Quantification of Health Impacts Related to PM$_{10}$ and O$_3$ Pollutants in Karaj City

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ABSTRACT

Although the numbers of death related to air pollution appear to be low, the incidence of related disease to air pollution would be too high that is because of exposure of the large population to air pollutants and also the existence of certain sensitive groups. The aim of this study was to quantification health impacts of two pollutants PM$_{10}$ and O$_3$ in Karaj city during 2012-2013. In this study, the air quality data were obtained from Karaj Department of Environment Protection. Quantification the health impacts of air pollutants were assessed using AirQ2.2.3 model which is a proposed method for assessing the health impact of air pollutants by World Health Organization. The annual, warm, and cold average concentration of PM$_{10}$ were 77.48, 87.86, and 62µg/m$^3$, respectively. O$_3$ average concentration in the warm semester was 63.5µg/m$^3$ and it is more than a cold season which was 60µg/m$^3$. Total mortality rate related to PM$_{10}$ and O$_3$ were assessed 282 and 164, respectively, which are 3.9 and 1.53 percent of all deaths, respectively. The Average cases of obstructive lung disease related to O$_3$ were 58 people and average cases of hospitalization due to cardiovascular diseases related to PM$_{10}$ were 492 people. This study was the first attempt to reveal the health outcome of air pollutants on a human in Karaj as one of the crowded city of Iran. Totally we found that the average concentration of 8-hours O$_3$ and 24-hours PM$_{10}$ were higher than the national standard of Iran and WHO guideline.

Keywords: Air Pollution, Cardiovascular Diseases, Hospitalization, Karaj City, Related Death

INTRODUCTION

Nowadays, Air pollution is a non-separable part of modern lifestyle which is the introduction of chemical matters, particulates, and biological materials into the atmosphere that causes discomfort, some diseases, probably of humans die, and damages other living organisms such as agriculture products, and natural environment [1, 2]. Particulate matters (PM) originate from natural and man-made resources and are a complex mixture of extremely small particles and liquid droplets which have a great share in megacities air pollution [3-5]. The size of particles is directly linked to their potential health problems [6]. PM$_{10}$ can pass through the upper respiratory tract and precipitate in the lungs, and eventually cause heart and lungs disorders [7].

Exposure time, PM concentration, age and overall health of exposed people, activity level and breathing rate, and type and toxicity of the PM are the several factors that determine the extent of health effects of particulate matters [8-10]. Permanent lung damage, chronic shortness of breath, aggravated asthma, nonfatal heart attacks, decreased lung function, fatigue, and irritation of the airways, are results of breathing in a location with a heavy concentration of PM [9, 11-13]. Although stratospheric ozone is as a good layer because it protect people against ultraviolet (UV) radiation which is formed naturally via of interaction of solar ultraviolet radiation with molecular oxygen, tropospheric ozone consider as a secondary air pollutant which is form via some complex photochemical reactions between two important classes of air pollutants, volatile organic compounds.

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(VOC) and nitrogen oxides (NOx) [14]. Tropospheric ozone can irritate the respiratory system, reduce lung function, inflame and damage cells that line lungs, make lungs more susceptible to infection, aggravate asthma, and aggravate other chronic lung diseases such as emphysema and chronic bronchitis [15-18]. The aim of this study was to quantification and assessment of particulate matters (PM) and ozone (O3) health effects in Karaj city during 2012 and 2013.

MATERIALS AND METHODS

Study area and demographic parameters

Karaj city with 162 square kilometers situated near Tehran city (capital of Iran). It is located in the center part of Iran at an altitude of 35°12’ to 35°21’ north and longitude of 50°18’ to 51°26’ east. This city has been enclosed by Alborz mountain ranges in north and internal plains of Iran plateau in the south. According to the last census, Karaj city with a population over than 1900000 was the 5th populated city in Iran. After Tehran city, this city has the most immigration among the Iranian cities. Karaj city has many environmental air pollution potentials. It can be due to the specific location of Karaj city which is located near to highway connecting to the western parts of Iran, as well as vicinity to the capital of Iran and having so many factories and industrial area. So investigating the health impacts of air pollutants such megacities looks remarkable [19].

Correlation evaluation and relative risk (RR) calculation

Relative risk (RR) present the increase in the probability of the side effect associated with a specified change in the exposure levels and obtained from time-series studies where daily changes in air pollutants over long periods were depending on daily mortality, hospitalization and other public health indices [20]. RR values used in this study are shown in Tables 1-5. The RR data applied for PM10 were derived from a quantitative meta-analysis data with a focused on European investigations [21]. Next, for O3 short-term effects the RR, we used directly data come from the previous investigation conducted by the Air Pollution and Health: a European Approach (APHEA) [22]. However, the baseline rates of all mortality from January 01, 2012 to January 01, 2013 were obtained from death evidence documented at the Civil Registration Office of Karaj, also for hospital admissions, we used the baseline rates that suggested by WHO [20].

Air Q2.2.3 software is designed to assess health effects of air pollutant. In this software, Contact-response information has combined with population exposure data [20]. Consequently, expected health effects would estimate. After evaluation of this software, it was released by the European health and environment Centre of WHO to facilitate health effects assessment of air pollutants.

Health impact assessment of air pollution

Attributable proportion (AP) is a part of the health outcomes associated with exposure to the specific population during a specific time which can calculate by equation (1).
\[ AP = \frac{\text{SUM} \{ [RR(C) - 1] \times P(C) \} }{\text{SUM} \{ RR(C) \times P(C) \} } \]  

(1)

Where RR(C) associated to the relative risk at stated group which is obtained as the ratio of the probability of the event in the exposed group against a non-exposed group and P (c) denotes the proportion of the stated group population (2).

\[ AP = I \times IE \]  

(2)

Where Incident Exposure (IE) refers the rate of the health outcome attributable to the exposure and I denote the baseline frequency of the health outcome in the population [20]. In a specific population, the number of estimated cases attributable to exposure can obtain as the equation (3).

\[ NE = IE \times N \]  

(3)

Where the Number of Estimated (NE) represents cases attributed to the exposure and N represents the size of the study population [20].

**Exposure assessment**

For the studied pollutants, the parameters required by the AirQ software (annual and seasonal maximum and annual 98th percentiles) were obtained and the concentrations were recorded to 10μg/m³ categories, corresponding to equivalent exposure categories. The data for PM₁₀ and O₃ were expressed as daily averages and 8 h-moving average, respectively. In view of the city of Karaj, have a population over than 1900000, exposure was estimated. In the AirQ software assumes that concentrations measured are representative of the average exposure of the people. For example, if on 10% of sampling days concentrations were between 10 and 20μg/m³, it was assumed that people were exposed to the corresponding concentration for 10% of their time. In continuing all necessary data which include air quality and exposed population data were entered into the software. In addition, estimation of the excess total mortality and health effect outcomes include cardiovascular diseases and respiratory diseases as a result of short-term exposure to PM₁₀ and O₃ were calculated based on Baseline Incidence (BI) and RR of WHO suggestions.

**Input adjustments**

In order to prepare the input data to the model, pressure and temperature should be corrected and also units have to adjust. Temperature data were collected from Meteorological Organization of Karaj city and barometric formula (equation (4)) was used to convert temperature to pressure [23, 24].

\[ \frac{P}{P_1} = \left( \frac{T}{T_1} \right)^{\frac{g_0}{R\lambda}} \]  

(4)

where P and P₁ donate the atmospheric pressures (mbar) at sea level and at height z (m), respectively; T and T₁ are the temperatures of the atmospheric layer at sea level and at height z; g₀ is the gravitational acceleration (m/s); R is the universal gas constant for air (8.3144598J/mol/K); and λ is the specified constant and defined by dT/dZ (K/m).

Some of pollutants concentration units in the software are inconsistent with pollutants concentration units in air pollution stations. The recorded units for PM₁₀ and O₃ in the monitoring stations were μg/m³ and ppb, respectively. To fit the units in the software, it would be necessary to transfer their units to μg/m³ by equation (5)

\[ C \left( \frac{\mu g}{m^3} \right) = \frac{C(\text{ppm}) \times MW}{V} \times 1000 \]  

(5)

Where C is the concentration of gaseous composition, MW expressed the molecular weight of the gaseous composition (g), and V is related to the volume of one mole of pure gas at the 1 atmosphere pressure and 0°C temperature [25].

The ideal gas equation derived from standard temperatures and pressures condition according to equation (6) [20];

\[ \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \]  

(6)

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

**RESULTS**

The annual average concentration of PM₁₀ and O₃ during cold and warm seasons and also annual 98 percentile concentration of these pollutants have shown in Fig. 2. Annual average concentrations of PM₁₀ and O₃ during the warm season were 87.86 and 63.5μg/m³, respectively, which were more than a cold season.

![Fig. 2: Concentration of PM₁₀ and O₃ in Karaj city from 2012 to 2013](image-url)

The Tables 1-4 represent the estimated AP and number of excess death due to increasing of PM₁₀ and O₃ concentration according to determined RR with Confidence Interval (CI) equal to 95%.
In Table 2 number of total death due to cardiovascular disease, respiratory disease as a result of 10μg/m³ PM₁₀ and Ozone concentration.

**Table 1**: Relative risk (RR), the attributable proportion (AP), and number of excess total death due to 10μg/m³ increase concentration of PM₁₀ and O₃ (BI=543.5).

<table>
<thead>
<tr>
<th>Estimation</th>
<th>PM₁₀</th>
<th>O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR (95% CI)</td>
<td>AP (10%)</td>
</tr>
<tr>
<td>Low</td>
<td>1.004</td>
<td>2.63</td>
</tr>
<tr>
<td>Average</td>
<td>1.006</td>
<td>2.63-5.13</td>
</tr>
<tr>
<td>High</td>
<td>1.008</td>
<td>5.13</td>
</tr>
</tbody>
</table>

**Table 2**: Attributable proportion (AP) and number of total death due to A- cardiovascular disease; BI=231, and B- respiratory disease; BI= 48.4 due to 10μg/m³ increase concentration of PM₁₀ and O₃.

<table>
<thead>
<tr>
<th>Estimation</th>
<th>PM₁₀</th>
<th>O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>AP</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Low</td>
<td>1.005</td>
<td>1.005</td>
</tr>
<tr>
<td>Average</td>
<td>1.009</td>
<td>1.013</td>
</tr>
<tr>
<td>High</td>
<td>1.013</td>
<td>1.020</td>
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</tbody>
</table>

**Table 3**: Attributable proportion (AP) and number of hospitalization due to cardiovascular disease; BI=231, due to 10μg/m³ increase concentration of PM₁₀.

<table>
<thead>
<tr>
<th>Estimation</th>
<th>PM₁₀</th>
<th>O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR (95% CI)</td>
<td>AP</td>
</tr>
<tr>
<td>Low</td>
<td>1.006</td>
<td>3.9</td>
</tr>
<tr>
<td>Average</td>
<td>1.009</td>
<td>5.74</td>
</tr>
<tr>
<td>High</td>
<td>1.013</td>
<td>8.08</td>
</tr>
</tbody>
</table>

Chronic obstructive pulmonary diseases (COPDs) are another health impact of tropospheric ozone which can lead to hospitalization [18]. In this research, Number of excess death due to COPDs related to ozone are presented in Table 4. the excess numbers were based on the RR data from the APHEA-2 project, which studied health effects of ambient O₃ in 23 European cities for a period of three years [22]. A summary of attributable health effect related to air pollutants is presented in Table 5.

**DISCUSSION**

As many studies have been used the AirQ software for assessing the human health impact of air pollutants [26-28], in this investigation the effect of short-term exposure of PM₁₀ and O₃ on increasing death related to respiratory and cardiovascular, and hospitalization because of COPD, respiratory and cardiovascular diseases were estimated. It’s clearly shown in Table 5 that PM₁₀ had the more health effect than O₃ on the 1,900,000 inhabitants of Karaj city, leading to an excess of the total death of 282 in a year, whereas the effect of O₃ on total death was an excess of approximately 164 people. According to the obtained results, the annual average concentration of PM₁₀ in Karaj city was 7.48μg/m³, which is 3.88 and 1.94 times higher than the global average and the WHO standards.
times higher than Iran national standard and WHO guideline, respectively [29-30]. Heavy traffic, lack of
an integrated public transport system, and existence Alborz mountain range around the city which led to a
poor dilution of atmospheric air pollutants are the most important factors of high concentrations of air
pollutants in the Karaj city. Another reason for this dilemma is the presence of large industries around the
town and a lot of times air pollutants move inside the city and deteriorate the air quality. The achieved data
from the annual average of PM$_{10}$ in Karaj show that it was slightly higher (1.1 times) than the world’s
average (71µg/m$^3$) [26].

The average concentrations of PM$_{10}$ in warm and cold seasons were 87.86 and 62µg/m$^3$, respectively.
Evaluation the concentration of PM$_{10}$ in Khorraramab, Iran, during 2014 shows that the PM$_{10}$ in July, with
the 136.48µg/m$^3$ mean concentration was the highest [31]. 250 days (68%) of the total study time, the average
concentrations of 24-hour PM$_{10}$ were higher than the national and European Union (EU) standards and also
WHO guideline.

Tomins et al. investigated on impacts of PM$_{10}$ in Trieste city in Italy with about 200,000 inhabitants, and
reported that death related to cardiovascular-respiratory disease and total mortality have been 628 and 52 cases in excess, respectively [26]. According to table 5, deaths related to cardiovascular and respiratory disease and total mortality in this study were estimated, 261, 77, and 282 cases in excess, respectively. As well as the investigation of Amarloei et al. in Ilam, Iran, shows that total patient admission and mortality attributed to PM$_{10}$ due to cardiovascular and pulmonary diseases were 208.7 and 80.3 cases respectively [10]. Furthermore, in a study by Martuzzi et al., about health impact assessment of air pollution in Milan city with 1,308,000 inhabitants, the total mortality attribute to PM$_{10}$ was 677 cases in excess [32]. Study on the health impact of air pollutant in an industrialized area of Northern Italy showed that PM$_{2.5}$ had the highest share on human health which yearly total mortality excess of 8 out of 177 inhabitants [26].

Based on findings, the annual average concentration of O$_{3}$ in Karaj city was 62µg/m$^3$ which is 1.7 times higher than Iran national standard and WHO guidance value (100µg/m$^3$), but it was less than EU standard (147µg/m$^3$). As well as, the average concentrations of O$_{3}$ during warm and cold seasons were 63.5 and 60µg/m$^3$, respectively. Higher concentration of O$_{3}$ in a warm semester is because of higher temperature is favourable for its production. Total attributable death of PM$_{10}$ and O$_{3}$ was 282 and 164 case, respectively, that are responsible for about 3.9 and 1.53 % of total death (with the exception of death caused by accidents), respectively. It proves that by decreasing concentration of particulate matter can reduce the related death of air pollutants. Tominz et al. estimated that Ozone can excess total mortality about three times [26]. Martuzzi et al. during the period 2002–2004 investigated about the impact of PM$_{10}$ and O$_{3}$ on human health in thirteen Italian cities, with about 9000000 inhabitants and reported that 516 deaths a year, were attributable to O$_{3}$ [33]. Another study conducted by Naddafi et al. in 2012, indicated that 819 of the total mortalities in Tehran city in Iran were related to O$_{3}$ [20].

Yu Shang et al. remarked that if PM$_{3.5}$ levels in mega-Chinese cities decrease to WHO Air Quality Guideline
of PM$_{10}$, mortality attributable to short-term exposure of PM$_{2.5}$ could be reduced by 2.7%, 1.7%, 2.3%, and 6.2% in Beijing, Shanghai, Guangzhou, and Xi'an, respectively [34].

Also during this study, the average attributable cases to O$_{3}$ for chronic pulmonary obstruction disease was
58 people and average attributable cases to PM$_{10}$ for hospitalization due to cardiovascular disease was 492
people. Fattore E. et al. showed that particulate matters, especially PM$_{2.5}$, have higher health outcome.
They applied AirQ 2.2.3 model to assess health effects of PM$_{2.5}$. Their results remarked that out of 177 death
of two small industrial cities, 8 people died because of PM$_{2.5}$ [27]. These results proved that the tangible
health effects of air pollutants which is similar to martuzzi et al. investigations. They studied on long-
term health effects of PM$_{10}$ and O$_{3}$ for 13 cities in Italy that enclosed 9 million people. They reported that
during their study between 2002 and 2004, the total attributable death of PM$_{10}$ concentration more than
20µg/m$^3$ was 8220 people, whilst total attributable death of O$_{3}$ was 516 people [33].

CONCLUSION

These results were in order to agree with other reports of the health impact of air pollutants and the AirQ
software looks an effective and easy tool, promising in decision-making. Based on the obtained results of
various studies, which have done using Air Q2.2.3 model, it can be acceptable tools for prediction and
assessment short and long-term effects of air pollutants. As well as, the results can represent this
fact that air pollutants have a significant contribution in the rate of hospital admissions and deaths in Karaj.
Authorities must apply suitable strategies based on comprehensive scientific and appropriate research and
also sustainable and applicable solutions to decrease health effects of air pollutants crisis in Karaj city.

ETHICAL ISSUES

The authors have been observed all ethical issues including double publication and/or submission,
plagiarism, references, Informed Consent, misconduct, data fabrication and/falsification, etc.

CONFLICT OF INTEREST
All authors state firmly that they have no conflict with any authors or an institution for any special issue.

AUTHORS’ CONTRIBUTION
Authors declare that they have read and approve the final manuscript.

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