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Investigating the Health Effects of Exposure to Criteria Pollutants Using AirQ2.2.3 in Shiraz, Iran

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ABSTRACT

The quality of air is one of the main environmental issues related to human health. The aim of this study was to evaluate the effects of air pollution on the health of residents in Shiraz, as one of the major cities in Southern Iran, with population of 1500000 people. In this study, AirQ2.2.3 model developed by the WHO European Centre for Environment and Health was used. Daily concentration of particulate matter less than 10 microns in diameter (PM_{10}), sulfur dioxide, nitrogen dioxide and maximum 8-hour average ozone concentration were used to evaluate the health effects of human exposure to these pollutants. The total number of excess deaths, Cardiovascular Disease (CVD) mortality, mortality from respiratory diseases, hospital admissions for CVD and hospital admissions for respiratory disease (RD) were calculated. In 2012 and 2013, hospital admissions for respiratory disease for the WHO baseline incidence of PM_{10} were respectively 54.6% and 38.6% of the total hospital admissions for respiratory disease. That was the highest short-term health effects on 1500000 Shirazi residents. The assessments carried out indicated the possibility that CVD mortality can play a major role in mortality due to PM_{10}, SO_2 and O_3 pollutants.

Overall, the results showed that health effects resulting from exposure to pollutants are directly related to their concentration. Therefore, immediate action to prevent pollution and reduce emissions from various sources, such as transport and energy production industries, is required to reduce the concentration of pollutants in Shiraz.

***Keywords*:** AirQ; Particulate matter; Sulfur dioxide; Nitrogen dioxide; Ozone; Mortality.

INTRODUCTION

Understanding the health effects of air pollution in the cities of Europe and America has been associated with important incidents happened in this regard, including those in Meuse River Valley in Belgium, London and Donora, Pennsylvania that led to acute sickness and death of hundreds of thousands of people (Logan, 1956; Ciocco and Thompson, 1996; Nemery *et al.*, 2001). Nowadays, air pollution is one of the major environmental problems in many cities around the world and is the fourth leading cause of death in the world. According to WHO estimates, 800,000 people per year die worldwide due to respiratory and cardiovascular diseases associated with air pollution. Approximately 150,000 of these deaths occur in South Asia. Major sources of air pollution in urban areas include industrial compounds, power plant fuels, and cars (Smith, 1993; Brunekreef and Holgate, 2002). Air pollution is a mixture of particles and gases such as ozone, Carbon monoxide, nitrogen oxides and sulfur dioxide (Brook *et al.*, 2004; Pope and Dockery, 2006).

Results of short and long-term studies on the effects of air pollution have shown an increase in hospital admissions for cardiovascular and respiratory diseases, asthma attacks, mortality and reduced longevity. In fact, many time-series and case-crossover studies showed the role of air pollution in hospital admissions, sicknesses and deaths due to cardiovascular and respiratory diseases (Garcia *et al.*, 2000; Hoek *et al.*, 2001; Bateson andSchwartz, 2004; Hosseinpoor *et al.*, 2005; Dominici *et al.*, 2006; Qorbani *et al.*, 2012).

Dominici *et al.* (2006) studied fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. Gurjar *et al.* (2010) and Fattore *et al.* (2011) showed a relationship between air pollution with total mortality

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and hospital admissions for cardiovascular and respiratory diseases. Goldberg's epidemiological study in 2000 showed an association between air pollution and cardiovascular and respiratory diseases (Goldberg *et al.*, 2003).

Shiraz, the center of Fars province in southwestern Iran, is one of the seven megacities in the country with a population of over 1500000 people, an area of 1268 sq. km and an altitude of 1540 meters above the sea level; it is located in latitude 29/37 N and longitude 52/32 E. In recent decades, it has been exposed to high levels of air population due to increased urbanization and traffic as well as dust storms, which has worsened weather conditions. PM_{10}, SO_2, NO_2, HC, O_3 and CO are the main air pollutants in Shiraz. AirQ is an instrument for health impact assessment of air quality developed by World Health Organization (WHO) to assess the potential effects of human exposure to a particular contaminant in a given urban area and in a specific period of time (Naddafi *et al.*, 2012). In this study, AirQ model was used to investigate the short-term effects of air pollution on residents of Shiraz in 2012–2013. The baseline incidence (BI) was calculated and localized using local statistics and compared with the results of the WHO. This has rarely been done in similar studies.

MATERIALS AND METHODS

AirQ Software

The software tool for health impact assessment of air quality (AirQ2.2.3) was developed by the WHO European Centre for Environment and Health. This software calculates the potential effects of exposure to air pollutants on human health in a given place and duration. This assessment is based on attributable proportion (AP) that expresses the health impacts of exposure of a particular population to air pollutants and shows the relationship between exposure and health outcomes without confounding effects on this relationship. AP is calculated using the following formula (Krzyzanowski, 1997; Fattore *et al.*, 2011):

$$AP = SUM\{[RR(C) - 1]\cdot P(C)\}/SUM[RR(C)\cdot P(C)] \quad (1)$$

where AP is the attributable proportion of health outcomes, and RR(c) is relative risk of health outcome in the group (c) or exposed group. The RR of selective health outcome can be obtained using the exposure-response functions. P(c) is population ratio of group (c) or exposed group. Knowing the baseline incidence of the selected health outcomes, the amount attributable to the population exposure will be calculated as follows:

$$IE = I\cdot AP \quad (2)$$

where IE is incidence of exposure and I is the baseline incidence of health outcome in the population under the study. Finally, knowing the population size, the number of excess cases can be calculated as follows:

$$NE = IE\cdot N \quad (3)$$

where NE is the number of cases attributable to exposure and N is the size of the population studied.

Relative Risk and Baseline Incidence

Research in epidemiology has shown the increased relative risk of disease as a result of exposure to various pollutants (WHO, 2003). In Table 1, the relative risk (per 10 µg m^{-3} increase in the daily average of PM_{10}, SO_2 and NO_2 and the 8-hour moving average of O3) and the baseline incidence

Table 1. WHO default values for RR (per 10 µg m^{-3} increase in concentrations of PM_{10}, SO_2, NO_2 and O_3) and BI (per 100,000 people).

Health endpoint	Relative Risk (95% CI) per 10 µg m^{-3}				Baseline Incidence [a]	
	PM_{10}	SO_2	NO_2	O_3	WHO	Part I (Shiraz)
Total mortality	1.0074 (1.0062–1.0086)[b]	1.004 (1.003–1.0048)[b]	-	1.0051 (1.00023–1.0078)[c]	1013	454.3
Cardiovascular mortality	1.008 (1.005–1.018)[b]	1.008 (1.002–1.012)[b]	1.002 (1–1.004)[b]	1.004 (1–1.006)[b]	497	125.3
Respiratory mortality	1.012 (1.008–1.037)[b]	1.01 (1.006–1.014)[b]	-	1.0125 (1.0046–1.0208)[c]	66	32.3
HA[d] Cardiovascular Disease	1.008 (1.0048–1.0112)[b]	-	-	-	436	373.6
HA Respiratory Disease	1.009 (1.006–1.013)[b]	-	-	-	1260	156
HA Respiratory Disease 15–64 years	-	1.01 (1.006–1.014)[b]	1.002 (1–1.004)[b]	1.0062 (1.0026–1.0098)[c]	66	82.3
HA Respiratory Disease > 65 years	-	1.004 (1.001–1.009)[b]	1.0038 (1–1.012)[b]	1.0076 (1.0036–1.0116)[c]	-	52.8

[a] Crude rate per 100,000 inhabitants.
[b] Daily average.
[C] 8 h moving average.
[d] Hospital Admission.

(per 100,000) for total mortality, CVD and RD mortality, and hospital admissions for cardiovascular and respiratory diseases are shown. The relative risk and default baseline incidence was obtained from the WHO tool for health impact assessment of air quality (AirQ2.2.3) in various studies (WHO, 2000). Also, the table provides baseline incidence of total mortality and CVD and RD mortality for the study period as obtained from information contained in the registration office of Shiraz. The baseline incidence of hospital admissions for cardiovascular and respiratory diseases was obtained from the data provided by central emergency department of Shiraz as mentioned in part I.

Input Adjustment

Health impact assessment (HIA) with AirQ software requires concentration of pollutants in µg m^{-3}. Therefore, it is necessary to convert ppm or ppb units taken from monitoring stations into µg m^{-3}. To this end, a number of temperature and pressure corrections have to be done. The following equation is used to convert ppm in to µg m^{-3}:

$$C\ (\mu g\ m^{-3}) = C\ (ppm) \times MW/V \times 1000 \quad (4)$$

where C is the concentration of gas compounds, MW is the molecular weight of gas compounds and V is moles of pure gas at standard temperature and pressure (at 0°C and 1 atmosphere pressure). For non-standard temperature and pressure, an ideal gas equation should be used:

$$P_1V_1/T_1 = P_2V_2/T_2 \quad (5)$$

where P1, V1 and T1 are pressure, initial volume and absolute temperature respectively, and P2, V2 and T2 are pressure, final volume and absolute temperature, respectively.

Air Pollution Data

In this study, data were collected from two air pollution monitoring stations, i.e., Setad square and Darvaze Kazeroon operated by Shiraz Department of Environment (Fig. 1). Air pollution data included particulate matter with a diameter less than 10 micrometers (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) as 24-hour average and ozone (O_3) as 8-hour moving average.

Mortality and Morbidity

Data on daily total mortality and CVD and RD mortality were obtained from Civil Registration Office of Shiraz and the number of hospital admissions for cardiovascular and respiratory diseases was obtained from the Central Emergency Department of Shiraz.

Exposure Assessment

The required parameters for the software (annual and seasonal maximum and annual 98 percentile) were obtained for all pollutants and the pollutant concentrations were reported based on 10 µg m^{-3}. Data for PM_{10}, SO_2 and NO_2 was expressed as 24-hour average and that of O_3 was expressed as 8-hour moving average. The number of exposures was estimated for Shiraz with a population of 1500000 people.

RESULTS

Table 1 shows the WHO RR default values and the

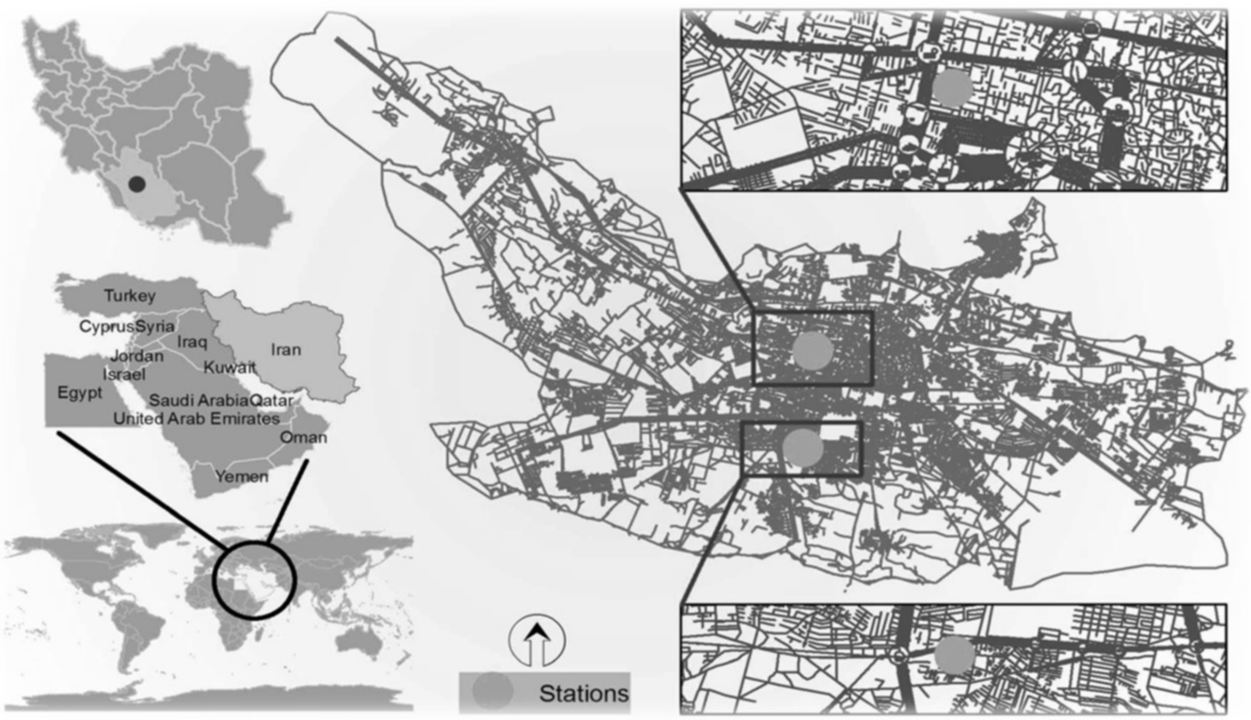

Fig. 1. Map of the study area and air quality monitoring stations.

estimated BI with 95% confidence interval in 10 µg increase of daily mean of PM_{10}, SO_2, and NO_2 pollutants as tabulated in relation to total mortality, CVD and RD mortality, hospital admission for cardiovascular diseases, hospital admission for respiratory diseases in the 15–64 age group and Hospital admissions for respiratory disease in ≥ 65 years group is shown with part I. Table 2 shows the air quality data for Shiraz during 2013–2012. The annual average PM_{10} concentrations in the 2012 and 2013 were 111.975 and 70.604 µg m^{-3}, respectively. Mean SO_2 in 2013 was 63.081 µg m^{-3}, which was higher than that of 2012. The maximum annual concentration of NO_2 was observed in 2012 and it was 27.3978 µg m^{-3}. The O_3 concentration in 2013 was 85.624 µg m^{-3}, which was more than that of 2012. The results indicated that the mean PM_{10} in 2012 and 2013 was 2.24 and 1.41 times the standard of the National Ambient Air Quality Standards (NAAQSs) respectively. According to Table 2, the maximum concentration of PM_{10} in 2012 was 960.885 µg m^{-3} whereas it was 192.495 µg m^{-3} in 2013. The maximum concentrations of SO_2, NO_2 and O_3 were 99.496, 43.322 and 105.564 µg m^{-3} in 2012 and about 138.902, 85.598 and 223.224 µg m^{-3} in 2013.

Fig. 2 shows the percentage of time people in Shiraz were exposed to different concentrations of pollutants during 2012 and 2013. The highest number of days of exposure to PM_{10} in 2012 and 2013 was observed in the concentration category of 80–89 and 60–69 µg m^{-3} which was higher than NAAQSs published standards for annual mean PM_{10}. Also, the highest numbers of days of exposure to SO_2, NO_2 and O_3 concentrations were in the concentration range of 60–69, 30–39 and 69–60 µg m^{-3} in 2012 and in the range of 20–29, 20–29 and 70–79 µg m^{-3} in 2013.

Table 3 shows the short-term health effects of exposure to PM_{10}, SO_2, NO_2 and O_3 on total mortality, CVD and RD mortality, hospital admission for cardiovascular diseases, and hospital admission for respiratory diseases, hospital admissions for respiratory disease in 15–64 age group and hospital admissions for respiratory disease in ≥ 65 years group based on a combination of RR and BI of WHO (default values) and the BI rate of part I for the reference 10 µg m^{-3}. According to this table, the total excess mortality associated with PM_{10}, SO_2 and O_3 for the WHO incidence rate was about 1028, 231 and 290 cases in 2012 and about 652, 316 and 563 cases in 2013. For part I, it was 473, 106 and 133 cases in 2012 and 285, 138 and 246 cases in 2013. In 2012 and 2013, hospital admissions for respiratory disease for the WHO baseline incidence of PM_{10} were respectively 54.6% and 38.6% of the total hospital admissions for respiratory disease. There were no default WHO BI values for hospital admissions for respiratory disease ≥ 65 years for SO_2, NO_2 and O_3 in AirQ2.2.3. Thus, the excess number was estimated based on the BI value for part I. The results showed that the highest number of ≥ 65 hospital admissions in 2013 belonged to SO_2 and O_3 with 15 and 39 cases and in 2012, O_3 with 24 cases.

DISCUSSION AND CONCLUSION

This article presents a case study using the WHO method for assessing the health impacts of atmospheric pollution on the residents of Shiraz as one of seven polluted megacities in Iran. Attempt was made to apply AirQ model to quantify the effects of short-term exposure to PM_{10}, SO_2, NO_2 and O_3 on health impacts including total mortality, and hospital admissions for CVD and RD in 2012 and 2013. Excess cases per 10 µg m^{-3} increase in pollutants for the mentioned health impacts were estimated and compared with air standards.

In this study, the BI rate for part I (Shiraz) per 100,000 people for total mortality, CVD mortality, RD mortality, hospital admission for cardiovascular diseases, hospital admission for respiratory diseases, and hospital admissions for respiratory disease in the 15–64 age group were about 0.45, 0.25, 0.49, 0.85, 0.12 and 1.12 times the incidence rate of WHO. These health impacts of hospital admissions for respiratory disease in the ≥ 65 age group was calculated based on the BI rate for local statistics due to lack of WHO BI default values. Based on the results, health effects resulting from exposure to pollutants in 2012 and 2013 are significantly related to the concentration of those pollutants. In this study, with a decrease in PM_{10} and NO_2 concentrations in 2013 compared to 2012 (Table 2), the studied health impacts in 2013 (Table 3) decreased. By an increase in the concentration of SO_2 and O_3 (Table 2) in 2013, the health impacts of these pollutants in 2013 (Table 3) increased. According to Table 3, PM_{10} had the highest short-term health impacts on the population of 1,500,000 people in Shiraz. The hospital admissions for respiratory disease due to PM_{10} in 2012 and 2013 were 56.6% and 38.6% of total hospital admissions for respiratory disease for WHO incidence rate. These values were 7.2% and 12.4% of the total cases for the incidence rate of Part I (Shiraz). Given the results for CVD and RD mortality associated with PM_{10}, SO_2 and O_3, it can be concluded that the CVD deaths play the main role in the mortality due to these pollutants.

Table 2. Summary of concentrations of air pollutants and meteorological changes in Shiraz during 2012 and 2013.

Pollutant	Unit	Average		Minimum		Maximum		Percentile 98	
		Year		Year		Year		Year	
		2012	2013	2012	2013	2012	2013	2012	2013
PM_{10}[a]	µg m^{-3}	111.975	70.604	28.910	23.915	960.885	192.495	489.470	151.972
SO_2[a]	µg m^{-3}	48.319	63.081	4.480	3.498	99.496	138.902	84.613	125.563
NO_2[a]	µg m^{-3}	27.978	23.321	1.538	0.837	43.322	85.598	40.620	44.201
O_3[b]	µg m^{-3}	48.359	85.624	3.478	8.755	105.564	223.224	88.496	162.224

[a] Annual 24 hr.
[b] Annual 8 hr.

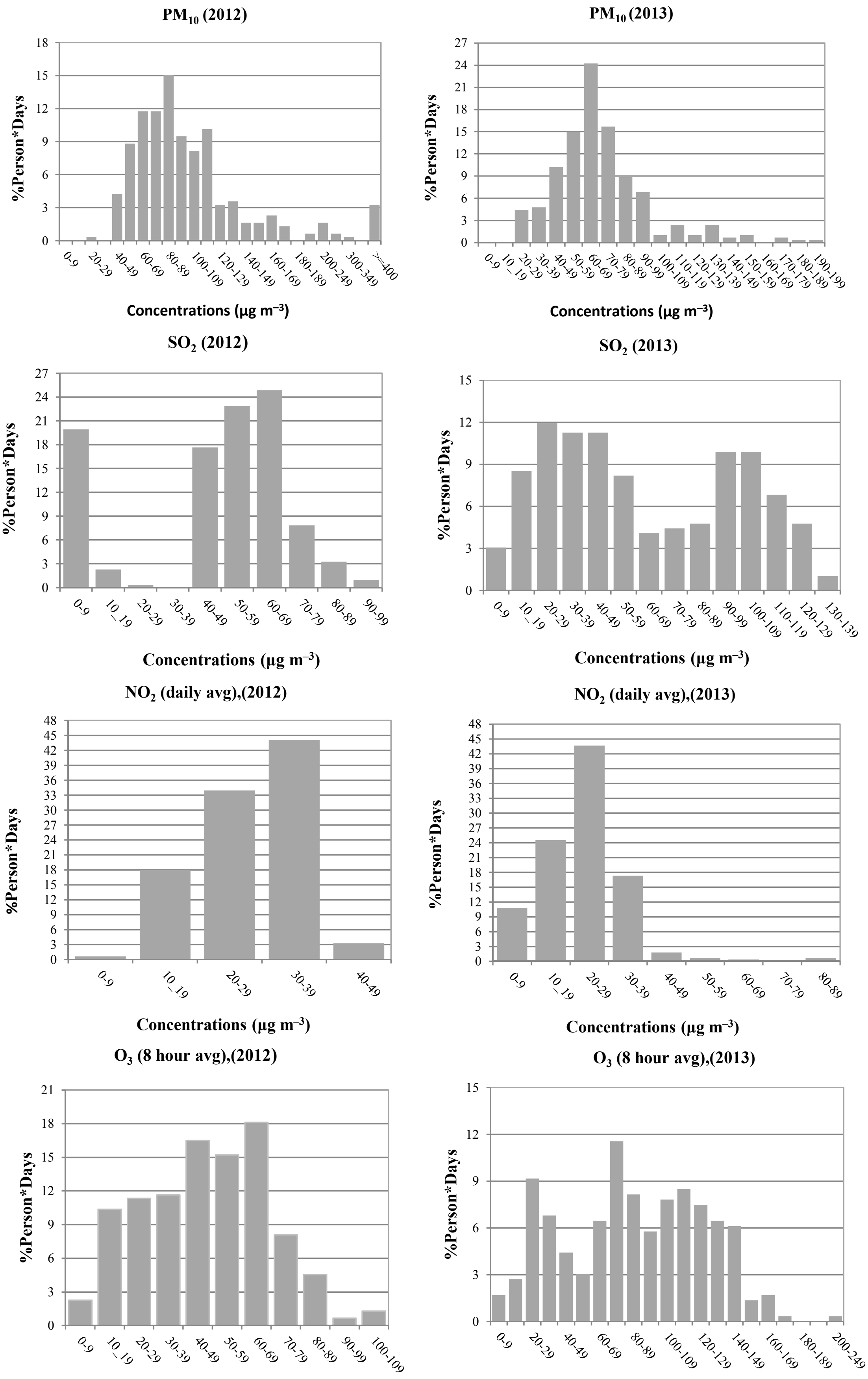

Fig. 2. Percentage of days that people in Shiraz were exposed to different concentrations of pollutants.

Table 3. Estimated number of excess cases attributable to the incidence rate of WHO and attributable to short-term effects of 10 μg m^{-3} increase in the concentration of PM_{10}, SO_2, NO_2 and O_3.

	No. of excess cases (uncertainty range) 2012		No. of excess cases (uncertainty range) 2013	
	WHO BI	Part I BI	WHO BI	Part I BI
Total mortality				
PM_{10}	1028.5 (871.2–1182.3)	472.9 (400.6–543.6)	652.1 (550.2–752.6)	285.1 (240.5–329.0)
SO_2	231.5 (174.3–276.9)	106.4 (80.1–127.3)	316.3 (238.4–377.9)	138.3 (104.2–165.2)
O_3	290.0 (11.6–439.2)	133.4 (5.3–201.9)	563.6 (22.9–845.4)	246.4 (10.0–369.6)
Cardiovascular mortality				
PM_{10}	542.5 (348.6–1118.2)	139.8 (89.8–288.4)	344.7 (219.2–733.2)	84.8 (53.9–180.4)
SO_2	223.7 (57.2–330.7)	57.7 (14.7–85.2)	304.0 (78.4–446.9)	74.8 (19.3–110.0)
NO_2	27.0 (0.0–53.8)	7.0 (0.0–13.9)	20.5 (0.0–41.0)	5.1 (0.0–10.1)
O_3	112.1 (0.0–166.8)	28.9 (0.0–43.0)	218.6 (0.0–323.2)	53.8 (0.0–79.5)
Respiratory mortality				
PM_{10}	104.3 (72.0–263.7)	53.7 (37.1–135.8)	67.1 (45.8–181.3)	31.1 (21.2–84.1)
SO_2	36.9 (22.5–50.9)	19.0 (11.6–26.2)	50.0 (30.6–68.6)	23.2 (14.2–31.8)
O3	45.1 (17.1–72.8)	23.2 (8.8–37.5)	85.4 (33.2–134.4)	39.6 (15.4–62.3)
HA Cardiovascular Disease				
PM_{10}	530.6 (363.6–739.7)	486.6 (333.4–678.4)	338.2 (229.4–447.6)	100.2 (61.2–137.7)
HA Respiratory Disease				
PM_{10}	1375.4 (850.0–1871.1)	183.0 (113.1–249.0)	837.9 (534.2–1201.2)	269.5 (182.8–380.5)
HA Respiratory Disease 15–64 years				
SO_2	6.8 (0.0–18.8)	9.4 (0.0–25.7)	9.4 (0.0–25.6)	10.6 (0.0–28.8)
NO_2	3.6 (0.0–12.8)	4.9 (0.0–17.5)	2.7 (0.0–9.7)	3.1 (0.0–11.0)
O_3	22.9 (9.7–35.7)	31.3 (13.3–48.8)	44.3 (19.0–68.2)	49.8 (21.5–76.8)
HA Respiratory Disease > 65 years				
SO_2	-	13.1 (3.3–28.9)	-	15.1 (3.8–33.1)
NO_2	-	5.9 (0.0–18.4)	-	3.8 (0.0–11.8)
O_3	-	24.2 (11.7–36.4)	-	39.4 (19.2–58.5)

Abbreviations: WHO (World Health Organization), BI (baseline incidence), HA (Hospital Admission).

The aim of this study was to assess the effects of air pollutants on human health. In quantitative assessments, the health effects of the interaction between different pollutants have not been studied. One limitation of this study is that in the estimates of the model (similar to other studies conducted using this method), it is assumed that a causal relationship exists between exposure and health outcomes studied and there is no intervening factors affecting this relationship.

AirQ software has been used in many studies around the world to assess short-term effects of air pollution on mortality and hospital admissions for CVD and RD (Tominz *et al.*, 2005; Boldo *et al.*, 2006; Shakour *et al.*, 2011; Naddafi *et al.*, 2012; Mohammadi *et al.*, 2013; Zallaghi *et al.*, 2014). For example, the health effects for the population living in two Italian towns in an industrial area were investigated. The authors found that the highest health effects on 24,000 residents of the small towns of Rezzato and Mazzano were 8 excess cases from a total of 177 deaths recorded during a year. PM_{10} and NO_2 caused about 3 excess cases and O_3 caused about 4 excess cases among the total deaths (Fattore *et al.*, 2011).

In another study, the effects of PM_{10} and O_3 on human health were reviewed in 13 cities in Italy with a population of about 9 million during 2004 to 2002. For PM_{10} concentration over 20 μg m^{-3}, about 1372 excess cases among a total of 8220 deaths per year were reported. For O3, approximately 516 excess cases among total deaths per year were estimated (Martuzzi *et al.*, 2006). In a study in Milan, Italy on 1308000 residents, the number of excess cases attributable to PM_{10} was 677 cases for total mortality (Martuzzi *et al.*, 2002). A study conducted in 2012 in Tehran showed short-term effects of air pollutants including PM_{10}, SO_2, NO_2 and O_3 to be 2194, 1458, 1050 and 819 excess cases for total mortality (Naddafi *et al.*, 2012). Goudarzi *et al.* (2014) used AirQ model in Ahvaz, Iran, to estimate the health effects of SO_2 and found165 CVD deaths attributable to SO_2.

Goudarzi *et al.* (2012) used AirQ model in Ahvaz, Iran, to estimate the health effects of NO_2. The results showed that about 3% of all CVD deaths and hospital admissions for Chronic Obstructive Pulmonary Disease can be attributed to NO_2 concentrations over 20 μg m^{-3}. Another study in Suwon, South Korea with 1118000 residents for assessing the health effects of air pollutants such as PM_{10}, SO_2, NO_2 and O_3 using the software showed that PM_{10} with excess cases of 105.5 among the total mortality of 4254 had the largest health effects and the effects of SO_2, NO_2 and O_3 on total mortality were 10.9, 81.3 and 42.7 excess cases (Jeong, 2013).

In this study, PM_{10} had the highest health effect on 1,500,000 people living in Shiraz. This is consistent with the results of AirQ studies conducted for assessment of health impacts in Tehran (Naddafi *et al.*, 2012), 13 towns in Italy (Martuzzi *et al.*, 2006), Milan, Italy (Martuzzi *et al.*, 2002) and Suwon, South Korea (Jeong, 2013). The health effects

Table 4. Comparison of BI, RR, and number of excess cases attributable to short-term exposure to pollutants in different studies.

Study	Pollutant	Health endpoint	Exposure Increment	Baseline Incidence	Relative Risk	No. of excess cases
Fattore *et al.* (2011)						
	PM_{10}		10 µg m^{-3}			
		Total mortality		735.7	1.006 (1.004–1.008)	4.4 (3.0–5.8)
		Cardiovascular mortality		283.4	1.009 (1.005–1.013)	2.5 (1.4–3.6)
		Respiratory mortality		58	1.013 (1.005–1.020)	0.7 (0.3–1.1)
	NO_2		10 µg m^{-3}			
		Total mortality		735.7	1.003 (1.002–1.004)	3.1 (2.3–3.9)
		Cardiovascular mortality		283.4	1.004 (1.003–1.005)	1.6 (1.2–2.8)
	O_3					
		Total mortality		735.7	1.003 (1.002–1.005)	2.6 (1.4–4.1)
		Cardiovascular mortality		283.4	1.005 (1.002–1.007)	1.4 (0.7–2.1)
		Respiratory mortality		58	1.013 (1.006–1.015)	0.8 (0.4–0.9)
Naddafi *et al.* (2012)						
	PM_{10}		10 µg m^{-3}			
		Total mortality		543.5	1.006 (1.004–1.008)	2194 (1486–2880)
		Cardiovascular mortality		231	1.009 (1.005–1.013)	1367 (738–1916)
		Respiratory mortality		48.4	1.013 (1.005–1.020)	402 (164–588)
		HA Cardiovascular Disease		436	1.009 (1.006–1.013)	2580 (1760–1617)
		HA Respiratory Disease		1260	1.008 (1.0048–1.0112)	6677 (4110–9126)
Goudarzi *et al.* (2012)						
	NO_2		10 µg m^{-3}			
		Cardiovascular mortality		497	1.002 (1–1.004)	18.7 (0.0–37.3)
Jeong (2013)						
	PM_{10}		10 µg m^{-3}			
		Total mortality		380.5	1.006 (1.004–1.008)	105.5 (70.9–139.5)
		Cardiovascular mortality		84.5	1.009 (1.005–1.013)	34.7 (19.6–49.3)
		Respiratory mortality		28.8	1.013 (1.005–1.020)	16.8 (6.7–25.2)
		HA Cardiovascular Disease		436	1.009 (1.006–1.013)	179.1 (120.9–254.6)
		HA Respiratory Disease		1260	1.008 (1.0048–1.0112)	462 (280.9–634.8)
	SO_2		10 µg m^{-3}			
		Total mortality		380.5	1.004 (1.003–1.0048)	10.9 (1–13.0)
		Cardiovascular mortality		84.5	1.008 (1.002–1.012)	4.8 (1.2–7.2)
		Respiratory mortality		28.8	1.010 (1.006–1.014)	2 (1.2–2.9)
	NO_2					
		Total mortality		380.5	1.003 (1.002–1.004)	81.3 (54.5–107.7)
		Cardiovascular mortality		84.5	1.004 (1.003–1.005)	23.9 (18–29.7)

of SO_2, NO_2 and O_3 in Shiraz were very similar to the results found in studies in Italy, Korea, Tehran and Ahvaz. A summary of the results of a number of similar studies is presented in Table 4.

This was a case study using the WHO method to quantify the effects of PM_{10}, SO_2, NO_2 and O_3 on the health of Shirazi residents. According to the results, the highest health effects in Shiraz during 2012 and 2013 were associated with the highest concentration of pollutants. Measures should be taken to prevent emissions from various sources such as transport and energy production facilities to reduce the concentration of pollutants. Although the results of this study are consistent with those of similar studies conducted around the world, further research with specific RR and BI according to geographical, climatic and statistical features is needed. There were some limitations in this study to assess the health impacts of air pollutants including the assumption of a causal relationship between the pollutants studied and the health endpoint resulting from exposure to them.

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REFERENCES

Bateson, T.F. and Schwartz, J. (2004). Who is Sensitive to the

Effects of Particulate Air Pollution on Mortality? A Case-Crossover Analysis of Effect Modifiers. *Epidemiology* 15: 143–149.

Boldo, E., Medina, S., LeTertre, A., Hurley, F., Mucke, H.G., Ballester, F., Aguilera, I. and Eilstein, D. (2006). Apheis: Health Impact Assessment of Long Term Exposure to $PM_{2.5}$ in 23 European Cities. *Eur. J. Epidemiol.* 21: 449–458.

Brook, R.D., Franklin, B., Cascio, W., Hong, Y., Howard, G., Lipsett, M., Luepker, R., Mittleman, M., Samet, J., Smith, S.C., Jr., Tager, I., Expert Panel on, P. and Prevention Science of the American Heart, A. (2004). Air Pollution and Cardiovascular Disease: A Statement for Healthcare Professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation* 109: 2655–2671.

Brunekreef, B. and Holgate, S.T. (2002). Air Pollution and Health. *Lancet* 360: 1233–1242.

Ciocco, A. and Thompson, D.J. (1996). A Follow-up of Donora Ten Years after: Methodol- ogy and Findings. *Am. J. Public Health Nations Health* 51: 155–164.

Dominici, F., Peng, R.D., Bell, M.L., Pham, L., McDermott, A., Zeger, S.L. and Samet, J.M. (2006). Fine Particulate Air Pollution and Hospital Admission for Cardiovascular and Respiratory Diseases. *JAMA* 295: 1127–1134.

Fattore, E., Paiano, V., Borgini, A., Tittarelli, A., Bertoldi, M., Crosignani, P. and Fanelli, R. (2011). Human Health Risk in Relation to Air Quality in Two Municipalities in an Industrialized Area of Northern Italy. *Environ. Res.* 111: 1321–1327.

Garcia-Aymerich, J., Tobias, A., Anto, J.M. and Sunyer, J. (2000). Air Pollution and Mortality in a Cohort of Patients with Chronic Obstructive Pulmonary Disease: A Time Series Analysis. *J. Epidemiol. Community Health* 54: 73–74.

Goldberg, M.S., Burnett, R.T. and Stieb, D. (2003). A Review of Time Series Studies Used to Evaluate the Short Term Effects of Air Pollution on Human Health. *Rev. Environ. Health* 18: 269–303.

Goudarzi, Gh., Mohammadi, M.J., Angali, K., Neisia, A.K., Babaei, A.A., Mohammadi, B., Soleimani, Z. and Geravandi, S. (2012). Estimation of Health Effects Attributed to NO_2 Exposure Using AirQ Model. *Arch. Hyg. Sci.* 1: 59–66.

Goudarzi, Gh, Geravandi, S., Salmanzadehe, S., Mohammadi, M.J. and Zallaghi, E. (2014). The Number of Myocardial Infarction and Cardiovascular Death Cases Associated with Sulfur Dioxide Exposure in Ahvaz-Iran. *Arch. Hyg. Sci.* 3: 112–119.

Gurjar, B., Jain, A., Sharma, A., Agarwal, A., Gupta, P., Nagpure, A.S. and Lelieveld, J. (2010). Human Health Risks in Megacities Due to Air Pollution. *Atmos. Environ.* 44: 4606–4613.

Hoek, G., Brunekreef, B., Fischer, P. and van Wijnen, J. (2001). The Association between Air Pollution and Heart Failure, Arrhythmia, Embolism, Thrombosis, and Other Cardiovascular Causes of Death in a Time Series Study. *Epidemiology* 12: 355.

Hosseinpoor, A.R., Forouzanfar, M.H., Yunesian, M., Asghari, F., Naieni, K.H. and Farhood, D. (2005). Air Pollution and Hospitalization Due to Angina Pectoris in Tehran, Iran: A Time-series Study. *Environ. Res.* 99: 126–131.

Jeong, S.J. (2013). The Impact of Air Pollution on Human Health in Suwon City. *Asian J. Atmos. Environ.* 7: 227–233.

Krzyzanowski, M. (1997). Methods for assessing the Extent of Exposure and Effects of Air Pollution. *Occup. Environ. Med.* 54: 145–151.

Logan, W.P. (1956). Mortality from Fog in London, January. *Br. Med. J.* 1: 722–725.

Martuzzi, M., Galassi, C., Ostro, B., Forastiere, F. and Bertollini, R. (2002). Health Impact Assessment of Air Pollution in the Eight Major Italian cities. WHO Europe. EURO/02/5040650. http://www.euro.who.int/healthimpactS.

Martuzzi, M., Mitis, M., Iavarone, I. and Serinelli, M. (2006). Health Impact of PM_{10} and Ozone in 13 Italian Cities. WHOEurope. http://www.euro.who.intpubrequests.

Mohammadi, M.J., Goudarzi, Gh., Neisi, A.K., Angali, K., Saki, H., Babaei, A.A., Mohammadi, B., Dehdari Rad, H., Borhani, M. and Shari, M. (2013). Estimation of Health Effects Attributed to NO_2 Exposure by Using of AirQ Model in Ahvaz. *Apadana J. Clinical. Res.* 1: 5–12.

Naddafi, K., Hassanvand, M.S., Yunesian, M., Momeniha, F., Nabizadeh, R., Faridi, S. and Gholampour, A. (2012). Health Impact Assessment of Air Pollution in Megacity of Tehran, Iran. *Iran J. Environ. Health Sci. Eng.* 9: 1–7.

Nemery, B., Hoet, P.H. and Nemmar, A. (2001). The Meuse Valley Fog of 1930: An Air Pollution Disaster. *Lancet* 357: 704–708.

Pope, C.A. and Dockery, D.W. (2006). Health Effects of Fine Particulate Air Pollution. Lines that Connect. *J. Air Waste Manage. Assoc.* 56: 709–742.

Qorbani, M., Yunesian, M., Fotouhi, A., Zeraati, H. and Sadeghian, S. (2012). Effect of Air Pollution on Onset of Acute Coronary Syndrome in Susceptible Subgroups. *East Mediterr. Health J.* 18: 550–555.

Shakour, A., El-Shahat, M., El-Taieb, N., Hassanein, M. and Mohamed, A. (2011). Health Impacts of Particulate Matter in Greater Cairo. *Egypt. J. Am. Sci.* 7: 840–848.

Smith, K.R. (1993). Fuel Combustion, Air Pollution Exposure, and Health: The Situation in Developing Countries. *Annu. Rev. Energy Environ.* 18: 529–566.

Tominz, R., Mazzoleni, B. and Daris, F. (2005). Estimate of Potential Health Benefits of the Reduction of Air Pollution with PM_{10} in Trieste, Italy. *Epidemiol. Prev.* 29: 149–155.

WHO (2000). Air Quality Guidelines for Europe, Second ed. World Health Organization Regional Office for Europe. WHO Regional Publications, Copenhagen. European Series No. 91.

WHO (2003). Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide. Report on a WHO Working Group Bonn, Germany, 13e15 January 2003. WHO Regional Office for Europe, Copenhagen. http://www.euro.who.int/document/e79097.pdf.

Zallaghi, E., Goudarzi, Gh, Geravandi, S. and Mohammadi, M.J. (2014). Epidemiological Indexes Attributed to Particulates with Less than 10 Micrometers in the Air of Ahvaz City during 2010 to 2013. *Health Scope* 3: e22276.

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