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Assessing the Effects of Nitrogen Dioxide in Urban Air on Health of West and Southwest Cities of Iran

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Background: Nitrogen dioxide (NO_2) is a corrosive, strong oxidant and a physiologic stimulant of lower respiratory tract. Every human being inhales an average of 10 m^3 air per day; therefore, assessment of the effect of inhaled air on health is a vital issue. The main source NO_2 in urban regions is intra-urban public transport system. The annual average of determined air quality for NO_2 is 40 μg/m^3.
Objectives: The present study aimed to estimate and compare epidemiologic indices attributed to the pollutant NO_2 in the urban air of southwest cities of Iran, namely, Ahvaz, Kermanshah, and Bushehr, in 2011.
Materials and Methods: In the present study, data relevant to the air-pollutant NO_2 in 2011 was obtained from the Iranian Department of Environment and meteorological organizations of the studied cities. Raw data processing by Excel software included instruction set correction of averaging, coding, and filtering. Then the meteorological parameters were converted as input file to the Air Q model. Finally, by using epidemiologic formulas, relative risk (RR) and attributed part to NO_2 in the three studied cites were estimated.
Results: The results showed that in summer, winter, and the whole year, Kermanshah and Bushehr had on average the maximum and minimum NO_2 concentration, respectively, in 2011. In addition, accumulative number of cases attributed to exposure with NO_2 in the studied cities was maximum in Kermanshah (21 cases) and minimum in Bushehr (one case). The results revealed that approximately, the maximum number of death cases attributed to NO_2 were observed in Kermanshah due to heart problems (1.06%), acute infarction (1.8%), and obstructive pulmonary disease (1.9%) with concentration > 20 μg/m^3.
Conclusions: Every 10 μg/m^3 increase in the concentration of the pollutant NO_2 in the studied cities led to increase in the RR of myocardial infarction, cardiovascular diseases, and obstructive pulmonary disease by 0.4%, 0.2%, and 0.4%, respectively, in 2011. Higher RR value can depict mismanagement in urban air quality. The lower level of RR value might be achieved if some control strategies for reducing NO_2 emission were used.

*Keywords:*Nitrogen Dioxide; Epidemiology; Iran

1. Background

During last two decades, epidemiologic studies throughout the world have evaluated the effect of air pollutionon human being health and related mortality, which showed increase in mortality due to air pollution (1, 2). Common air pollutants in the list of "National Ambient Air Quality Standards" include carbon monoxide (CO), ozone (O_3), $PM_{2.5}$, PM_{10}, SO_2, nitrogen dioxide (NO_2), and lead (Pb) (3). Every human being inhales an average of 10 m^3 air per day; therefore, assessment of inhaled air effects on health is a vital issue. Predictive models of concentration are classified into deterministic and statistical models. Deterministic models of air pollution, which reflect base condition of turbulence in atmosphere, are applicable tools for modeling gas pollutants and particles; however, their results are always associated with substantial errors. This could be due to partial and brief description of atmosphere-complicated processes in the models. Many factors contribute to such errors among which uncertainty due to intrinsic variability of atmosphere is the most important one. Moreover, the focus of such models is based on the assumption that pollutants are dispersed in a homogenous condition, although practically the earth could be an effective factor in imbalance turbulence in a vertical pathway. In addition, input of the above mentioned models (mainly Gaussian) are frequently based on a simple programming, which assumes turbulence in classes stability atmosphere, while each class includes a wide range of atmospheric stability condition and depends on the place where it is evaluated (4). By utilizing available meteorological and pollution data, and analyzing their statistical correlation, statistical methods are simpler methods for predicting pollutants concentration and their applicability as well as usefulness has been demonstrated by studying short-term predictions of air pollutants using such methods (5, 6). Determination models of health consequences are mostly epidemiologic-statistical, integrating air quality data in concentration intervals with epidemiologic parameters such as relative risk (RR), update base, and attributable fraction, and presenting the result as death toll or mortality (1). Among seven different nitrogen oxides, NO and NO_2 pose health consequences in human being. NO_2 is considered a greenhouse gas that contributes to global warming. NO_2 is a reddish-orange to brown gas with boiling point at 21.2℃ and low partial pressure, which ensure its gas state. It is a corrosive, strong oxidant and a physiologic stimulant of lower respiratory tract with toxicity much more than that of NO. NO_2 is initially formed as NO by combination of azote and oxygen during combustion at an elevated temperature, especially in internal combustion engines and when exhausted, it is rapidly converted to NO_2 (7). The main anthropologic sources of the gas include car's tailpipe, fossil fuels, power stations, industrial boilers, incinerate, and home heating systems. In urban areas, the main source of NO_2 is intra-urban transport system. The concentration of NO_2 changes from day to night. Air quality guidance level for NO_2 is an annual average of 40 μg/m^3. Some of its health impacts include increase in Met-hemoglobin (Met-Hb), enzyme activity inhibition, respiratory tract effects, general pathologic effects, and systemic effects (7). In similar work, Goudarzi et al. studied the association between chronic obstructive pulmonary disease (COPD) and NO_2 levels in the Ahvaz in 2009 (8). in addition, Goudarzi et al . studied the association between COPD and NO_2 levels in the Tehran in 2007 and 2011 (9, 10). Zalaghi et al. studied the association between COPD and NO_2 levels in the Ahvaz, Bushehr, and Kermanshah in 2010 (11). Furthermore, health effect of air pollution in terms of NO_2, ozone, and particulate matter in most of megacities, particularly Ahvaz, was reported. Health Impact Assessment software (AirQ 2.2.3, developed by the WHO European Centre for Environment Health, Bilthoven Division) was proved to be a valid and reliable tool to estimate the potential short-term effects of air pollution; AirQ predicts health endpoints attributed to criteria pollutants, and allows the examination of various scenarios in which emission rates of pollutants vary (12).

2. Objectives

The present study aimed at estimating and comparing epidemiologic indices attributed to the pollutant NO_2 in the urban air of southwest cities of Iran, namely, Ahvaz, Kermanshah, and Bushehr in 2011.

3. Materials and Methods

In the present study, data relevant to the air-pollutant NO_2 in 2011 were obtained from the Iranian Department of Environment as a Microsoft Excel file format. Since all air pollution measurement stations were lacking temperature sensors, 24-hour and daily air pressure and temperature data were collected from meteorological organizations of the studied cities. NO_2 concentration was expressed in volume/volume percent (v/v), which was subsequently converted to mass/volume percent (m/v) using following calculations (13, 14):

Formula (1): $B1 = 273.15 + A1$

Formula (2): $D1 = (1013.25 \times e\,[-(0.0342 \times C1)/B1]\,)$

Formula (3): $E1 = D1/1013.25$

Formula (3): $G1 = [(273.15 \times E1) \times (2.05 \times F1)]/B1$

Where A is temperature (℃), B is temperature (kelvin),C is pressure (mbar), D is pressure (atm), E is ratio P/P0, G is concentration NO_2 (ppb), and F is concentration NO_2 (μg/m^3) (8, 9, 12). Primary processing including eliminating, sheet classifications of pollutant, and temporal homogenizing for mean estimation, secondary processing including code writing, mean calculation, and condition correction, primary filtering, secondary filtering, and Finally, using following equations, RR and attributable fraction of the pollutant NO_2 was obtained in three studied cities. Thereafter, 24-hour means were calculated for NO_2 pollutant. We estimated the health impact that was attributable to the exposure of air pollution on the target population using AirQ model, which estimates the impacts of specific air pollutants on a resident population in a certain area and period. Attributable proportion (AP) may be obtained by the following equation (15):

$AP = SUM\,([RR\,(c) - 1]\,P\,(c))\,z/SUM\,[RR\,(c)\,P\,(c)]$

where RR (c) is RR of health implications in the group c or any group of interest, and P (c) is population proportion of the group c or any group of interest. RR of selected health implications is obtained using response-exposure functions (15)

RR = Probability of event when exposed/Probability of event when non-exposed

3.1. Study Regions

Ahvaz, the capital of Khouzestan Province, Iran, with an area of 8,152 km^2, lies on the geographical coordinates of 30° 45' to 32° N, 48° to 49° 29' E, southwest of Iran, with height of 22.5 m above sea level (16). Its climate is hot and humid. Kermanshah, the capital of Kermanshah Province, Iran, lies on the geographical coordinates of 34° N, 47° 4' E in the middle of the western part of Iran, whose climate is semiarid and mountainous temperate (17). Kermanshah's height is 1200 m above sea level. Bushehr is the capital of Bushehr Province, Iran, with coordinates of 28° 95' 76" N, 50° 83' 71" E and with an area of around 1441 km^2 (18) (Figure 1).

4. Results

Table 2 shows that in summer, winter, and the whole year 2011, Kermanshah and Bushehr had on average the maximum and minimum NO_2 concentrations, respectively. In addition, according to the results, concentration of the pollutant NO_2 in 2011 was more in winter than in summer in any of the three studied areas. The indices of RR, attributable percentage, and attributable cases of NO_2 for myocardial infarction (MI) with baseline incidence of 132 were calculated (Table 3). According to calculations, RR in the three studied cities for acute MI was estimated 1.0036. In addition, accumulative number of cases attributed to exposure with NO_2 in the studied cities was maximum (21 cases) in Kermanshah and minimum (one case) in Bushehr. RR attributed to NO_2 for COPD was estimated 1.0038 and the accumulative numbers attributed to COPD were eight and 19 in Kermanshah and Bushehr, respectively. Therefore, Kermanshah had the maximum cases of COPD among the three studied areas. Studied implications due to NO_2 for calculated RR in study areas (Ahvaz, Bushehr, and Kermanshah). Figures 2-4 show health implications due to NO_2 based on accumulative number of cases and epidemiologic indices. RR attributed to NO_2 for mortality due to cardiovascular diseases (CVD) was estimated at 1.002 at intermediate level. In addition, accumulative number of death due to CVD attributed to exposure to NO_2 in the studied cities was maximum (44 cases) in Kermanshah. Figures 2 and 3 illustrate that despite the estimated RR, health impacts of NO_2 in concentrations $< 20\ \mu g/m^3$ was zero due to lack of public exposure to such concentration. In other words, there was no day with concentration $< 20\ \mu g/m^3$ in Ahvaz and Kermanshah. Figure 4 indicates that despite the estimated RR, health impacts of NO_2 in concentrations $< 10\ \mu g/m^3$ was zero due to lack of public exposure to such concentration. In other words, there was no day with concentration $< 10\ \mu g/m^3$ in Bushehr.

Figure 1. Study Areas Map (Ahvaz, Bushehr,Kermanshah)

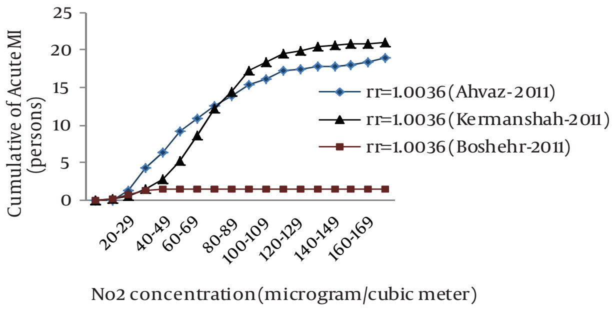

Figure 2. Accumulative Number of Cases of Myocardial Infarction due to Nitrogen Dioxidein Concentration Intervals in Ahvaz, Bushehr, and Kermanshah Cities in 2011

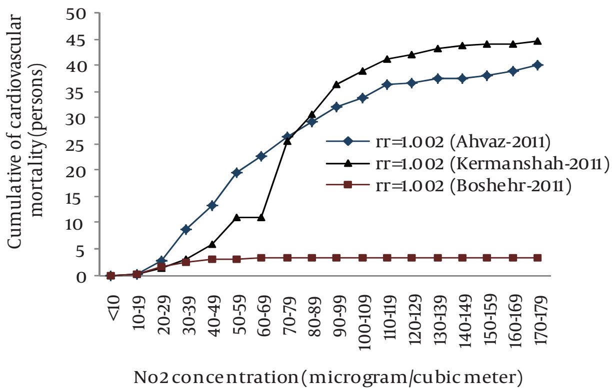

Figure 3. Accumulative Number of Cases of Cardiovascular Diseases Due to Nitrogen Dioxidein Concentration Intervals in Ahvaz, Bushehr, and Kermanshah Cities in 2011

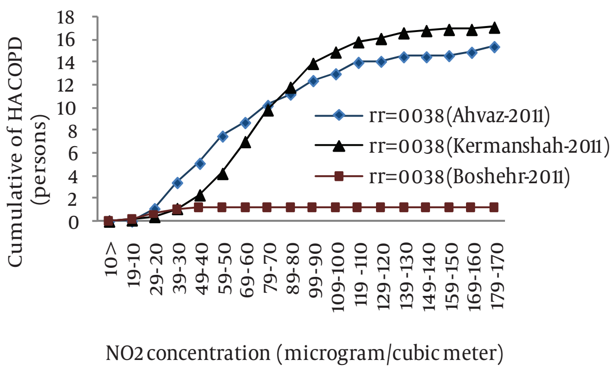

Figure 4. Accumulative Number of Cases of Chronic Obstructive Pulmonary Disease Due to Nitrogen Dioxidein Concentration Intervals in Ahvaz, Bushehr, and Kermanshah Cities in 2011

Table 1. Nitrogen Dioxide-Pressure and Temperature Correction in Excel (Zallaghi, et al. (11)) [a]

T, ℃	T, kelvin	P,mbar	P	P/P0	NO_2, ppb	NO_2, µg/m^3
17	290.15	1017	898.7855	0.887032	19.2	32.868
18	291.15	1013	899.5782	0.887815	33.8	57.713
20	293.15	1011	900.5189	0.888743	40	67.905
20	293.15	1013	900.3088	0.888536	32.4	54.99
21	294.15	1010	900.9848	0.889203	44	74.48
25	298.15	1005	902.9231	0.891116	15.9	26.61
20	293.15	1009	900.729	0.88895	19.9	33.791
19	292.15	1014	899.8393	0.888072	53.3	90.725
23	296.15	1015	901.1791	0.889395	42.3	71.134
21	294.15	1012	900.7753	0.888996	45.2	76.493
22	295.15	1015	900.8213	0.889041	20.8	35.083
20	293.15	1015	900.0988	0.888328	19.6	33.258

[a] Abbreviations: T, Temperature; P, Pressure; P0, Primary Pressure; and NO_2, Nitrogen Dioxide.

Table 2. Nitrogen DioxideConcentration in 2011 [a]

	Ahvaz	Bushehr	Kermanshah
Annual average	51.53	27/76	63.56
Summer average	37.29	23.48	56.53
Winter average	66.32	32.20	70.86
Annual 98 percentile	130.03	49.74	130.35
Annual Maximum	179.54	62.39	170.244
Summer Maximum	106.01	39.18	156.66
Winter Maximum	179.54	62.39	170.24

[a] Values are measured in µg/m^3.

Table 3. Estimating Indices of Relative Risk, Attributable Proportion and Attributable Cases to Nitrogen Dioxidefor Acute Myocardial Infarction (Baseline Incidence, 132) (2011)

	Relative Risk, Low	Attributed Proportion (Estimated Percentage), %	Attributable Excess Cases, %
Ahvaz (2011)	1.0036	1.4890	19
Kermanshah (2011)	1.0036	1.8936	21.1
Bushehr (2011)	1.0036	0.6419	1.5
Ahvaz (2011)	1.0038	1.5704	15.4
Kermanshah (2011)	1.0038	1.9967	17.1
Bushehr (2011)	1.0038	0.6773	1.2

Table 4. Estimating Indices of Relative risk, Attributable Fraction and Attributable Cases to Nitrogen Dioxidefor Deaths due to Cardiovascular Diseases (Baseline Incidence of 497) (2011)

INDEX Estimation	Relative Risk, Medium	Attributed Proportion (Estimated Percentage), %	Attributable Excess Cases, %
Ahvaz	1.002	0.8327	40.1
Kermanshah	1.002	1.0610	44.5
Bushehr	1.002	0.3576	3.2

5. Discussion

According to the results, the accumulative number of MI attributed to exposure with NO_2 in 2011 was 19 (10 cases more than in 2010). About 56% of MI had occurred in days with concentration < 70 µg/m^3. On the other hand, 80% of the cases had occurred in days with concentration of NO_2< 100 µg/m^3. Regarding intermediate level of RR, the accumulative number of CVD due to exposure with NO_2 was 40 (21 more than in 2010) in which 66% were related to concentration < 80 μg/m^3. Low values of attributable percentage of COPD indicate low RR at low level (5%); hence, the numbers of the cases in accumulative central level was estimated at 15 (18 cases more than in 2010). The indices of RR, attributable percentage, and attributable cases to NO_2 for MI with baseline incidence of 132 were calculated. According to the results, accumulative number of MI attributed to exposure to NO_2 in 2011 was 21. Moreover, 41% of MI cases had occurred in days with concentration < 70 μg/m^3. On the other hand, 82% of the cases had occurred in days with concentration of NO_2<100 μg/m^3. Regarding intermediate level of RR, the accumulative number of CVD due to exposure to NO_2 was 44 in 2011, in which 57% were related to concentration < 80 μg/m^3. Accumulative number of COPD attributed to NO_2 was estimated at 17. Based on the results, total cumulative number of MI attributed to exposure with NO_2 was two in Bushehr in 2011 and 45% of MI cases had occurred in days with concentration < 80 μg/m^3. Accumulative number of CVD cases, regarding intermediate level of RR due to exposure with NO_2 was three in 2011, in which 45% were related to concentration < 30 μg/m^3. Moreover, Accumulative number of COPD attributed to NO_2 was only one in 2011.

Among the three study areas (Ahvaz, Bushehr, and Kermanshah cities), maximum and minimum annual averages of NO_2 concentration were reported from Kermanshah (63.58 μg/m^3) and Bushehr (27.76 μg/m^3), respectively. The observed increased NO_2 concentration in Kermanshah might be due to increase in home heating systems, and more burning fossil fuels, and topographical conditions of the region, which led to more stability of the pollutants in atmosphere in comparison with Ahvaz and Bushehr. The obtained results in Toronto, Canada, showed that the number of referrals to hospitals due to COPD was 7.72 cases of which 40.4% were due to exposure with NO_2 (19). Goudarzi utilizes AirQ model for estimating health impacts of NO_2 in Tehran, Iran, in 2007. According to the results, about 2.18% of total deaths due to CVD, 3.8% of MI, and 4.06% of hospital referrals due to COPD were attributed to concentrations > 40 μg/m^3 (10). Goudarzi et al. attributed about 0.38% of total deaths due to CVD, 0.69% of MI, and 0.73% of hospital referrals due to COPD to concentrations > 20 μg/m^3 (8, 9). In addition, about 0.83% of deaths due to CVD, 1.48% of MI, and 1.57% of hospital referrals due to COPD were attributed to concentrations > 20 μg.m^{-3}. Comparing the results in Ahvaz, Tehran, and Toronto, suggests that the more percentage regarding death of the two implications in Ahvaz may be related to higher average of NO_2 and/or days with higher concentrations in comparison to 2010. In 2011, the maximum number of observed death cases attributed to NO_2 in Kermanshah were due to CVD (1.06%), acute MI (1.8%), and COPD (1.9%) with concentration > 20μg/m^3. On the other hand, the minimum number of death cases was seen in Bushehr due to CVD (0.03%), acute MI (0.06%), and COPD (0.6%) with concentration > 20 μg/m^3. Every 10 μg/m^3 increase in the concentration of the pollutant NO_2 in the cities of Ahvaz, Kermanshah, and Bushehr led to increase in the RR of MI, CVD, and COPD by 0.4%, 0.2%, and 0.4%, respectively, in 2011.

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