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EVALUATION OF PUBLIC HEALTH IMPACTS RELATED TO URBAN AIR POLLUTION IN SHIRAZ AND BUSHEHR, IRAN

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Abstract

The objective of this work was assessing the health-endpoints of short-term exposure to the air pollutants including PM_{10}, O_3, SO_2, NO_2 and CO in Shiraz and Bushehr, Iran in 2013-2014. The approach suggested by the World Health Organization (WHO) was utilized using the AirQ2.2.3 software developed by the WHO European Centre for Environment and Health, Bilthoven Division. The main disadvantage of this approach was that the relative risks (RRs) and baseline incidences (BIs) which were used in this software belong to European countries, so, in part I of this study, local RRs and BIs were determined using generalized additive models. In part II, different concentrations of air pollutants were used to assess human exposure and health impacts in terms of attributable proportion of the health outcome, annual number of excess cases of mortality for all causes, and cardiovascular and respiratory diseases. The annual average of PM_{10}, SO_2, NO_2 and O_3 in Shiraz were 126.47, 73.92, 63.10, 75.97µg/m3, respectively, while the annual average of PM_{10}, SO_2, NO_2 and O_3 in Bushehr were 143.7, 56.08, 47.23, 51.09µg/m3. Regarding short-term endpoints, PM_{10} had the most important health effect on inhabitants in both cities, causing an excess of total mortality of 634 and 147 cases in a year, respectively. Also the effect of SO_2, NO_2 and O_3 on total mortality was an excess of about, respectively, about 431(112), 367(87) and 213(67) cases in year for Shiraz (Bushehr). AirQ software has been proved to be a valid and reliable tool to estimate the potential short term effects of air pollution and special attention was required choosing the relative risks to be utilized

Keywords:

Shiraz and Bushehr air pollution, Air Q software, Health impact assessment, Mortality, Morbidity

Introduction

Air pollution is one of the most important issues in the urban areas that eclipsed the human's life. A wide range of adverse health consequences due to short- and long-term exposure to air pollutants, at levels usually experienced by urban populations throughout the world, have been recorded (1-4). Moreover,even though pollution has been declined significantly in recent years due to combustion fuels, emerging contaminants such as O_3 and NO_2, and variations of suspended particles, have become important in the health consequences of air pollution (5). Range of health effects from growth occurrence of pneumonia and asthma intensification of chronic obstructive pulmonary diseases, increased respiratory symptoms and decreased lung function, to an increased cardiovascular mortality rate (5-8).

The present study assessed the health impact of air quality on the residents of Shiraz and Bushehr (Figure 1), the two largest cities which are in counter with high amounts of air pollution since last decades as a result of population growth, urbanization, and increased traffic-related air pollution. Moreover, the high influxes of air pollutants during the last decade through dust storms, well known as Middle Eastern Dust (MED) events, have deteriorated the welkin dramatically (9). The major aim of this research was the assessment of the short-term health impact of air pollutants for inhabitant living in these cities, by using World Health Organization (WHO) approach. But the major disadvantage of this approach is that relative risks (RRs) and baseline incidences (BIs) which used in this software belong for European countries conditions, so this study was conducted in two sections, in section I, local RRs and BIs were determine using generalized additive models. In section II, concentrations of the air pollutant were used to assess human exposure and health impacts in terms of attributable proportion of the health outcome, annual number of excess cases of mortality for all causes, and cardiovascular and respiratory diseases.

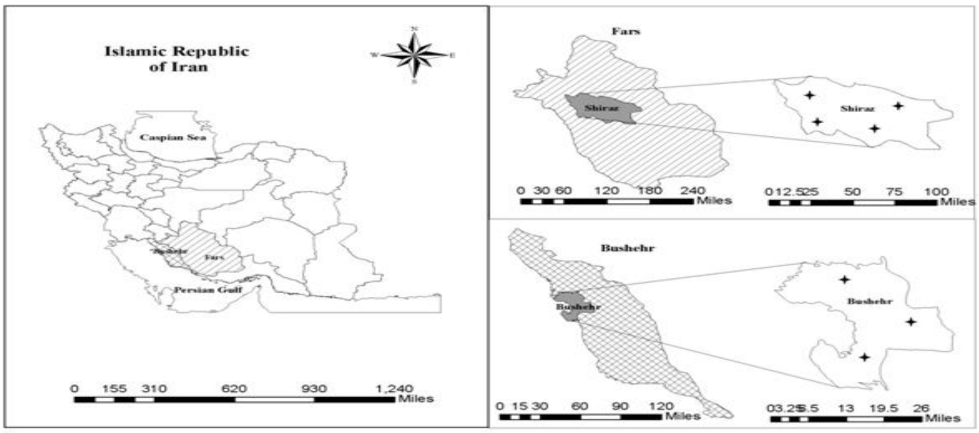

Figure-1: Map of the study area and locations of monitoring stations (Monitoring S) with valid observations.

Materials and Methods

In this study, we have tried to quantification of the short-term health effects of air pollutants for people living in Shiraz and Bushehr cities (Iran) during 2012-2013 in two sections. In section I, relative risks (RRs) and baseline incidences (BIs) were calculated for local condition. In section II, the numbers of the excess cardiovascular and respiratory hospitalizations were calculated due to exposure to air pollutants by computing RR and BI of section I and comparing them with obtained results of default relative risk (RR) and baseline incidence (BI) following mentioned software.

Section I: calculation of RRs and BIs in local condition

In this section, relations of exposure to air pollutants and hospitalizations because of respiratory and cardiovascular causes were investigated in these cities as the target population from 2000 to 2010.

Study area and demographic parameters

Shiraz is the capital city of Fars province (Figure 1). This city is located in latitude of 29°36ʾN and longitude of 52°32ʾE with average elevation of 1500 m above sea level. Boushehr is the capital city of Bushehr Province (Figure 1). This city is also located in latitude of 27°14ʾN and longitude of 50°12ʾE with average elevation of 18 m above sea level. In conformity with the latest census report by Statistical Centre of Iran (SCI) in 2005, the population was 1,227,331 and 259541 ones lived in Shiraz and Bushehr, respectively, which this number has been estimated to increase to 1,306,927 and 312364 ones in 2010. The population of people older than 65 years was about 85913 and 14561 ones respectively in Shiraz and Bushehr. Meanwhile, population growth rate of 1.3% and 1.17% occurred in Shiraz and Bushehr, respectively based on the estimates of SCI (10)

Morbidity cases and classification

The statistics related to hospitalizations because of respiratory and cardiovascular causes were obtained from Medical Records' Departments (MRD) of Shiraz and Bushehr hospitals. The morbidity cases were provided in line with taxonomy of the International Classification of Diseases (ICD-10) from MRDs of these cities hospitals. In conformity with ICD-10, J00 to J99 and I00 to I99 codes were defined for respiratory and cardiovascular diseases, respectively (11)

Correlation evaluation and RR calculation

Poisson regression with logarithmic link in generalized additive models (GAM) was used for correlation evaluation and RR calculation. This model is expressed as the following formula(12):

$$\log[E(Y)] = \beta_0 + \beta_1 \times pollutant + S_1(X_1) + \cdots + S_P(X_P) \quad (1)$$

Where *E(Y)* stands for the number of expected cases; *Y* stands for the number of daily hospitalizations; *Xi*, $i = 1$, *p*stands for time, temperature, relative humidity, etc.; and *Si*, *i = 1,…,p* stands for smooth functions.

Before to data analysis, their quality was evaluated primarily to find out errors and missing data applying Microsoft Office Excel and SPSS, and was revised if possible. In this section of the research, the impacts of meteorology variables including relative humidity and temperature; day of the week including holidays, days after holidays and working days; and time were imported to the model as confounder agents and their impacts were eliminated on number of hospitalizations applying smooth function to measure net impact of pollutant on the number of hospitalizations. To adjustment the impact of those predictor variables that affect response variable with lag of several days, smooth function was used on auto regressive values. At last, GAM models were assorted on the data employing "mgcv" package in R statistical software (13, 14).

Section II: health impact assessment of air pollution

In this section**,** we have tried to quantificationof the short-term health effects of air pollutants as a main target of this investigation. To do so, we applied the approach proposed by the WHO using the Air.$Q_{2.2.3}$ software developed by the WHO European Centre for Environment and Health.

Air pollution data

The selected pollutants in this study were PM_{10}, CO, SO_2, NO_2 and O_3.We used the air quality data from the permanent monitoring stationsof these cities from January 2012 until January 2013. HIA(Health Impacts Assessment) by AirQ needs concentration data of pollutants in µg/m3 units. Thus, if the measurements of the monitors were reported in parts-per-million (ppm) or parts-per-billion (ppb) units, it would be necessary first to transform ppb or ppm to µg/m3 units. In this procedure, there would be some adjustments for pressure and temperature. Moreover, for all of the pollutants except CO, the required parameters by the software (annual and seasonal maximum and annual 98th percentiles) were obtained and concentrations were recorded to 10 $\mu g/m^3$ categories, corresponding to equivalent exposure categories.

Pressure and temperature corrections

Pollutantunits required for this software (except PM_{10}) were different with measured units by monitoring stations. So for modifying these units, raw data were converted into a data based on temperature and pressure by writing the appropriate program. (supplementary data in Table1).

Table-1: Pressure and temperature corrections methods for AirQ.

A	B	C	D	E	F	G
NO	Temp(℃)	Temp(K)	Pressure(mbar)	P/P_0	CO(ppm)	CO(mg/m^3)
1	6.8	279.95	941.54	0.93	2.85	2.89
2	6.81	279.96	941.54	0.93	3.63	3.68
3	6.17	279.32	941.18	0.93	3.18	3.23
4	5.57	278.72	94.85	0.93	3.19	3.24

Columns F and B are raw data that getting from monitoring stations and the other columns are calculated through the following equations:

$$G_1 = 271.15 + B_1 \qquad (2)$$

$$D_1 = [1013.25 \times e^{\left(-\frac{0.0342\times1520}{C_1}\right)}] \qquad (3)$$

$$E_1 = \frac{D_1}{1013.25} \qquad (4)$$

$$G_1 = {[(273.15 \times E_1) \times (1.25 \times F_1)]}\Big/{[C_1]} \qquad (5)$$

Data were expressed as an 8 h ‘‘moving average’’for O3 and as a 1 h average concentrations for NO2 and CO and as daily averages for SO_2 and PM_{10}.

Quantification

To quantificationthe health effects of air pollution in these megacity we applied approach proposed by the WHO using the AirQ 2.2.3 software developed by the WHO European Centre for Environment and Health. This quantification is based on the attributable proportion (AP), defined as part of the health consequences in specific populations attributable to exposure to a given air pollutant, assuming a proven causal relation between exposure and health consequences and no major confounding effects in that relation(5, 15). The AP can be computed by equation6 (5)**:**

$$AP = \frac{\sum\{[\boldsymbol{RR(C)-1}]\times \boldsymbol{P(C)}\}}{\sum[\boldsymbol{RR(C)}\times \boldsymbol{P(C)}]} \qquad (6)$$

In this formula AP stands for the attributable proportion of the health consequences, RR stands for the relative risk (RR) for a given health consequence, in category “c” of exposure, acquired from the concentration–response functions obtained from multitude epidemiologic studies and *P(c)* indicated the proportion of the population in category “c” of exposure.

Equation 6 can be used to calculate the attributablerate of the exposure if the baseline frequency of the health consequence is known in the population:

$IE = I \times AP$ (7)

In this equation IE stands for the rate of the health attributable consequence to the exposure and I stands for the baseline frequency of the health consequence in the population under investigation.

Finally the equation 7 can be used for estimate the number of attributed cases to the exposure if the size of the population is known:

$NE = IE \times N$ (8)

In this equation, NE stands for number of attributed cases to the exposure and N stands for the size of the population investigated.

In this study, estimation of excess daily mortality, hospitalizations due to cardiovascular diseases, respiratory diseases, COPDs, respiratory diseases and other public health indicators as a result of short-term exposure to PM10, SO2, and NO2 were calculated using RR and BI of WHO guideline and RR and BI of section I .

Results

Results of section I

Calculated RR and BI of the section I with 95% confidence interval (CI) in 10 µg increase of daily mean of PM_{10}, SO_2, NO_2 and O_3 pollutants and in 10 mg increase of hourly mean of CO are shown in Table 2. These factors (RR and BI) have been tabulated in relation with mortality and morbidity (excess hospitalization). Mortality included cardiovascular diseases, respiratory diseases and total mortality, and morbidity included cardiovascular diseases, respiratory diseases, respiratory diseases in elderly group, and COPDs.

Table-2: Relative risks with 95% confidence interval for PM_{10}, SO_2, NO_2 ,O_3 and CO.

Health Impact		RR(per 10µg/m^3)								RR(per 1 mg/m^3)			
		PM_{10}		SO_2		NO_2		O_3		CO		BI per 100000	
		WHO RR (95% CI)	Section I (95% CI)	WHO RR (95% CI)	Section I (95% CI)	WHO RR (95% CI)	Section I (95% CI)	WHO RR (95% CI)	Section I (95% CI)	WHO RR (95% CI)	Section I (95% CI)	WHO RR	Section I
mortality	Total mortality	1.0074	1.006	1.004	1.007	1.003	1.0031	1.00046	1.003	-	-	1013	5435
		1.0062-1.0086	1.004-1.008	1.003-1.0048	1.002-1.005	1.0018-1.0032	1.002-1.004	1.00023-1.00066	1.002-1.005	-	-		
	Cardiovascular mortality	1.008	1.009	1.008	1.006	1.002	1.004	1.0004	1.005	1.007	1.002	497	231
		1.005-1.018	1.004-1.013	1.002-1.012	1.001-1.010	1.000-1.002	1.003-1.005	1.0002-1.0006	1.002-1.007	1.002-1.012	1.000-1.008		
	Respiratory mortality	1.012	1.013	1.01	1.009	-	-	1.0008	1.0013	-	-	66	488
		1.008-1.037	1.005-1.02	1.006-1.014	1.004-1.012	-	-	1.0004-1.0012	1.0015-1.007	-	-		
Morbidity	Hospital	1.009	1.002	-	-	-	-	-	-	-	-	436	1447

admissions due to CDs	1.006 - 1.013	1.0001 - 1.0040	-	-	-	-	-	-	-	-		
Hospital admissions due to RDs	1.0080	1.0049	-	-	-	-	-	-	-	-	1260	849
	1.0048-1.0112	1.0004-1.0110	-	-	-	-	-	-	-	-		
Hospital admissions due to RDsE **	-*	-	1.004	1.054	1.0038	1.028	-	-	-	-	-***	61
	-	-	1.001-1.009	1.005-1.12	1.000-1.012	1.011-1.045	-	-	-	-		
Hospital admissions due to COPDs	-****	-	1.0044	1.095	1.0038	1.036	1.00058	1.0027	-	-	101.4	92
	-	-	1.000-1.011	1.07-1.11	1.0004-1.0094	1.021-1.051	1.00022-1.00094	1.0011-1.0034	-	-		

Abbreviations: *CDs* cardiovascular diseases, *BI* baseline incidence, *COPDs* chronic obstructive pulmonary diseases, *CI* confidence interval , *PM10* particulate matter with aerodynamic diameter less than 10 μ m , *NO2* nitrogen dioxide, *SO2* sulfur dioxide, *RDs* respiratory diseases, *RDsE*respiratory diseases in elderly group (people older than 65 years-old), *RR* relative risk, *WHO* World Health Organization.

* For cardiovascular and respiratory diseases there are no RRs due to short-term exposure to SO_2 and NO_2 in AirQ software so that they were not calculated in section I of the research.

** Based on categories of AirQ.

*** In AirQ, the BI has not been presented for respiratory diseases in elderly group.

**** For COPDs there is no RR due to short-term exposure to PM_{10} in Air Q so that it is not calculated in section I of the research.

As illustrated in Table 2, there is no BI for respiratory diseases in elderly group, therefore due to short-term exposure to SO2 and NO2 pollutants, calculation of excess cases have been computed regarding RR of WHO & BI of section I; and RR & BI of section I. In conformity with finding of section I, there was no significant correlation ($p > 0.05$) between PM10 and CO hospitalizations due to cardiovascular diseases. However, association of PM10 and hospitalizations due to respiratory diseases was significant ($p = 0.042$). Moreover, In conformity with results of section I, there was significant correlation among SO2 and NO2 and O_3 pollutants and hospitalizations due to respiratory diseases in elderly group and COPDs ($p < 0.001$).

Table-3: Summary of the concentrations of air pollutants, and meteorological variables, Shiraz and Boushehr (2012–2013).

Parameters	Mean (SD)		P75		P98		Maximum		No. of station	
	Shiraz	Boushehr	Shiraz	Boushehr	Shiraz	Boushehr	Shiraz	Boushehr	Shiraz	Boushehr
PM10, Annual 24 h (μg/m3)	126.47(38.90)	143.7(41.2)	121.84	127.09	173.45	204.40	336.19	475.9	4	2
SO2, Annual 24 h (μg/m3)	73.92(24.07)	56.08(18.76)	117.56	98.97	168.92	113.09	217.57	141.94	4	2

NO2, Annual 24 h (µg/m3)	63.10(27.83)	47.23(17.81)	109.83	67.43	123.12	88.12	143.63	97.89	4	2
O3, Annual 8 h (µg/m3)	75.97(29.91)	51.09(20.56)	97.67	71.22	132.8	91.44	172.21	103.98	4	2
Temperature (°C)	21.52(11.21)	37.42(15.98)	30.43	41.09	37.84	45.98	43.09	48.98	-	-
Relative humidity (%)	39.76(17.87)	57.84(19.21)	46.09	78.98	74.84	87.21	100	100	-	-

The summary of the statistics of environmental data in Shiraz and Bushehr are shown in Table3.

As shown in Table 3, maximum concentrations of PM_{10} in Shiraz was detected in the summer period with value of 336.19 µg/m^3. The maximum 8 h average concentration of O_3 was 172.21µg/m^3 in summer. While the maximum NO_2 and SO_2 concentrations were 143.63 and 217.57 µg/m^3 in winter, respectively. Also as indicated in table 2, maximum concentration of PM_{10} in Bushehr was achieved in the summer period with value of 475.9µg/m^3. The maximum 8 h average concentration of O_3 found to be 103.98 µg/m^3 as expected in summer. Also, the maximum NO_2 and SO_2 concentrations were 97.89 and 141.94µg/m^3 in winter, respectively.

According to the results, the annual average of PM_{10} in Shiraz and Bushehr were 1.78 and 2.02 times more than world's average (71 µg/m3) concentrations (16)and 6.35 and 7.2 times more than the WHO guideline, respectively (17). Also the annual average of NO_2 in Shiraz and Bushehr were 1.57 and 1.18 times more than the WHO guideline, respectively (17).

Figure 3 and 4 show the levels of various pollutants and the percentage of time to which people were exposed to these levels in Shiraz and Bushehr, respectively.

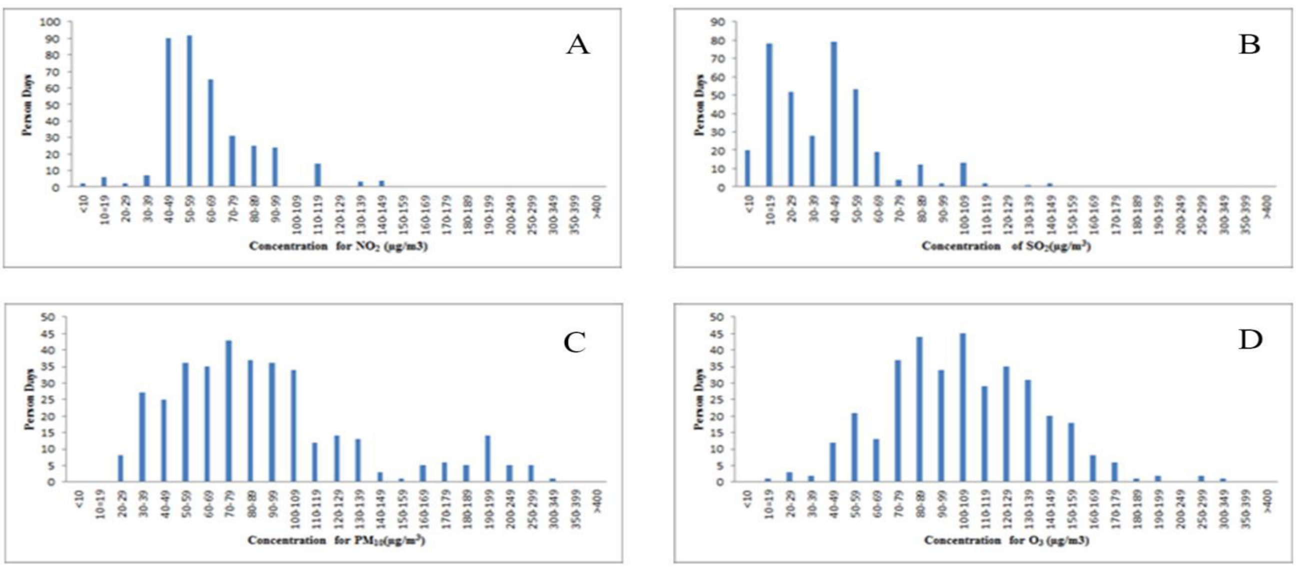

Figure-2: The days of days on which people in Shiraz are exposed to different concentrations of (A) NO_2, (B) SO_2, (C)PM_{10} and (D) O_3.

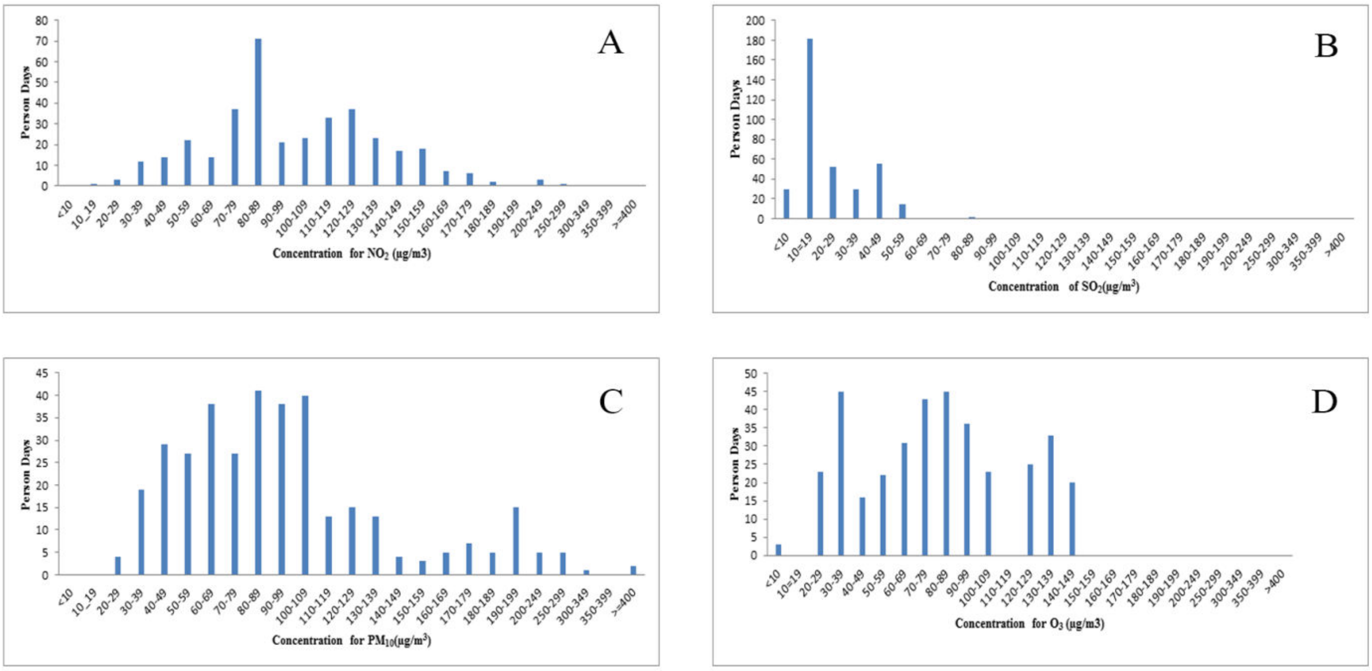

Figure-3: The days of days on which people in Bushehr are exposed to different concentrations of (A) NO_2, (B) SO_2, (C)PM_{10} and (D) O_3.

Results of section II

The data were used to estimate the short- term impacts. The short-term health consequences of exposure to PM_{10}, SO_2, NO_2 and $O_3$of 10 µg/$m^3$are shown in Table 4.

Table-4: Estimated attributable proportion (AP) expressed as percentage and number of excess cases in a year due to short-term exposure above 10 µg/m3 for PM_{10}, SO_2, O_3 and NO_2.

Health Impacts	Air pollutants	AP (uncertainty range)[a]		No. of excess cases (uncertainty range)[a]	
		Shiraz	Boushehr	Shiraz	Boushehr
Total Mortality	PM_{10}	5.02(3.4-6.58)	6.04(3.7-7.34)	634(368-712)	147(73-232)
	SO_2	1.53(1.07-2.21)	1.27(0.98-1.87)	431(284-523)	112(53-174)
	NO_2	1.21(0.9-1.45)	1.12(0.72-1.34)	367(254-481)	87(34-117)
	O_3	1.09(0.87-1.22)	0.98(0.77-1.09)	213(172-243)	67(31-97)
Cardiovascular mortality	PM_{10}	7.34(4.22-10.27)	6.78(3.99-9.25)	337(238-417)	109(42-156)
	SO_2	2.4(0.7-3.56)	2.13(1.00-3.28)	298(254-321)	71(48-110)
	NO_2	2.03 (1.53-2.67)	1.78(1.49-2.01)	97(83-107)	45(19-92)
	O_3	3.27(2.87-4.44)	2.81(1.88-3.78)	83(62-93)	33(13-71)
Respiratory mortality	PM_{10}	10.27(4.22-14.98)	9.12(4.12-13.23)	174(149-213)	59(22-89)
	SO_2	3.01(1.81-4.37)	2.92(1.47-4.01)	123(102-152)	68(34-121)
	O_3	6.9(3.3-9.7)	6.45(3.10-8.89)	117(98-143)	53(27-82)
Hospital Admissions Cardiovascular Disease	PM_{10}	6.58(4.05-8.95)	6.08(3.99-8.78)	1648(1016-2249)	347(118-562)
Hospital Admissions Respiratory Disease	PM_{10}	7.34(5.02-10.27)	7.04(5.82-9.23)	2692(2110-3241)	541(451-771)
Hospital Admissions COPD	NO_2	1.67(1.32-2.98)	1.57(1.33-2.88)	37(26-43)	12(9-27)

	O_3	3.4(2.98-4.87)	3.35(2.74-4.67)	84(71-107)	21(17-41)
	SO_2	1.33(0-3.28)	1.36(0.12-3.88)	97(0-115)	32(20-67)
Acute Myocardial Infarction	SO_2	1.93(0.79-3.02)	1.87(0.89-3.22)	123(117-142)	44(19-81)
	NO_2	2.14(1.98-2.74)	2.21(1.94-2.80)	63(51-76)	19(8-39)

As shown in Figure 3-4 and Table 4 the estimated AP and number of excess cases compared with the cases if levels of the pollutants were 10 µg/m3 are shown. For NO_2 the estimated short-term endpoints (Table 3) are based on the pooled estimates for the increase in mortality related with an increase of 10 µg/m3 in 30 European cities participating in the APHEA-2project (18).For O_3, the numbers of excess cases over total mortality, cardiovascular and respiratory mortality (Table 3) were based on the calculated RR from section I and values from the APHEA-2 project, which surveyed health endpoints of ambient O_3 in 23 European cities/areas for at least three years (19).

Discussion

In this study, we tried to assess the impacts of short-term exposure to particular air pollutants such as PM_{10}, SO_2, O_3 and NO_2 on some health consequences including cardiovascular and respiratory mortality, and hospital admissions for cardiovascular and respiratory diseases, COPD and acute myocardial Infarction using AirQ model in various scenarios. Regarding the short-term endpoints, PM_{10} had the most important health effect on inhabitants in these cities, causing an excess of total mortality of 634 and 147 cases in a year in Shiraz and Bushehr, respectively. After that the effect of SO_2, NO_2 and O_3 on total mortality was an excess of about 431, 367and 213 cases in a year in Shiraz, respectively. Also the effect of SO_2, NO_2 and O_3 on total mortality was an excess of about 112, 87 and 67 cases in a year in Bushehr, respectively. In conformity with this few sentences, which were mentioned, the importance of PM_{10} in the total mortality is clearly determined. Also, in other researches, this approach is employed to determine the health effects of air pollution. The majority of them, however, have focused on short-term effects of air pollutants on mortality because of cardiovascular and respiratory diseases. For example in Northern Italy, this approach has been used to determine the people health impacts in relation to air quality in two town in an industrialized area and the authors found that $PM_{2.5}$ had most important health impact on the 24,000 inhabitants of the two small towns, causing an excess of total mortality of 8 out of 177 in a year; also ozone and nitrogen dioxide each caused about three excess cases of total mortality(5, 20, 21).In research in Athens, Greece the central estimate of the number of excess cases attributable to PM_{10} was 534 for total mortality(5, 22). In another investigation in Trieste a city in north-east Italy with about 200,000 inhabitants for PM_{10}concentrations above 20 µg/m3, 52, 28 and 6 cases in excess, respectively, were estimated for total, cardiovascular and respiratory mortality(21). These reports, if normalized to the of Shiraz would result in a number of excess cases very similar to those reported for PM_{10} in our study. Regarding the PM_{10} , we can say findings gained from investigations of health impacts of air pollution in various parts of the world differ but PM_{10} is the most important pollutant with the biggest health effects in all of these studies, including the our paper.

To be honest, there are various drawbacks in this study. One of the major drawbacks of AirQ was focusing on some particular pollutants regardless to the simultaneous exposure to several, which will usually happen(5). For example NO_2 and SO_2 as water-soluble constituents could increase the solubility of toxic organic compounds, such as polycyclic aromatic hydrocarbons (PAHs) and n-alkanes by acting as surface active agents. Therefore, they canraise the toxicity of these compounds in human life (23-25).Moreover the water soluble fraction of airborne particles contains large number important compounds, which can change the composition, density, particle size and longevity of aerosols owing to their hygroscopic nature and this mechanisms can intensify their health effects(26). To give effect to co-exposure to various pollutants, it is assumed that the health impacts of particular pollutant are augmentative. Another drawback of this method was that the reported pollutant levels in a particular measuring station were Indicative of the mean exposure suffered from inhabitants living in Shiraz and Bushehr.

Conclusion

AirQ has been proved to be valid and reliable software to estimate the short term potential effects of air pollution such as PM_{10}, SO_2, NO_2 and O_3 on the human health in a certain area. In this study, we have tried to quantificate the short-term health effects of air pollutants on people living in Shiraz and Bushehr cities of Iran during 2012-2013. Special attention was required to choose the relative risks to be utilized. The obtained results of this study were similar to other researches and, despite the restrictions, which were similar to other investigations, introduced AirQ as effective and easy software, helpful in decision-making.

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Conflict of interest

There is no conflict of interest.

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