RESEARCH ARTICLE

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Cardiopulmonary Mortalities and Chronic Obstructive Pulmonary Disease Attributed to Ozone Air Pollution

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A-B-S-T-R-A-C-T

Background & Aims of the Study: Ozone is a summer pollutant which can cause respiratory complications, eye burning sensation and failure of immune defense against infectious diseases. Ahvaz city (southwestern Iran) is one of the seven polluted Iranian metropolises. In this study we examined the health impacts of ozone pollution in Ahvaz city during years 2010 and 2011.

Materials & Methods: The health effects of ozone pollution in Ahvaz estimated by determining mortality and morbidity, and incidence of diseases attributed to the ozone, *i.e.*, cardiopulmonary mortalities and chronic obstructive pulmonary disease (COPD) using Air Quality Model. Ozone data were taken from Ahvaz Department of Environment (ADoE). Conversion between volumetric and gravimetric units (correction of temperature and pressure), coding, processing (averaging) and filtering were implemented.

Results: Sum of accumulative cases of mortalities attributed to ozone was 358 cases in 2010 and 276 cases in 2011. Cardiovascular and respiratory mortality attributed to ozone were 118 and 31 persons, respectively; which revealed a considerable reduction compared to those values in 2010. Number of cases for hospital admissions due to COPD was 35 in 2011, while it was 45 cases in 2010. The concentration of ozone in 2011 was lower than that of 2010 and this is why both mortalities and morbidities of 2011 attributed to ozone pollutant had decreased when compared to those values of 2010.

Conclusions: Mortality and morbidity attributed to ozone concentrations in 2011 were lower than those of 2010. The most important reason was less concentration in ground level ozone of 2011 than that of 2010 in Ahvaz city air.

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Background

Reports of air pollution effects on the human health and the resulted death toll have been carried out by epidemiological investigations throughout the world for the last two decades. It has been showed that the rate of death toll attributable to the air pollution is increasing (1, 2). United States National Ambient Air Quality

Standards (NAAQS) lists air pollutants as CO, OZONE, particulate matter equal or less than 10 micrometer (PM_{10}), SO_2, NO_2, and Lead (Pb) (2). On average, every person breathes in 10 m^3 of air every day and this is why health impact studies on air pollutants are very importance (2-4).

The health impacts of air pollution can be classified into short and long term impact. Health end points such as death tolls, hospitalization, and respiratory and cardiovascular diseases have been categorized into short and long term. According to estimates of World Health Organization (WHO) 800,000 lives are lost prematurely due to cardiovascular and respiratory diseases caused by air pollution throughout the world. Nearly 150,000 lives are lost in south Asia in 2003 (5,6).

The predictive models of concentration of air pollutants can be classified into categorical and statistic groups. The categorical models of the air pollution which reflect the fundamental state of turbulence transfer in the atmosphere are considered to be the sensitive device of modeling gas pollutants, though the results of these models were always significantly erroneous.

The reasons for the errors could be the brief and partial description of the complex processes in the atmosphere. Many factors help the increase of errors in these models. The most important ones refer to the indefiniteness caused by the inherent changeability of the atmosphere. These models are based on the assumption that the pollutants spread in homogeneous conditions.

In addition, the consequences of the above mentioned models (which are based on Gaussian models) are mainly based on a simple design which assumes the turbulence to be in the sustainable classes. Meanwhile each class covers an extensive range of the stability conditions in the atmosphere which is dependent on the wind speed, solar radiation and cloud coverage (8).

These factors along with the other factors such as difficulties of accessing to the correlations of dispersing pollutants which are difficult to access in most cases and the structural complexity of the categorical models have drawn special attention to the advanced statistical models (9,10).

The statistical procedures are considered to be easier strategies for prediction of concentration of pollutants and their impacts on health via the available data from the weather forecast, air pollution and the analysis of statistical correlation among them. Using these procedures, short term prediction of air pollutants have confirmed the usefulness of the statistical devices (11,12).

The statistical models do not require any diffusion data and indices either. They have simpler structures than categorical ones. So far numerous statistical methods have been used to predict the concentration of air pollutants, including linear and nonlinear regression models (14), artificial neural network and neural, phase (15), and comparative and deductive systems.

Models estimating health impacts of air pollutants combine the air quality data with the epidemiological parameters such as Relative Risk of basic occurrence and its attributable components in concentration intervals. The models also display the output in the form of death toll (16).

Geographical features of Ahvaz: Ahvaz city, the capital of Khuzestan Province (southwestern Iran), with an area of 8152 km^2, is located between 48 degrees to 49°29′ east of Greenwich meridian and between 30 to 32 degrees and 45 minutes to the north of the equator.

It has a semi-humid and sweltering climate. Ahvaz is located in the dry area of Iran and its average yearly rainfall is about 250 mm. In 2011 its population was 970,000 people.

Ozone is a powerful oxidant. It is created as a secondary pollution under the effects of sun radiation.

The average daily concentration of ground-level ozone pollution (tropospheric ozone) is 0.06 ppm. The value has been calculated above the Atlantic Ocean at the height of 3000 meters. The one-hour concentration has been more than 0.18 ppm in some European countries (17).

The ozone concentration in Tehran (Capital of Iran) changes greatly and depends on the sun radiation and NO_2 concentrations. It has been reported 21.4 ppb in August and 1.7 ppb in September at maximum and on average about 4 ppb. This is different from the stratosphere ozone which absorbs UV radiation and protects life on the Earth.

The following formula represents the ozone formation on the earth surface (lower layer of troposphere) (18):

$$VOC+NOX+Heat+Sunlight \rightarrow Ozone$$

Where: VOC=Volatile Organic Compound; NOX= Nitrogen Oxide

The maximum concentration of ozone is formed in the afternoon. In general it is a summer pollutant. The maximum concentration of ozone rarely lasts for 2 to 3 hours on the earth surface. Half of the pollutant lasts for 3 days at 20°C.

Inhalation is the entry way of ozone into the body. Forty percent of ozone is absorbed in the nasal cavity and larynx, while the remaining 60% penetrates into the lungs (19-23).

In general, according to Miller, the ozone enters the body as follows:

- The ozone is able to penetrate into every pore of the lung tissue depend on the primary concentration;
- Small amounts of ozone is absorbed into the blood;
- A small increase in ozone concentrations affects bronchioles slightly, but its main effect is on the lower parts of lung such as alveolar system. It is mostly absorbed by alveolar sacs. (24,25).

Table 1 shows ozone concentrations causing 5% decrease in air output volume (26).

Table 1) Ozone concentration (ppb) causing 5% decrease in air output volume

Health Status	2 Hours Mild	2 Hours Severe	6.6 Hours Mild	2.5 Hours Very Severe
Healthy	300	250	70	160
Sensitive	100-150	80-120	--	--

Health impacts of ozone: Ozone exerts its effects using following mechanisms:

a) Oxidation of sulfides, amino acids, enzymes, co-enzymes, proteins, and lipids;

b) Oxidation of unsaturated fatty acids into the peroxides.

The membranes are made of both proteins and lipids; therefore, they are the proper targets for the ozone attack. Studies on human and animals showed that some pulmonary disorders and complications are caused by the ozone exposure.

United States National Ambient Air Quality Standards has established 0.075 ppm as the highest daily maximum 8- hour ozone concentrations (27-30).

Epidemiologic studies on children have shown that their lung function decreases at the ozone concentrations 200 $\mu g/m^3$ or less. Other reports have indicated that the lung function fluctuate when they contact with 160 to 340 $\mu g/m^3$ ozone. These fluctuations can be intensified at high temperature and in presence of other pollutants. Other symptoms such as cough and headache are associated with 160-300 $\mu g/m^3$ concentrations of ground level ozone.

The ozone inhalation without other oxidants also causes the pulmonary complications even at lower concentrations. Furthermore reports of untimely exhaustion and sports record drops have been received from the areas of high ozone (*e.g.*, Los Angeles). Studies on animals exposed to ozone showed that side effects of ozone exposure have been appeared in concentrations 160 to 400 $\mu g/m^3$ (0.08 to 0.2 ppm). The effects included susceptibility to lung infections in rats (31-34).

The ozone effects can be summarized as follows:

1. Histological changes in bronchiolar epithelium when it is in long -term exposure to ozone concentrations of 1 to 0.2 ppm;
2. Changes in lungs function in contact with ozone concentrations of 0.3 ppm for two hours which is reversible after discontinuation of the contact.
3. Changes in the protein structure of lungs after one hour of contact with ozone;
4. Biochemical changes of lungs and other organs after four hours of contact with ozone concentrations of 3 to 6 ppm;
5. Increased susceptibility to bacterial infections in a three- hour contact with ozone concentration of 0.8 ppm;
6. Effect on expiratory volume (35-38).

Aims of the study: Ahvaz (southwestern Iran) is one of the seven air polluted Iranian metropolises. In this study we studied the health impacts of ozone pollution in Ahvaz during years 2010 and 2011.

Materials & Methods

This study consists of two parts: the first part deals with quantifying and surveying the health impacts of ozone in Ahvaz city using Air quality (Air Q) model, and the second one pertains to predict and estimate the amount of ozone pollution with the use of Minitab statistical software.

The procedure was designing input file for the model from the raw data. For this purpose, the following steps were performed:
1. Modification of temperature and pressure, and conformation of doses with the model;
2. Primary processing: This stage included deletion, spreadsheet of pollutants and synchronization for the average estimate;
3. Secondary processing: This stage involved three parts of code writing, mean calculation, and condition correction.
4. Primary filtering;
5. Secondary filtering;
6. Quantifying ozone by means of Air Q software.

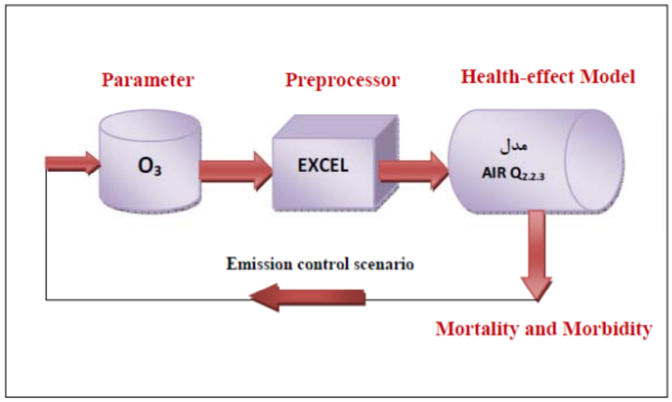

Figure 1) Schematic plan of the study

Data analysis: Air Q model is based on statistical equations. Sample community was Ahvaz city (southwestern Iran) which its population has been estimated one million persons.

Data capture was collected for criteria air pollutants. Attributable proportion (AP) was calculated as following formula:

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

Where: p(c) is population of city; RR is relative risk

Relative Risk (RR) is a ratio of the probability of the event occurring in the exposed group versus a non-exposed group.

$$RR = \frac{Probability\ of\ event\ when\ exposed}{Probability\ of\ event\ when\ non-exposed}$$

Attributable proportion was multiplied at baseline incidence and divided to 10^5. Obtained value should be multiplied at population (10^6). The results will be the excess cases of mortality or morbidity attributed to given pollutant (ozone).

Results

The results of quantifying ozone in Ahvaz city obtained in percentage using the model explicated and the numbers of consequences are shown in the following tables and figures.

Table 2) Ozone concentrations (μg/m^3) by means of the model (Ahvaz- Iran, 2011)

Parameter \ Weather Forecast Station	Meteorology (maximum)	Downtown (minimum)	Ahvaz
Annual, average maximum of one hour	81.81	66.98	72.67
Average maximum of one hour for the summer	96.41	78.87	84.38
Average maximum of one hour for the summer	66.64	54.62	60.51
98 percentile (one hour, annual)	186.62	133.98	121.24

Table 3) Estimation of indexes for the relative risk part and cases Attributable to the ozone for the total mortality (Ahvaz-Iran, 2011) (baseline incidence = 1013)

Estimated Number of Excess Cases (Persons)	Attributable Proportion(%)	RR High	Index Estimation
169.9	1.7312	1.0028	Low
276.1	2.8128	1.0046	Middle
391.4	3.9870	1.0066	High

Table 4) Estimation of indices for the relative risk part and cases Attributable to the ozone for the mortality caused by cardiovascular diseases (Ahvaz- Iran, 2011)

Estimated Number of Excess Cases (persons)	Attributable Proportion(%)	RR Medium	Index Estimation
59.8	1.2427	1.002	Low
118.2	2.4549	1.004	Middle
175.2	3.6377	1.006	High

Table 5) Estimation of indices for the relative risk part and cases attributable to the ozone for the mortality caused by Respiratory Diseases (Ahvaz-Iran, 2011)

Estimated number of excess cases (persons)	Attributable Proportion(%)	RR Medium	Index estimation
15.7	2.4549	1.004	Low
30.6	4.7922	1.008	Middle
44.9	7.0201	1.012	High

Table 6) Estimation of indices for the relative risk, part and cases attributable to the ozone for chronic obstructive pulmonary disease (Ahvaz- Iran, 2011)

Estimated Number of Excess Cases (Persons)	Attributable Proportion(%)	RR Medium	Index Estimation
13.4	1.3653	1.0022	Low
34.6	3.5208	1.0058	Middle
54.9	5.5840	1.0094	High

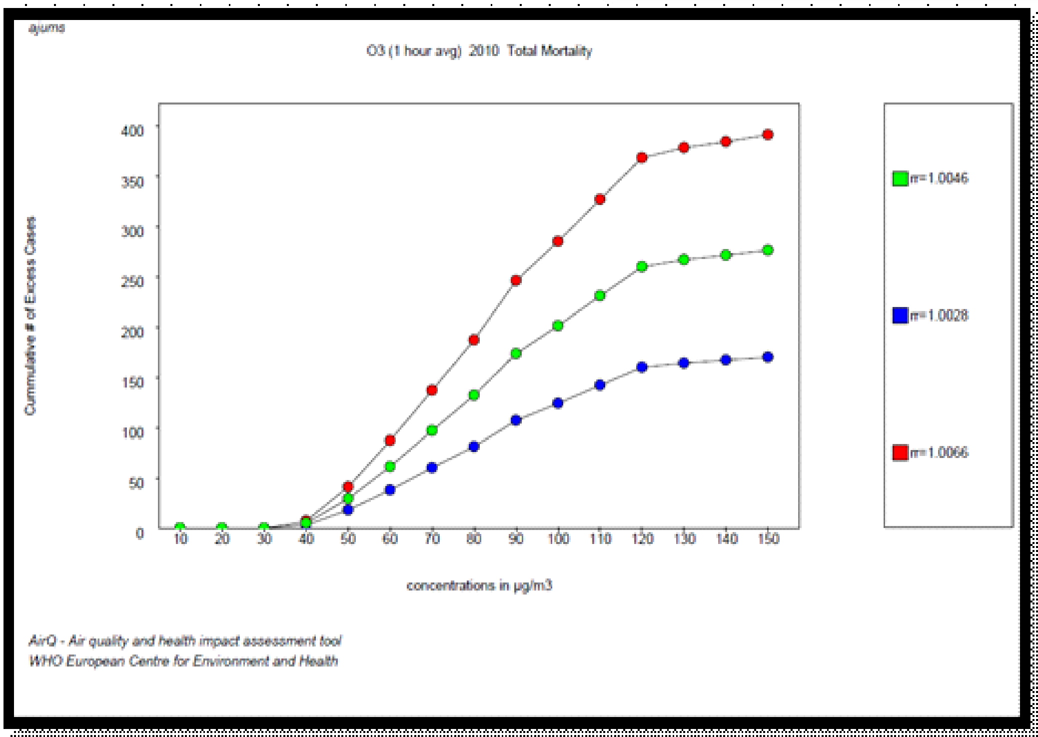

Figure 2) Estimation of total and cumulative number of mortality cases Attributable to ozone comparing concentration intervals by means of the model (Ahvaz-Iran, 2011)

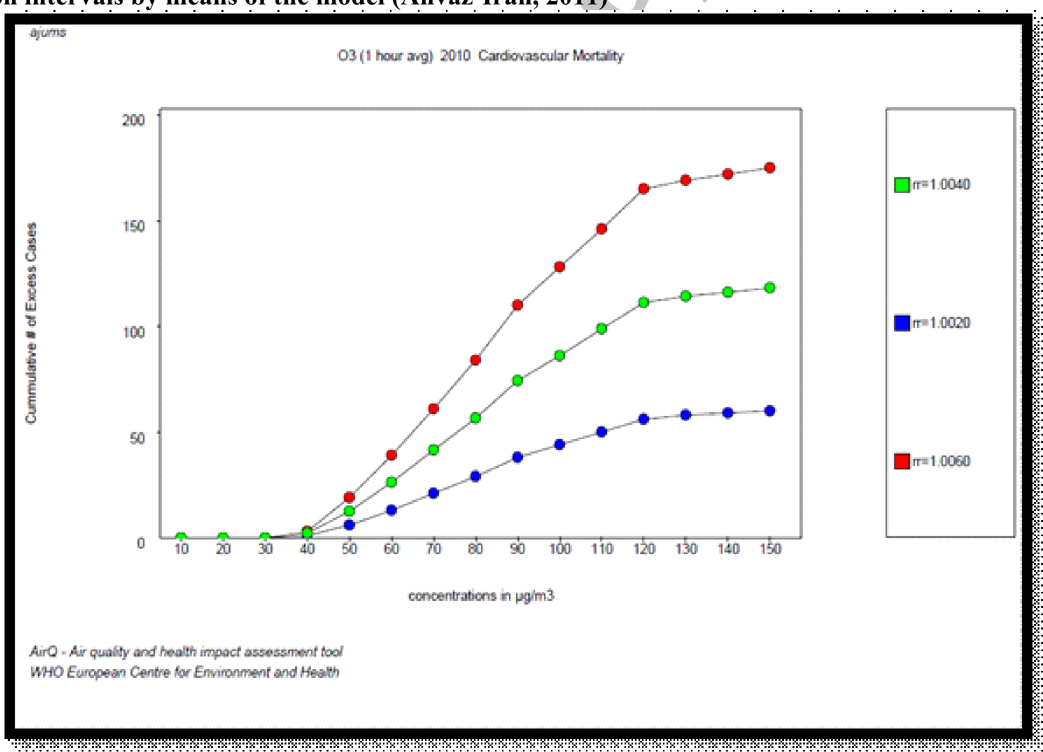

Figure 3) Estimation of cumulative number of mortality cases created cardiovascular Diseases Attributable to ozone comparing concentration intervals (Ahvaz-Iran, 2011)

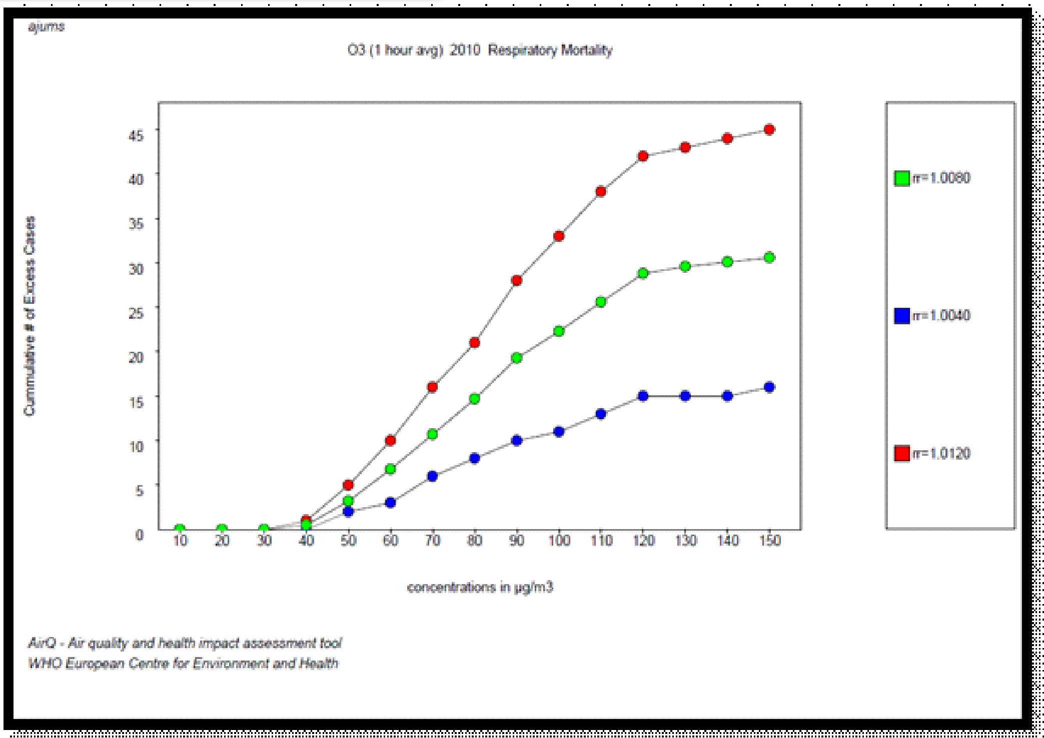

Figure 4) Estimation of cumulative number of mortality cases made by the Respiratory Diseases Attributable to ozone compared to the concentration intervals by means of the model (Ahvaz-Iran, 2011)

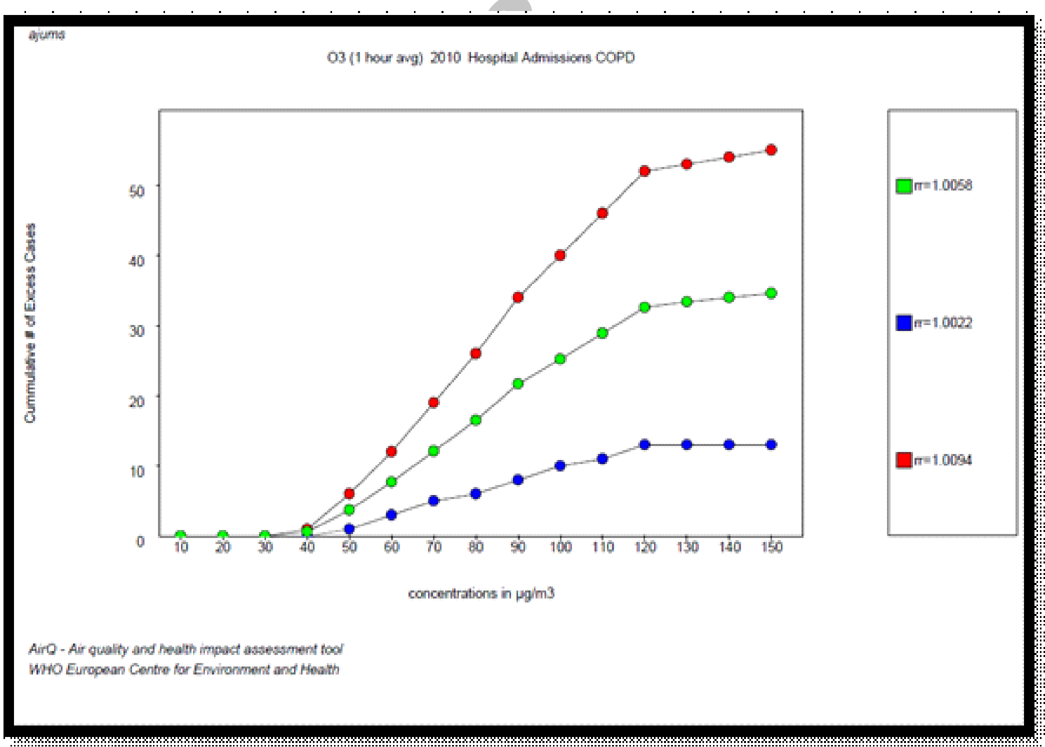

Figure 5) Estimation of cumulative number of cases in reference to hospitals because of chronic obstructive pulmonary disease (COPD) Attributable to ozone comparing concentration intervals by mean of the model (Ahvaz-Iran, 2011)

Discussion

Table 2 shows that the weather forecast and downtown station have got the most and the least amount of concentrations in terms of average maximum for one hour during summer, winter and the whole year. It also shows that the maximum hourly average ozone concentrations during year, summer, winter and 98 percentile have been 72.67, 84.38, 60.51, and 121.44 μg/m^3, respectively. In addition, the maximum mean of ozone concentration in summer has been more than concentration in winter.

Estimation of RR, partial percentage or attributable ratio, and the number of cases for all mortalities attributed to ozone have been showed in table 3. The scientific certainty of the RR for health impacts (the whole mortality) is high. The total number of mortality cases due to ozone has been 276 cases in 2011. Mortality cases have been reduced by 82 in comparison to the previous year. The figure has been appraised with regard to the concept for the basic outbreak of 2.81% mortalities occurred in Ahvaz city. It has been reduced 0.83% more than the previous year. The rate of mortality risk increases by 0.46% per each 10 μg/m^3 increase in the ozone concentration. Although about 62% of whole mortalities happened during the days when ozone concentrations has not surpassed 90 μg/m^3. Also the greatest number of death toll [n=41 (15%)] has occurred in concentrations of 80 to 90 μg/m^3.

Relative Risk equal to 1 has no impact. Therefore ozone concentrations less than 10 μg/m^3 correspond to relative risk equal to 1, indicating not tangible health impact on human. The great slope of curve in the area of 80 to 90 μg/m^3 concentration interval confirmed that a large number of mortalities occurred in this region (figure 2).

The RR of cardiovascular mortality has increased by 0.4% with 10 μg/m^3 increase in the ozone concentrations.

Regarding to the same trend in fluctuation of cardiovascular and death toll rates, the highest death toll is associated with 80-90 μg/m^3 concentration interval of ozone, while 83% of the cardiovascular mortalities attributed to ozone were related to days when the ozone levels has not exceeded 110 μg/m^3.

Based on figure 3, the cumulative number of cardiovascular mortality cases has been estimated to be 118 cases in Ahvaz city, which displays a reduction of 35 cases approximately equal to 0.73% compared with the previous year (175 casualties per CI= 0.95) in accordance to baseline incidence equals to 497 among 100,000 lives the number has nearly been 2.45% of the whole cardiovascular mortalities in Ahvaz city.

As table 5 shows the estimated rate of the relative risk for the respiratory mortality has been of acceptable and scientific certainty because the central number of the index has been assessed to be 1.008 (1.004 per CI=0.05 and 1.012 per CI= 0.95). On this basis, the cumulative number of respiratory mortality cases has been computed to be 31 cases (cCompared with the previous year, 9 fewer deaths occurred.).

The highest rate of death (5 cases) equal to 15% related to the same illness corresponds to concentrations of 80 to 90 μg/m^3. About 83% of the whole respiratory mortalities due to ozone pollution have occurred during the days when ozone concentrations have not surpassed 110 μg/m^3.

In the case of referring patients to hospitals due to chronic obstructive pulmonary disease (COPD), the relative risk indices with the acceptable scientific certainty have been appraised to be 1.0058 and the attributable ratio equal to 3.52% (1.0022 per CI= 0.05 and 1.0094 per CI= 0.95)(1.36% per CI=0.05 and 5.58% per CI= 0.95).

According to table 6, the relative risk (RR) of this disease has increased 0.58% in lieu of each 10 μg/m^3 increase in ozone concentrations (0.22% per CI= 0.05 and 0.94% per CI= 0.95).

The cumulative number for respiratory disease has been 35 losses, which is indicative of a reduction for 10 losses compared to the previous year (13 losses per CI= 0.05 and 55 persons per CI= 0.95); meanwhile 83% of outpatients with COPD attributed to the ozone belongs to the days when the ozone concentrations has not surpassed 110 μg/m^3.

Rate	Place/Year	Effect
About 2.45- 3.5- 4.79 percent	Ahvaz 2011	Cardiovascular, respiratory mortalities and hospitalization of patients suffering from the chronic disease of lung clogging in concentrations more than 30 μg/m^3.
Nearly 0.60- 5.39- 3.77 percent	Bushehr 2011	Cardiovascular and respiratory death toll, hospitalization of patients suffering from the chronic disease of lung clogging in concentrations more than 30 μg/m^3
Roughly 1.79- 5.39- 3.77 percent	Tehran 2008	Cardiovascular and respiratory mortalities hospitalization of patients suffering from the chronic disease of lung clogging in concentrations more than 20 μg/m^3.
About 3.18- 6.17- 4.5 percent	Ahvaz 2010	Cardiovascular and respiratory mortalities and hospitalization of patients suffering from the chronic disease of lung clogging in concentrations more than 30 μg/m^3.

Consequently the cardiovascular mortalities attributed to the ozone have decreased in Ahvaz in 2011 compared to 2010. However, comparing instances of Tehran and Bushehr (southwestern Iran), its figure of losses has been higher because flu concentration of the ozone pollutant in Ahvaz has been higher than Tehran and Bushehr.

Conclusions: Our study indicated that mortality and morbidity attributed to ozone concentrations in 2011 were lower than 2010. The most important reason was less concentrations in ground level ozone in 2011 than that of 2010 in Ahvaz city air.

Footnotes

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Conflict of Interest:

The authors declare no conflict of interest.

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