentrations of five major air pollutants and their correlations with daily admissions of patients for asthma attack.

O_3 (ppm)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	PM_{10} (μg/m^3)	Year
					2007
0.010 ± 0.006	5.343 ± 1.482	0.026 ± 0.005	0.183 ± 0.031	89.218 ± 47.48	Mean ± SD
0.001	1.617	0.013	0.129	13.1	Min
0.033	9.063	0.043	0.254	331.3	Max
0.085	2.01	0.006	0.051	50.36	Interquartile range
218	218	218	218	218	Annual admissions
0.06	0.32	0.06	0.13	0.01	P-value
					2008
0.010 ± 0.006	4.338 ± 1.087	0.022 ± 0.004	0.232 ± 0.057	102.66 ± 97.50	Mean ± SD
0.001	1.482	0.002	0.148	21.29	Min
0.07	8.134	0.034	0.393	966.5	Max
0.008	1.477	0.007	0.108	55.17	Interquartile range
417	417	417	417	417	Annual admissions
0.00	0.20	0.01	0.001	0.06	P-value
					2009
0.013 ± 0.007	1.189 ± 0.862	0.026 ± 0.007	0.057 ± 0.092	115.68 ± 86.00	Mean ± SD
0.003	1.189	0.005	0.005	23.97	Min
0.099	5.731	0.074	0.36	980	Max
0.01	0.726	0.008	0.01	96.49	Interquartile range
360	366	360	366	366	Annual admissions
0.005	0.03	0.35	0.07	0.4	P-value
					2010
0.015 ± 0.007	2.689 ± 1.007	0.046 ± 0.014	0.011 ± 0.003	96.70 ± 61.22	Mean ± SD
0.005	0.94	0.013	0.003	34	Min
0.061	6.60	0.082	0.022	698.6	Max
0.011	1.16	0.018	0.004	96.49	Interquartile range
338	338	338	338	338	Annual admissions
0.00	0.00	0.003	0.12	0.28	P-value
					2011
0.026 ± 0.012	1.747 ± 0.681	0.018 ± 0.009	0.005 ± 0.003	109.812 ± 52.747	Mean ± SD
0.006	0.403	0.004	0.001	18	Min
0.077	5.12	0.073	0.016	425.5	Max
0.014	0.073	0.005	0.004	50.11	Interquartile range
454	454	454	454	454	Annual admissions
0.01	0.12	0.21	0.38	0.33	P-value
					first 6 months of 2012
0.031 ± 0.010	1.447 ± 0.455	0.014 ± 0.002	0.003 ± 0.002	148.329 ± 180.02	Mean ± SD
0.015	0.371	0.008	0.001	24.74	Min
0.061	2.674	0.018	0.009	1901	Max
0.014	0.69	0.003	0.002	81.90	Interquartile range
163	163	163	163	163	Annual admissions
0.09	0.23	0.36	0.21	0.11	P-value
					2007 till mid-2012
0.01 ± 0.01	3.25 ± 1.67	0.026 ± 0.01	0.092 ± 0.1	106.86 ± 88.62	Mean ± SD
0.001	0.37	.002	0.001	13.10	Min
0.099	9.06	0.082	0.393	1901	Max
0.013	2.48	0.004	0.17	60.59	Interquartile range
1939	1939	1939	1939	1939	Total admissions
0.03	0.06	0.00	0.005	0.06	P-value

PM_{10}, particulate matter ≤10 µm in diameter; SO_2, sulfur dioxide; NO_2, nitrogen dioxide; CO, carbon monoxide; O_3, ozone. *, significant correlation (2-tailed P-value < 0.05).

developing countries [9]. We found positive associations between outdoor levels of NO_2, SO_2 and O_3 and monthly admission rates of patients with asthma attacks in Shiraz.

The possible effects of NO_2 in the air include increased sensitivity to respiratory viral infections and enhanced reactions to allergens (e.g., house dust mites), which exacerbates asthma and reduces lung function in children [10]-[12]. The results of our findings on the adverse effects of NO_2 for patients in Shiraz are consistent with

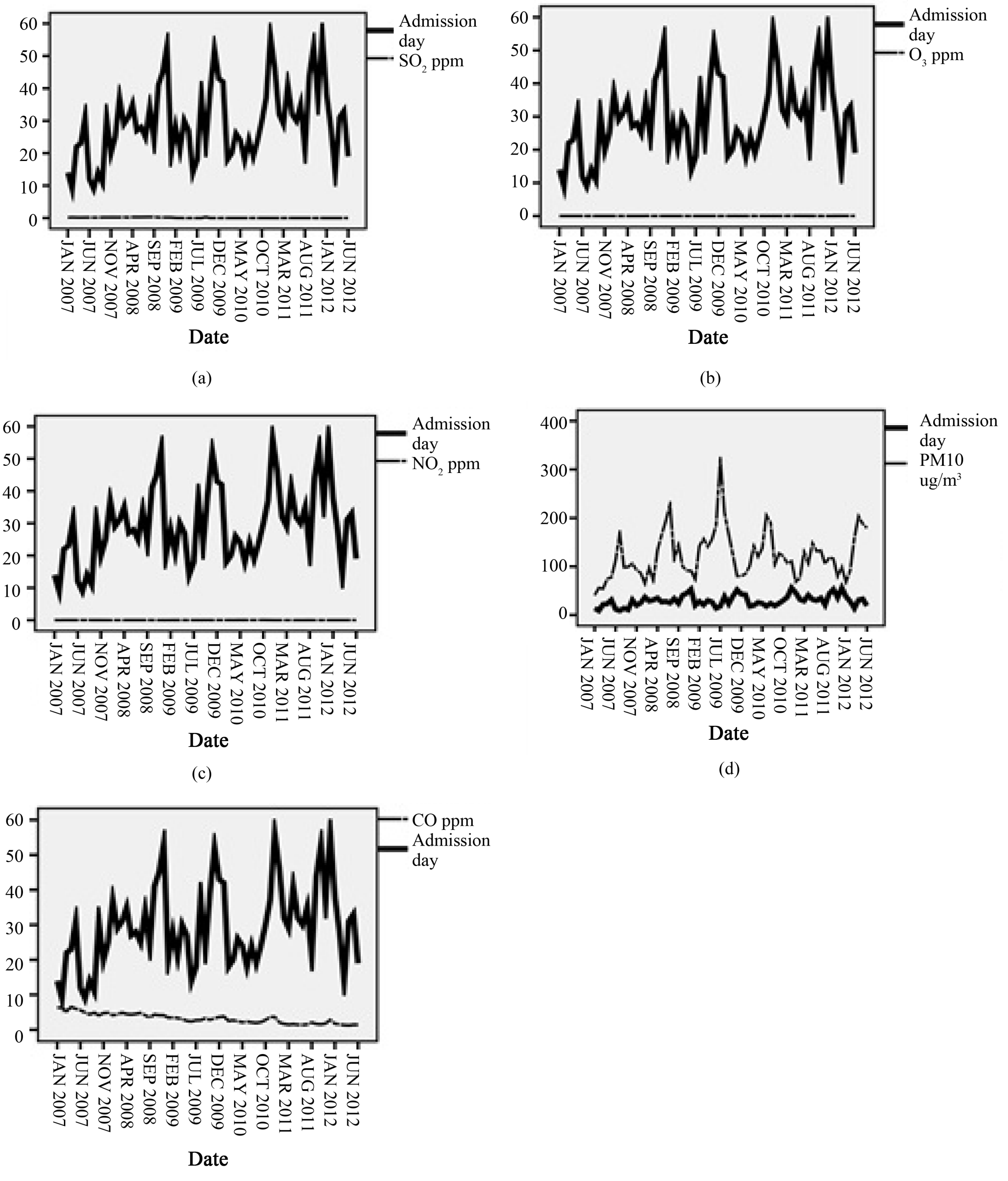

Figure 1. Correlation of monthly mean air pollutant levels and number of hospital admissions of patients for asthma attack.

other studies in Iran [3] [13].

Ozone is an air pollutant related to sunlight. Because of the warm climate in our area, O_3 concentration is high. Prolonged lung injury, oxidative stress, macrophage accumulation and extensive abnormal lung function have been reported in mice that inhaled O_3 [14]. The results of a similar study in humans also indicated airway disruption and susceptibility to influenza infections [15]. In agreement with most epidemiologic studies especially from North America and Europe, exposure to O_3 exacerbates asthma [16] [17].

Coal is still used as the main source of energy in some parts of Asia. The burning of coal emits a considerable amount of SO_2 which increases bronchoconstriction in patients with asthma. We found a positive relationship between SO_2 level and hospital admissions for asthma attack, which is in consistent with other reports from Iran and Turkey [3] [13] [18].

Among air pollutants, particulate matter has the greatest effects on human health [19]. However, in contrast to the results of similar studies in Tabriz and Tehran [19] [20], we found no significant association between PM_{10} levels and monthly admissions for asthma. The deposition of PM in the respiratory tract depends on the size of the particles as a strong correlation has been shown between $PM_{2.5}$ and asthma morbidity [21].

Carbon monoxide, a marker of vehicle traffic, is a product of incomplete combustion of carbon-containing fuel. During the period covered by our study there were no reports of CO levels ≥ 9 ppm, the level considered toxic according to National Ambient Air Quality Standards (NAAQS) [22]. Our data showed no association between monthly concentrations of CO and exacerbations of asthma.

An analysis of the relationship between seasonal variations in asthma incidence and air pollutants in Taiwan showed strong associations with PM_{10}, O_3 and SO_2 in children [23]. Our findings showed that the effect of PM_{10}, SO_2, CO and O_3 on the rates of hospitalization of patients with asthma was higher during warm seasons. This may be a result of people spending more time outdoors and leaving windows open during the warm seasons, which can increase the exposure to O_3 and other pollutants. We speculate that dust storms from neighboring countries also exacerbate asthma during warm seasons in our region.

Admission rates for patients with asthma are usually higher during cold seasons, which may be explained by the exacerbations of asthma after viral infections [2]. According to our results, only NO_2 levels showed a greater association with the rates of admission of patients with asthma during the cold seasons than the warm seasons, a finding in line with the results reported by Castellsague *et al*. [24].

The stationary R-squared value and goodness-of-fit for the ARIMA model to predict monthly admissions were 0.523 and 0.62, respectively. Based on our data, we predicted an increasing trend in monthly mean levels of air pollutants and numbers of patient admissions to 2015 (**Figure 2**).

Many studies suggest that the prevalence of asthma has reached a plateau or may be declining in developed countries, whereas it continues to increase in Asian countries. A factor that may be related to these opposing trends is that economic development in Asia is supported by the increased use of fossil fuels–which contribute to air pollution–as energy sources. On the basis of our data, we predicate that air pollution and asthma admission rates will be a major problem in 2015 in our region.

In this study we did not measure temperature, humidity and indoor allergens, all of which, along with air pollution, can affect asthma exacerbations. We recorded admission rates of patients with asthma at university hospitals only, and did not obtain data from private clinics and hospitals that also manage patients with asthma attacks in our region. Generally, different air pollutants interact with each other and an exact quantitation of each pollutant is rarely possible. The effect of air pollutants on asthma is likely to be a chronic process, and delayed

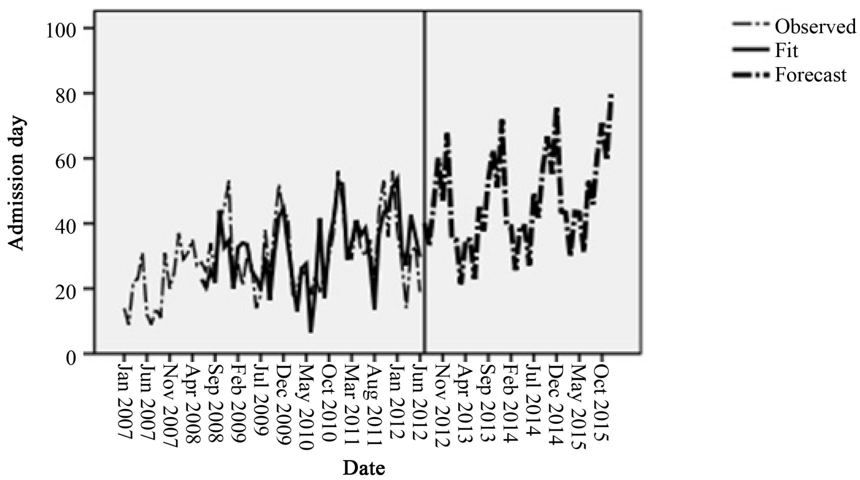

Figure 2. Forecast through 2015 of the trend in hospital admissions for asthma based on monthly mean levels of air pollutants.

outcomes may appear long after exposure. Another potential limitation of this study is that we did not obtain follow-up data for our sample of patients later than mid-2012. We were not able to measure the concentration of $PM_{2.5}$, and cannot speculate on the possible relationship between the levels of particles smaller than PM_{10} and hospital admissions for asthma in our setting.

4. Conclusion

Our results confirm the findings of previous studies of the effect of air pollution on asthma exacerbation. Further parallel studies are needed to evaluate the cumulative effects of meteorological factors, indoor allergen concentrations and outdoor air pollutants on asthma attack and admission rates. Because the prevention of asthma exacerbations is strongly preferable to emergency management, and because air pollution is a contributing factor, environmental protection measures aimed at controlling air pollution are advisable to prevent hospital admissions due to asthma attacks.

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