Quantification of Health Impacts Related to PM_{10} and O_3 Pollutants in Karaj City

Kamyar Yaghmaeian[1,2], Hoda Amiri[3], Sadegh Hassanvand[4], Farzad Mohammadi[5], Heshmatollah Nourmoradi[6,7], Ali Amarloei[6], Sajad mazloomi*[6,7]

1) Center for Solid Waste Research (CSWR), Institute for Environmental Research (IER), Tehran University of Medical Sciences (TUMS), Tehran, Iran
2) Department of Environmental Health Engineering, School Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
3) Department of Environmental Health Engineering, School of Public Health, Shiraz University of Medical Sciences, Shiraz, Iran
4) Center for Air Pollution Research (CAPR), Institute for Environmental Research (IER), Tehran University of Medical Sciences, Tehran, Iran.
5) Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran
6) Department of Environmental Health Engineering, School of Public Health, Ilam University of Medical Sciences, Ilam, Iran
7) Biotechnology and Medicinal Plants Research Center, Faculty of Medicine, Ilam University of Medical Sciences, Ilam, Iran

**Author for Correspondence:* mazloomi-s@medilam.ac.ir

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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 concentrations 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

(VOC) and nitrogen oxides (NO_x) [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 (O_3) health effects in Karaj city during 2012 and 2013.

MATERIALS AND METHODS

Study area and demographic parameters

In this descriptive cross-sectional study, the health impact of two pollutants PM and O_3 on Karaj city population was investigated. Karaj city is the capital of the Alborz province (Fig. 1) and it was covered by three air pollution monitoring station for describing air quality index of the Karaj. For evaluating health effects of air pollutants, data were obtained from Department of Environment Protection of Karaj. All daily O_3 and PM_{10} data from January 01, 2012 to January 01, 2013 were collected from three monitoring stations Farhangsara, Environment protection, and Fardis which are situated near traffic stations.

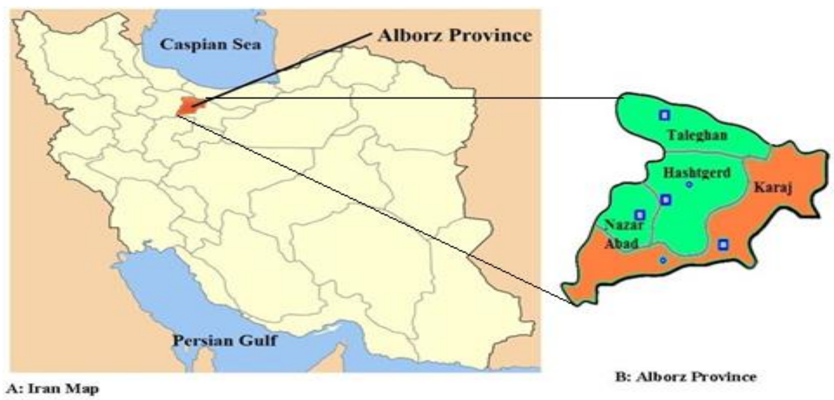

Fig. 1: Location of the studied region (Karaj city)

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 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 PM_{10} were derived from a quantitative meta-analysis data with a focused on European investigations [21]. Next, for O_3 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).

$$AP = \frac{SUM\ \{[RR(C)-1]\times P(C)\}}{SUM\ [RR(C)\times P(C)]} \quad \textbf{(1)}$$

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 againest a non-exposed group and P (c) denotes the proportion of the stated group population (2).

AP = I × 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 × 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/m^3 categories, corresponding to equivalent exposure categories. The data for PM_{10} and O_3 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/m^3, 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 PM_{10} and O_3 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].

$$\frac{P}{P_1} = \left(\frac{T}{T_1}\right)^{-\frac{g_0}{R\lambda}} \quad (4)$$

where P and P_1 donate the atmospheric pressures (mbar) at sea level and at height z (m), respectively; T and T_1 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 PM_{10} and O_3 in the monitoring stations were µg/m^3 and ppb, respectively. To fit the units in the software, it would be necessary to transfer their units to µg/m^3 by equation (5)

$$C\left(\frac{\mu g}{m^3}\right) = \frac{C\,(ppm)\times MW}{V}\times 1000 \quad (5)$$

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$^{℃}$ temperature [25].

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

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad (6)$$

Where P_1 and P_2 are initial and final pressure, V_1 and V_2 are initial and final volume, and T1 and T2 are initial and final absolute temperature, respectively.

RESULTS

The annual average concentration of PM_{10} and O_3 during cold and warm seasons and also annual 98 percentile concentration of these pollutants have shown in Fig. 2. Annual average concentrations of PM_{10} and O_3 during the warm season were 87.86 and 63.5µg/m^3, respectively, which were more than a cold season.

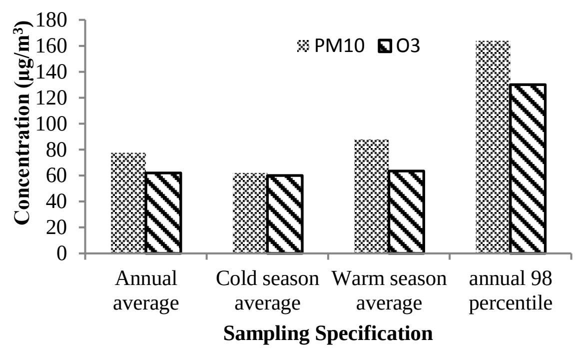

Fig. 2: Concentration of PM_{10} and O_3 in Karaj city from 2012 to 2013

The Tables 1-4 represent the estimated AP and number of excess death due to increasing of PM_{10} and O_3 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 PM_{10} and Ozone concentration.

Table 3 represents the increasing hospitalization due to cardiovascular disease as result of increasing PM_{10}.

Table 1: Relative risk (RR), the attributable proportion (AP), and number of excess total death due to 10µg/m³ increase concentration of PM_{10} and O_3 (BI=543.5)

Estimation	PM_{10}			O_3		
	RR	AP (10%)	Number of excess death	RR (95% CI)	AP (10%)	Number of excess death
Low	1.004	2.63	282	1.002	1.025	110
Average	1.006	2.63-5.13	282-549	1.003	1.53	164
High	1.008	5.13	549	1.005	2.52	270

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 PM_{10} and O_3

Estimation	PM_{10}						O_3					
	RR		AP		Excess death		RR (95% CI)		AP		Number of excess death	
	A	B	A	B	A	B	A	B	A	B	A	B
Low	1.005	1.005	3.27	3.27	149	31	1.002	1.006	1.025	3.015	47	29
Average	1.009	1.013	5.74	8.08	261	77	1.005	1.013	2.52	6.31	115	60
High	1.013	1.020	8.08	11.92	367	113	1.007	1.015	3.5	7.21	159	69
RR certainty	Unknown						Unknown					

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

Estimation	RR (95% CI)	AP	Number of excess death
Low	1.006	3.9	334
Average	1.009	5.74	492
High	1.013	8.08	693
RR certainty	High		

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 O_3 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.

Table 4: Attributable proportion (AP) and number of hospitalization due to chronic obstructive pulmonary diseases (COPDs); BI=101.4, due to 10µg/m3 increase concentration of O_3

Estimation	RR (95% CI)	AP	Number of excess death
Low	1.0022	1.12	22
Average	1.0058	2.92	58
High	1.0094	4.64	93
RR certainty	Medium		

Table 5: Attributable proportion and number of excess total death, death related to cardiovascular and respiratory disease

Attributable health effect related to air pollutants	Air pollutants	Number of attributable cases	Attributable proportion
Total death	PM_{10}	282 (417-549)	3.9 (2.63-5.13)
	O_3	164 (110-270)	1.53 (1.025-2.52)
death related to cardiovascular disease	PM_{10}	261 (149-367)	5.74 (3.27-8.08)
	O_3	115 (47-159)	2.52 (1.025-3.5)
death related to respiratory disease	PM_{10}	77 (31-113)	8.083 (3.27-11.92)
	O_3	60 (29-69)	6.3 (3.01-7.2)

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 PM_{10} and O_3 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 PM_{10} had the more health effect than O_3 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 O_3 on total death was an excess of approximately 164 people. According to the obtained results, the annual average concentration of PM_{10} in Karaj city was 77.48µg/m³, which is 3.88 and 1.94

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 Khorramabad, 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 were estimated, 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 $PM_{2.5}$ 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 PM2.5 [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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