Effect of Air Pollution on the Emergency Admissions of Cardiovascular and Respiratory Patients, Using the Air Quality Model: A Study in Tehran, 2005-2014

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ABSTRACT

Background: Air pollution is one of the most important factors threatening the health of citizens. It increases the prevalence of cardiovascular and respiratory diseases as well as emergency admissions to hospitals in the polluted metropolitan cities. The present study was conducted using Air Quality (AirQ) model and aimed to investigate the effects of air pollution on the number of emergency cardiovascular and respiratory patients admissions in Tehran hospitals during 2005-2014.

Materials and Methods: This was cross-sectional study. First, the needed hourly information was received from the Bureau of Air Quality Control, and the Environmental Protection Agency of Tehran City. Then, the information was validated according to WHO criteria, and the statistical indicators and the stages required to quantify the harmful effects of air pollutants were calculated by using appropriate application.

Results: According to the results, the number of cases admitted to the emergency ward of hospitals due to heart diseases (by exposure to particulate matter) during the years 2005 to 2014 were respectively 1797, 1280, 1766, 1980, 2132, 2703, 2389, 2594, 2158, and 2291 cases, totaling 20990 persons, and for respiratory diseases (due to exposure to particulate matter) during the same years were respectively 4643, 3301, 4650, 5117, 5511, 6999, 6180, 6452, 5577, and 5922 cases, totaling 54352 people. Also, the number of cases admitted to the emergency wards of hospitals due to chronic obstructive pulmonary disease caused by exposure to emissions of pollutants such as sulfur dioxide, nitrogen dioxide, and ozone were respectively, 1806, 2454, and 2941 cases.

Conclusion: Air pollution in Tehran increases the load of emergency visits to hospitals and increases the risk of respiratory and heart diseases. Therefore, measures to reduce and control air pollution and to prepare, equip, and mobilize hospitals, particularly emergency wards, are among important priorities that should be pursued seriously by the authorities.

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1. Introduction

According to WHO reports in 2014, seven million deaths are occurring annually due to air pollution. This shows that air pollutants are associated with a high rate of mortality [1]. Air pollution is one of the most important environmental issues that its exposure causes several harmful effects, and given its growing trend in many large cities of the world, it threatens human health [2, 3]. Tehran with more than 10 million population and home for many industries, along with its location, topography, and specific climate zone, is one of the most polluted cities in the world [4]. Air pollutants by penetrating human lungs induce or exacerbate respiratory illnesses such as emphysema and bronchitis. They can also exacerbate cardiovascular diseases and increase the number of cases admitted to hospitals and may also lead to early death [5].

In a study conducted by Dehghani et al. entitled "The Effects of Air Pollutants on Cardiorespiratory Patients Admitted to Selected Hospitals of the City of Shiraz" a significant correlation was found between the median carbon monoxide pollutants and cardiorespiratory patients admitted to studied hospitals [6]. Another study conducted by Younusian et al. in Tehran Heart Hospital entitled "The Relationship between Exposure to Air Pollution and the Onset of Acute Coronary Attacks Syndrome" employing the case-crossover design, showed a significant positive association between acute coronary syndrome and median 24-hour carbon monoxide as per the increase of each unit of carbon monoxide [7].

Another study by Goodini and colleagues entitled "The Relationship Between Concentration of Particulate Matter in the Air With the Number of Respiratory and Cardiac Patients Admitted to Hospitals in the City of Kermanshah in 2011" showed that the maximum and minimum numbers of admittance of respiratory patients had been, respectively, in the spring and winter seasons, and the maximum and the minimum numbers of admittance of cardiac patients were in the summer and autumn seasons. With regard to gender, male patients constituted the largest number of admitted patients. Connection between the number of admitted respiratory and cardiac patients with the existence of particulate matter in the air was statistically significant [8].

The problem of air pollution has attracted the political and scientific communities in the past decade and it seems that the damages of this phenomenon on human health are worthy of investigation. Tehran is one of the most polluted cities in the country and its level of air pollution increases each day in a way that conditions of life has become difficult and intolerable for many residents in this city. Therefore, it is expected that the number of patients admitted to the emergency wards of hospitals due to air pollution would increase in this city every year. Accordingly, there is a need for research in this area. Also, the authorities and experts should pay more attention in controlling air pollution. In addition, hospitals, especially emergency, cardiovascular, and respiratory wards should be prepared for admitting such patients. Hence, the present study was conducted with the aim of examining the effect of Tehran air pollution on the number of cardiovascular and respiratory emergency cases admitted to hospitals of Tehran during 2005-2014.

2. Materials and Methods

This study, conducted in the Greater Tehran metropolitan area, was a cross-sectional and descriptive study. We used AirQ 2.2.3 application to examine the effect of air pollution in Tehran on the number of cardiovascular and respiratory emergency admissions to hospitals. Hourly measurement of air pollutants was conducted by the Environmental Protection Agency and the Tehran Air Quality Control Institute through weather stations all over the city. The needed data were collected by referral to the mentioned organizations.

To determine the data validity for performing statistical analyzes, based on WHO criteria, the data recorded at weather stations were subjected to primary and secondary processing. In the primary processing, the exclusion of unnecessary data, sheet layout of the pollutants, and time standardization (to provide the median estimate) were performed and on the basis of WHO criteria, the number of weather stations with valid data were identified. In this regard, the ratio between the number of valid data for the 2 seasons (warm and cold season) should not be more than 2. Also, in order to achieve the median 24-hour values, at least 50% data must exist with sufficient validity.

For secondary processing in Excel, statistical indicators are needed, including annual average, warm season average, cold season average, and 98 percentile annual, the annual maximum, as well as the maximum values for warm and cold seasons of the pollutants. The population reported by Iran Statistics Center was considered as the population at risk of exposure to pollution. In the software, determination of the adverse health effects is related to the mass of the inhaled pollutant. Therefore, the input data should be in terms of weigh/volume units ($\mu g/m^3$). For this purpose, by writing the program in Ex-

cel and based on temperature and pressure conditions, the data were converted to proper units. For converting the unit of mass to unit of volume, the following general formula was used in which P represents air pressure, T represents temperature, and MW is molecular weight of the pollutants:

$$\frac{\mu g}{m^3} = \frac{P\ (mmHg) \times MW \times ppm}{62.4 \times T\ (°K)} \times 100$$

Attributable component or attributed ratio is a part of health outcome that is related to the exposure of specific population (assuming there is a possible association between exposures and health consequences without major confounding effect on this relationship) during a specified time period. This component is measurable using the following formula:

$$AP=SUM\{[RR(c)-1] \times p(c)\}/SUM[RR(c) \times p(c)]$$

Where RR(c): Relative risk of health consequence in group c or the target group, and P(c): The ratio of group c or the target group. The relative risk (RR) of the selected health consequences can be obtained with the help of exposure-response functions.

By knowing the rate of incidence on the basis of the selected health consequences (I) in the target community, the amount attributed to population exposure (or the number of cases per population unit) (IE) can be calculated as follows:

$$IE=I \times AP$$

In a population with the size of N, this rate can be converted to the number of estimated cases attributed to the exposure (NE):

$$N \times NE=IE$$

The user, instead of determining the quantity of incidence of the basis of health consequence, can use local statistics. As a result, the incidence of consequences in a population that is not faced with exposure (INE) can be estimated as follows:

$$1 \times INE=I-IE=(1-AP)$$

In addition to all attributed cases, we can estimate the distribution of attributed cases in terms of the pollutant's concentration intervals. By knowing the relative risk at a particular level of the pollutant's concentration and the incidence of the illnesses in the unexposed population, the level of added incidence, I+(c), and the number of added cases, N+(c), in an exposed group c can be calculated through the following formula:

$$I+(c)P(c) \times INE=RR(c-1)$$

All above formulas are based on the assumption that estimates used in this analysis have been controlled as regards to all possible confounding elements. By placing RR estimate confidence intervals in the formula, we can determine the low and high limits of AP estimate and the range of cases attributed to the expected exposure.

Eventually, by entering the processed data in AirQ, the results in the form of attributed component as regards to the number of emergency admissions to the hospitals of Tehran due to air pollution during the recent decade, were presented in the Tables 1-6.

3. Results

At first, after validation of data received from the Air Quality Control Institute and the Environmental Protection Organization, according to WHO criteria, the number of air stations in Tehran having valid data for analysis was identified. Of 11 stations in 2005, 14 stations in 2006, 14 stations in 2007, 15 stations in 2008, 18 stations in 2009, 37 stations in 2010, 36 stations in 2011, 42 stations in 2012, 35 stations in 2013, and 33 stations in 2014, 10, 10, 11, 11, 11, 19, 15, 33, 11, 29 stations, respectively were valid for air quality index calculation and quantification of the health effects of air pollutants. After carrying out the analyses based on the results derived from AirQ, the number of additional cases and the component attributed to air pollutants were estimated for the total number of emergency admissions for hospitalization. For calculating the health effects and consequences through AirQ, 2 methods can be implemented:

1) Using WHO default values for baseline incidence and relative risk (with 95% confidence intervals). By running the program, these values are automatically displayed.

2) Replacing the default values with estimates of baseline incidence and relative risk (95% confidence intervals) using national and regional epidemiological studies. Because, there is a great difference between Iran and Europe with regard to the age pyramid and the software's own default data are based on the European community, it cannot be used. Therefore by reviewing the relevant texts [9, 10], we used the incidence and relative risks calculated for Iran. Tables 1-6 below demonstrate the results related to quantifying the health effects.

Table 1. Estimate of relative risk indicators, component, and cases attributed to PM_{10} for emergency admissions to hospitals due to cardiovascular disease in Tehran (BI=436 for every 100000 persons).

Relative Risk (RR) as per every 10µg/m³						
Estimate indicator						
Upper limit		Central limit		Lower limit		
1.013		1.009		1.006		
Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Year
2539	7.19	1797.5	5.09	1219.1	3.45	2005
1820.5	5.02	1280.1	3.53	863.6	2.38	2006
2497.6	6.79	1766	4.8	1196.5	3.25	2007
2794.9	7.49	1980.6	5.31	1344.2	3.6	2008
3004.5	7.94	2132.2	5.63	1448.7	3.82	2009
3786.6	9.86	2703.6	7.04	1845.7	4.81	2010
3360	8.63	2389.6	6.13	1626.4	4.17	2011
3504.2	8.87	2494.1	6.31	1698.5	4.30	2012
3044.4	7.6	2158.1	5.38	1465.1	3.65	2013
3228.4	7.94	2291.1	5.63	1556.7	3.83	2014
29576		20990		14260		2005-2014

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Table 2. Estimate of relative risk indicators, component, and cases attributed to PM_{10} for emergency admissions to hospitals in Tehran due to respiratory illness (BI=1260 for every 100000 persons).

Relative Risk (RR) for every 10µg/m³						
Estimate indicator						
Upper limit		Central limit		Lower limit		
Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Year
6385.1	6.25	4643.8	4.55	2838	2.78	2005
4564.3	4.35	3301.3	3.15	2006.1	1.91	2006
6277.5	5.9	4650.9	4.29	2784.4	2.62	2007
7031.5	6.52	5117.9	4.74	3130.2	2.9	2008
7563.8	6.91	5511.7	5.04	3375.1	3.08	2009
9558.4	8.61	6999.8	6.31	4308.7	3.88	2010
8466.9	7.52	6180.7	5.49	3791.7	3.37	2011
8833.2	7.74	6452.1	5.65	3960.9	3.47	2012
7660.4	6.61	5577.2	4.81	3412.1	2.94	2013
8127.5	6.92	5922.5	5.04	3626.7	3.08	2014
74464		54352		33230		2005-2014

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Table 3. Estimate of relative risk indicators, component, and cases attributed to SO_2 for emergency admissions to hospitals of Tehran due to acute myocardial infarction (BI=132 for every 10µg/m³).

Relative Risk Indicator for every 10µg/m³						
Upper limit		Central limit		Lower limit		
1.0101		1.0064		1.0026		
Number of attributed cases (person)	Atributed component estimate (%)	Number of attributed cases (person)	Atributed component estimate (%)	Number of attributed cases (person)	Atributed component estimate (%)	Year
356.1	3.33	228.5	2.13	94	0.87	2005
733.6	6.68	476.5	4.34	198.7	1.81	2006
840.9	7.55	548	4.92	229.3	2.06	2007
345.5	3.06	221.4	1.96	91	0.80	2008
794.4	6.91	516.5	4.49	215.6	1.87	2009
418.8	3.6	268.9	2.31	110.8	0.95	2010
561.4	4.76	362	3.07	149.8	1.27	2011
484.6	4.05	311.7	2.6	128.6	1.07	2012
362.5	2.98	232.2	1.91	95.4	0.78	2013
352.6	2/86	225.8	1.83	92.7	0.75	2014
5245		3478		1401		2005-2014

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Table 4. Estimate of relative risk, component, and cases attributed to SO_2 for emergency admissions to hospitals due to chronic obstructive pulmonary disease (BI=101.4 for every 10µg/m³).

Indicator				Relative Risk (RR) for every 10µg/m³		
Upper limit		Central limit		Lower limit		
1.011		1.0044		1		
Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Year
297.1	3.61	121.5	1.47	0	0	2005
610.1	7.23	255.1	3.02	0	0	2006
698.8	8.17	293.9	3.46	0	0	2007
288.3	3.32	117.7	1.35	0	0	2008
660.5	7.48	276.6	3.13	0	0	2009
349.3	3.91	143.1	1.6	0	0	2010
467.7	5.16	193	2.13	0	0	2011
403.9	4.39	166	1.8	0	0	2012
302.5	3.24	123.4	1.32	0	0	2013
294.3	3.11	119.9	1.26	0	0	2014
3980		1806		0		2005-2014

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Table 5. Estimate of relative risk, component, and cases attributed to NO_2 for emergency admissions to hospitals in Tehran due to chronic obstructive pulmonary disease (BI=101.4 for every 10µg/m³).

Indicator				Relative Risk (RR) for every 10µg/m³		
Upper limit		Central limit		Lower limit		
1.0044		1.0026		1.006		
Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Year
297.9	3.62	178.7	2.17	41.9	0.51	2005
353.8	4.19	212.7	2.52	50.1	0.59	2006
566.8	6.62	344.3	4.02	82	0.95	2007
655.3	7.55	399.6	4.6	95.6	1.10	2008
427.5	4.85	257.7	2.92	60.8	0.69	2009
456.7	5.11	275.7	3.08	65.2	0.73	2010
318.2	3.51	190.7	2.10	44.7	0.49	2011
297.9	3.24	178.4	1.94	41.8	0.45	2012
359.6	3.85	215.9	2.31	50.7	0.54	2013
344.6	3.64	206.7	2.18	48.5	0.51	2014
3972		2454		576		2005-2014

Table 6. Estimate of relative risk indicators, component, and cases attributed to O_3 for emergency admissions to hospitals in Tehran due to chronic obstructive pulmonary disease (BI=101.4 for every 10µg/m³).

Indicator				Relative Risk (RR) for every 10µg/m³		
Upper limit		Central limit		Lower limit		
1.013		1.009		1.006		
Number of attributed cases (Person)	Atributed component estimate (%)	Number of attributed cases (Person)	Atributed componentestimate (%)	Number of attributed cases (Person)	Atributed component estimate (%)	Year
298.1	3.62	186.5	2.27	71.8	0.87	2005
425.4	5.04	286.3	3.39	149	1.76	2006
453.6	5.3	285.7	3.34	110.7	1.29	2007
652.6	7.52	414.6	4.78	162.1	1.86	2008
596.3	6.77	377.8	4.29	147.2	1.67	2009
509	5.7	321.1	3.59	124.6	1.39	2010
435.7	4.81	273.9	3.02	105.9	1.16	2011
447.4	4.87	281.3	3.06	108.8	1.18	2012
442.5	4.75	278.1	2.98	107.5	1.15	2013
383.7	4.06	240.5	2.54	92.7	0.98	2014
4640		2941		1175		2005-2014

4. Discussion

In the present study, the number of emergency cases admitted and hospitalized due to cardiovascular and respiratory illnesses, chronic obstructive pulmonary disease, and heart attack resulting from exposure to air pollutants in the Greater Tehran metropolitan area during the recent decade was quantified and estimated by employing the AirQ model. The results of the study showed that air pollution has increased the emergency admissions of respiratory and cardiac patients to hospitals in Tehran. Quantifying the effects of air pollution, especially defines how much the people are affected by air pollutants and demonstrates better the critical condition of air quality. Establishing a direct link between the exposure to different concentrations of air pollutants and their impact on human health is very difficult.

This method is one of the most valid methods provided by the World Health Organization used for examining the health effects attributed to air pollutants. According to Tables 1 and 2, the numbers of cases attributed to PM_{10} for hospitalization due to cardiovascular and respiratory illnesses during the past decade have been 20990 and 54352 persons, respectively, which shows that particulate matter is responsible for more emergency admissions as compared with other causes. The studies conducted by Kosha and colleagues have also shown that there is a significant relation between the concentration of particulate matter and the number of admissions of cardiovascular and respiratory patients to the hospitals in Tabriz. They demonstrated that by increase in the concentration of particulate matter, the number of admissions of patients suffering from the above mentioned illnesses to hospitals has increased [11].

The study by Ebrahimzadeh et al. also showed that by every 110 µg increase of air pollutant in a cubic meter of air, there will be an increase of 1.35% and 0.021%, respectively, in the incidence of cardiac and respiratory illnesses in Sanandaj [12]. Studies by Pan et al. showed significant relationship between storms of dust and particulate matter with increase in hospital admissions [13]. According to the studies by Al-Hurban, high concentration of particulate matter in the storms of dust leads to bronchitis, asthma, and allergies [14]. Research by A. Peter et al. showed a close relationship between daily changes in particulate matter and hospital admissions and worsening of symptoms in cardiovascular patients [15].

According to Table 3, the number of emergency admissions to hospitals due to acute myocardial infarction resulting from exposure to sulfur dioxide during the past decade is 3478 patients. According to Tables 4-6, the numbers of emergency admissions in hospitals due to chronic obstructive pulmonary disease resulting from exposure to sulfur dioxide, nitrogen dioxide, and ozone are respectively, 1806, 2454, and 2941 patients.

Studies carried out in Tehran also showed that in addition to particulate matter, sulfur dioxide and nitrogen dioxide are the most important causes of death resulting from cardiac diseases in Tehran [16]. Masjedi in his study also showed that there was a significant relationship between air pollutants of sulfur dioxide and nitrogen dioxide and asthma attacks in Tehran [17]. High level of sulfur dioxide arises from failure to remove sulfur from fuel, especially diesel fuel. Regarding the issue of transportation and industries located in the city, the use of heavy fuels such as fuel oil and diesel fuel with high-sulfur content has a significant role.

In another research in Australia, the most important factor for admission of patients to the emergency ward of hospitals in Brisbane City due to respiratory complications, besides particulate matter with diameter less than 10 microns, was ozone as a pollutant agent [18]. Zhong also showed that the most important factor in admission of children to hospitals is asthma attack resulting from exposure to particulate matter and ozone [19]. Based on a research conducted during 14 years in Toronto, Canada, the median annual number of hospital admissions due to chronic obstructive pulmonary disease was 8 patients, 40.4% of whom were reported as the result of exposure to nitrogen dioxide [20].

In a study done by Ghanbari et al. in Tabriz entitled "The Effect of Exposure to Nitrogen Dioxide, Ozone, and Sulfur Dioxide on Hospital Admissions Resulting From Chronic Obstructive Pulmonary Disease in the City of Tabriz" it was shown that there is a direct link between exposure to gaseous pollutant and respiratory diseases and chronic obstructive pulmonary disease in a way that in Tabriz during just 1 year, 69 patients were hospitalized due to respiratory illnesses; out of them, 32 cases suffered from chronic obstructive pulmonary disease [21]. Based on the present study results, most important air pollutant agent of the air in Tehran is the particulate matter.

To summarize, the research findings have shown a significant and positive relationship between the respiratory and cardiac patients admitted to the hospitals and air pollution in Tehran. By equipping, mobilizing, and preparing hospitals, health care centers, and other related centers, as well as specialized training and better preparation in health centers, the adverse health effects can be

minimized at the time of air pollution. It is noteworthy that in all formulas used in AirQ model, it is supposed that estimates used in the analysis were controlled as regards to all possible confounding factors [22].

5. Conclusion

Increasing population has led to uncontrolled urban development and increased use of fossil fuels which are the main causes of air pollution. Generally, the number of cardiovascular and respiratory illnesses as well as the chronic obstructive pulmonary disease and heart attacks clearly indicate the impact of air pollution on the health of citizens. Therefore, proper and effective planning is needed to control and reduce the harmful impacts of air pollutants, especially the particulate matter. Results of this study and software output showed that air pollution in Tehran has increased the load of emergency admissions to hospitals as well as the incidence of respiratory and cardiac illnesses.

Therefore, the readiness and mobilization of hospitals, especially the emergency wards, are among the important priorities that should be seriously considered by the authorities. Obviously, the preparedness and mobilization of hospitals and health centers can play an effective role in reducing the adverse effects resulting from air pollution. Also, the decision-makers and authorities should employ appropriate, practical, sustainable, and enforceable resolutions based on scientific studies to reduce and control air pollution in the Greater Tehran metropolitan area.

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Conflict of Interests

The authors declared no conflict of interests.

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