

Estimation of cardiovascular and respiratory diseases attributed to PM10 using AirQ model in Urmia during 2011-2017

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Abstract

Background: Quantification of the attributed effects of air pollution determines the impact of air pollutants on the community and shows the critical condition of air quality.

This study aimed to quantify and estimate the cardiovascular and respiratory diseases attributed to PM10 in Urmia during 2011-2016.

Methods: In this descriptive-analytic study, at first, hourly data of pollutant PM10 concentrations were received from air pollutants station located in the Department of Environmental Protection. The data were evaluated using AirQ2.2.3 software after primary and secondary processes and filtering.

Results: The results showed that the mean annual concentration of PM10 during 2011-2016 was 88.66, 92.45, 81.22, 78.38, 113.78, and 92.67 $\mu\text{g}/\text{m}^3$, respectively. The number of hospitalized cases due to respiratory diseases attributed to PM10 in this period was 486, 525, 459, 453, 684, and 552, respectively, and the number of cases due to cardiovascular diseases was 188, 203, 177, 175, 263, and 213, respectively.

Conclusion: Considering the attributed health effects of PM10, the necessary measures should be taken to identify the causative agents and to understand the mechanisms of these processes and correct them.

Keywords: Air Q model, PM10 particles, Cardiorespiratory diseases, Urmia

Conflicts of Interest: None declared

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Introduction

Air pollution is not a new phenomenon and is blended with modern life. In fact, it is the product of urban construction and the remaining wastes which are derived from such activities as the production of goods, transportation, heating, recreation, and human work (1). In addition to environmental degradation and economic losses, air pollution is

one of the 10 most important causes of mortality worldwide, with death rates from 800 000 in the year 2000 to 1.3 million in the year 2010 (2). Previous studies have shown that photochemical particles and photochemical pollutants of urban traffic may have adverse effects on humans, although they are lower than the maximum level (3).

Air pollution can cause some acute and chronic health

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↑What is “already known” in this topic:

Air pollution has imposed serious problems on the society's health and environment in Urmia. In Urmia, the mean annual concentration of air pollutants is more than the standard level, and air pollution leads to more hospitalization due to cardiovascular and respiratory diseases.

→What this article adds:

No assessment has been done on the effects of air pollution on the health of Urmia residents in recent years. In this study, AirQ software based on the WHO approach was used. The results of air pollution studies can help policymakers to reduce air pollution.

problems such as cardiovascular and respiratory diseases and death (4-7).

Suspended particles less than 10 microns are considered to be major contaminants for public health (8). Also, these particles are the main source of concern for air quality due to combustion, traffic, and industrial activities (9, 10). Some studies have provided strong evidences that suspended particles are associated with a high rate of mortality in long-term and short-term exposures (11), so that short-term exposure to PM10 causes lung irritation, respiratory function, coughing, and respiratory responses (4).

In the results of studies conducted by Goodarzi et al, it was found that about 4% of all cardiovascular and respiratory deaths in Tehran have been attributed to concentrations of more than 20 $\mu\text{g}/\text{m}^3$ of PM10 (12). Another study in Mecca have shown that the risk to humans exposed to suspended particles with an emphasis on respiratory diseases is roughly increasing (13). A study by Chen et al showed a significant relationship between suspended matter with a diameter of less than 10 microns in the traffic-intensive areas of Australia and the number of patients referring to the emergency departments for respiratory problems (14). This research was conducted to study the air quality of Urmia. The city faces the problem of air pollution due to urbanization, increasing number of cars, industrialization, increasing factories, and its special geographical conditions.

To illustrate the extent to which people living in a region are exposed to pollutants, the effects of pollutants need to be quantified. AirQ2.2.3 software provides short-term effects of air pollutants and predicts the health of airborne contaminants (15).

The nature of the effect of air pollution (acute and chronic) and the type of exposure (short-term or long-term) are effective in selecting the type of study (16). Management plans to control air pollution in large cities are considered to be the most important strategies that use precise data sources about environmental conditions to determine all effects of air pollution on human health (17, 18). Considering that the health effects of air pollution have not been scientifically investigated, we used AirQ2.2.3 software in this study to determine the short-term effects of suspended particles and their health-related problems in Urmia. Therefore, this study was aimed to quantify and estimate the cardiovascular and respiratory diseases attributed to PM10 in Urmia during 2011-2016.

Methods

This cross sectional study was conducted in Urmia, a metropolitan city in the center of West Azerbaijan province and in the northwest of Iran. According to the last census done in 2017, Urmia is the 10th most populated city in Iran and the second most populated city in the northwest of Iran (Fig. 1). Required data were collected from the Department of Environmental and Meteorological Organization of Urmia, and according to the criteria stated by the World Health Organization (WHO). Also, the number of stations with valid data was identified to determine the credibility.

According to the criteria stated by the WHO, the number of stations with valid data was identified. Therefore, the registered data of all stations were filtered to assess data validity, according to the WHO standards. To delete invalid data during the primary filtering, the ratio of warm seasons/cold seasons needed to be less than 2. Also, 50% of the data needed to have enough validity to estimate the daily mean (19).

Iran Meteorological Organization provided daily values of humidity and temperature mean. After preparing the input file, the following raw data were entered into the AirQ software: (1) primary processing: elimination and time alignment to calculate the total mean of each pollutant; (2) secondary processing: writing codes, calculating daily mean, eg, extracting the required statistical indices such as the annual mean, mean warm season, mean cold season, 98th percentile score, annual maximum and maximum warm and cold seasons as presented in (Table 1); (3) primary filtering: temperature and pressure correction and conformity of units with the model; (4) secondary filtering: pollutants concentration, required parameters, etc.; and (5) some quantitative data. AirQ software, a reliable and valid tool, was developed by WHO to evaluate the potential of short-term effects of exposure on people living in a specific geographical area during a period of time (19). Estimation of the adverse effect of air pollution on health is correlated to the volume of air pollutants in AirQ. Iran Statistics Center presented the population at risk from air pollution (Fig. 2).

Considering that the input data units should be in volumetric weight, PM10 was recorded as $\mu\text{g}/\text{m}^3$. Subsequently, the results of the data mining in the software were derived from the results of the examinations and the number of admitted patients suffering from cardiovascular and

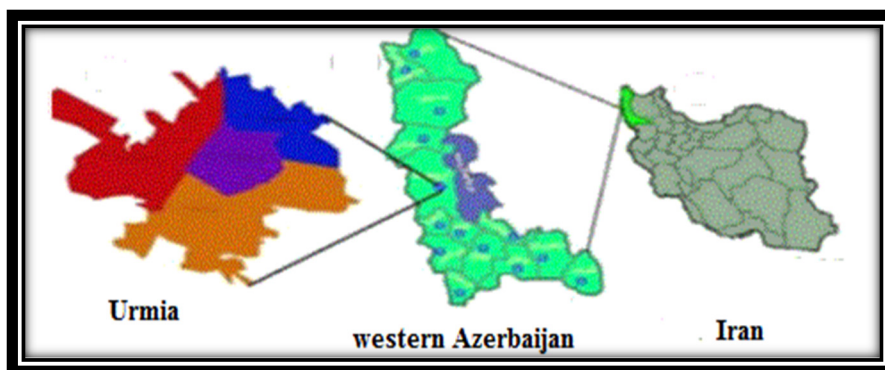
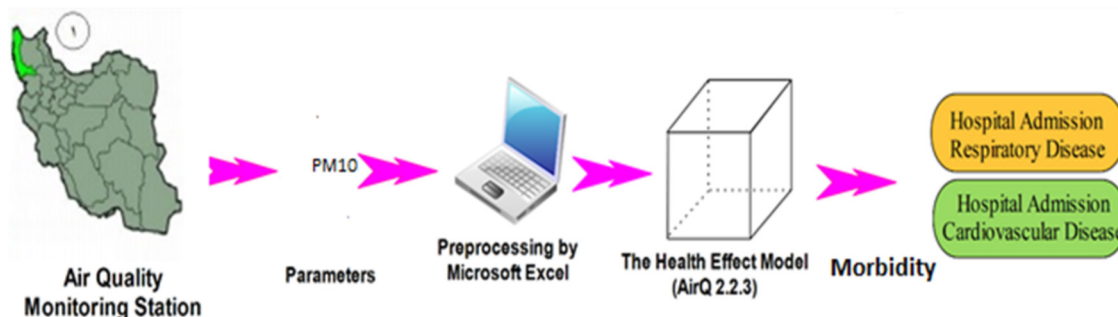


Fig. 1. Geographic situation of Urmia in Iran (20)

Table 1. Indicators to estimate the effects of PM10 and the mean annual concentration ($\mu\text{g}/\text{m}^3$) from 2012 to 2017

Parameter	2012	2013	2014	2015	2016	2017
Annual average	88.60	92.45	81.02	78.33	113.83	92.67
Cold season average	72.19	87.99	82.63	26.60	103.47	95.53
Warm season average	104.04	96.76	79.35	82.39	124.14	89.94
Annual 98th percentile	239.86	226.05	182.99	167.17	259.03	202.53
Annual maximum	931.15	869.54	737.30	344.61	594.61	356.86
Cold season maximum	288.23	227.73	195.00	250.52	350.62	237.05
Warm season maximum	931.15	869.54	737.30	344.61	594.61	356.86

**Fig. 2.** Schematic view of performed process in this study (Draw writers)

respiratory diseases. To calculate the health effects and outcomes, the number of hypotheses was replaced with personal estimates of relative risk and baseline incidence (95% confidence intervals) from regional and national epidemiological studies, which were specific to Iran and were entered into AirQ.2.2.3 software (21, 22). The AirQ model, relative risk, and baseline incidence are main parameters in epidemiology studies (6, 7).

To estimate the effects of exposure to specific air pollutants on the people's health in a certain area or time, the AirQ model can be applied using attributable proportion (AP). Indeed, AP is considered as a fraction of the health outcome in a defined population exposed to air pollutants. AP is calculated based on the following formulae (23).

$$AP = \frac{\sum \{(RR(c)-1) p(c)\}}{\sum RR(c) p(c)} \quad (1)$$

AP shows a proven causal relationship between health outcome and known exposure without major confounding effects. RR indicates the relative risk and P(c) the population at risk. RR is simply calculated using the following formula:

$$RR = \frac{\text{Disease with exposure}}{\text{Disease without exposure}} \quad (2)$$

While the baseline frequency for the outcome of interest

is determined in the certain population, the rate attributable to the exposure is calculated using the following formula: $IE = I * AP$ (3).

IE is the rate of the health outcome attributable to the exposure and I the baseline frequency of the health outcome in a given population. Considering the population, the frequency of patients attributable to the exposure is calculated using the following formula: $NE = IE * N$ (4).

NE is the frequency of patients attributed to the exposure of interest and N refers to the population size. Following the data analysis through AirQ, the proportion attributable to PM10 and the excess patients of emergency hospitalizations were calculated.

Results

The results of this study covers the statistical parameter of the concentration of PM10 during 2011-2016 in Urmia. Initially, after verifying the data according to WHO standards, they were obtained from the Department of Environment of West Azerbaijan province. Only one of the 4 stations located in Urmia had valid data for analysis.

Relative risk and baseline incidence based on previous

Table 2. Relative risk, component, and cases attributed to PM10 for emergency hospitalization due to cardiovascular disease

Year	Relative risk (RR) as per every $10 \mu\text{g}/\text{m}^3$					
	Estimate indicator					
	Lower limit		Central limit		Upper limit	
	1.006		1.009		1.013	
Attributed component estimate (%)	Number of attributed cases (Person)	Attributed component estimate (%)	Number of attributed cases (Person)	Attributed component estimate (%)	Number of attributed cases (Person)	
2012	4.4	128	6.4	188	9.7	264
2013	4.7	138	6.8	203	9.7	284
2014	4.0	120	5.9	117	8.3	250
2015	3.9	119	5.8	175	8.1	264
2016	5.9	181	8.6	263	12	362
2017	4.7	145	6.9	213	9.7	299
2012-2017		832		1219		1723

studies obtained for admission to hospitals due to cardiovascular disease (RR=1.009, CI: 1.006-1.013, n=436) and admission to hospitals due to respiratory disease (RR=1.008, CI: 1.004-1.011, n=1260) entered into the AirQ software (21, 22). In fact, the increase in every 10 µg/m³ of PM10 will increase the risk of admission due to respiratory disease and cardiovascular disease by up to 0.8% and 0.9%, respectively.

Based on the results of AirQ2.2.3 software, the number of additional cases and associated items for the total number of cases of respiratory and cardiovascular diseases was

estimated (Tables 2 and 3).

The number of cases attributed to PM10 based on the central limit of relative risk in 6 years was 486, 525, 459, 453, 684, 559, and 552 due to respiratory disease, with attributable fraction of 5.7, 6.1, 5.3, 5.2, 7.7, 6.2; also, 188, 203, 177, 175, 263, and 213 cases were due to cardiovascular disease, with attributable fraction of 6.4, 6.8, 5.9, 5.8, 8.6 and 6.9, respectively.

In the present study, the concentration of pm10 in Urmia was analyzed and the health effects attributed to air pollution were assessed. The Charts 1 and 2 show the exposure

Table 3. Relative risk, component, and cases attributed to PM10 for emergency hospitalization due to respiratory disease

Year	Attributed component estimate (%)	Relative risk (RR) as per every 10 µg/m ³					
		Estimate indicator			Number of attributed cases (Person)	Attributed component estimate (%)	Number of attributed cases (Person)
		Lower limit	Central limit	Upper limit			
		1.004	1.008	1.011			
2012	3.5	299	5.7	486	7.9	666	
2013	3.8	323	6.1	525	8.4	718	
2014	3.2	281	5.3	459	7.3	629	
2015	3.1	277	5.2	453	7.1	621	
2016	4.8	423	7.7	684	10.5	928	
2017	3.8	340	6.2	552	8.4	755	
2012-2017		1943		3159		4317	

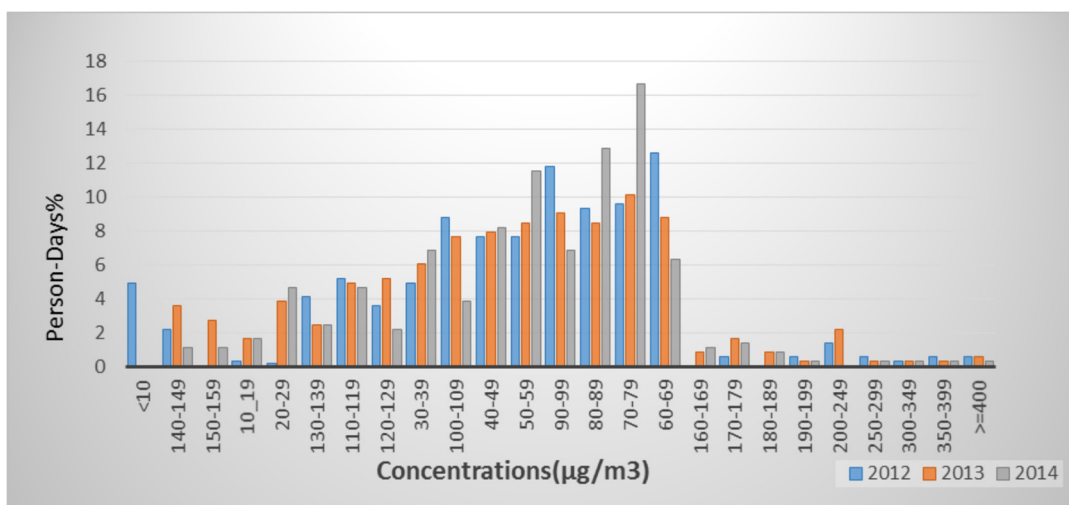


Chart 1. The percentages of the days that residents of Urmia encountered with various amounts of PM10 during 2012-2014

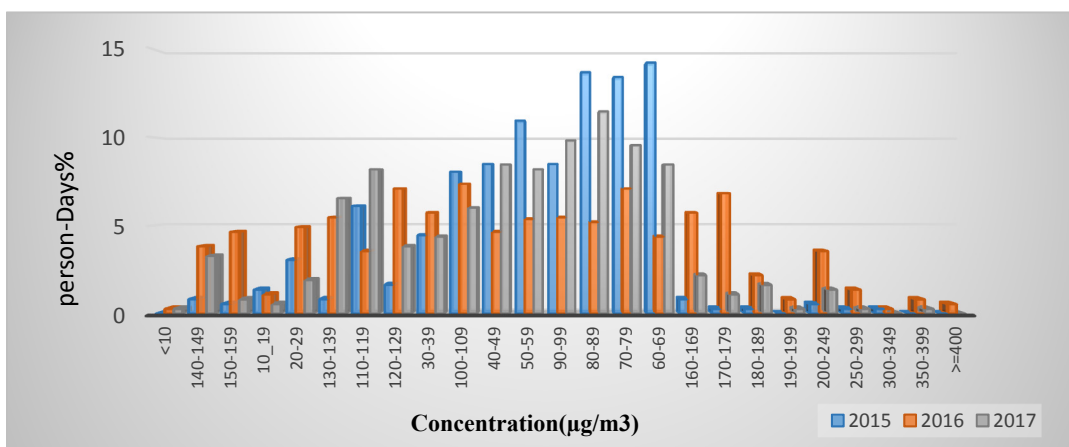


Chart 2. The percentages of the days with various amounts of PM10 during 2015-2017

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Table 4. Standards and guidelines for the mean ambient particulate concentration ($\mu\text{g}/\text{m}^3$)

Standard or Guideline PM10	Annual Mean ($\mu\text{g}/\text{m}^3$)	Year	Concentration PM10 ($\mu\text{g}/\text{m}^3$)
WHO Guidelines (WHO 2005)	20	2012	4.43
National Ambient Air Quality Standards (NAAQS)	50	2013	4.62
Iran National Standard	20	2014	4.05
State of California	20	2015	3.91
Other European Countries	20	2016	5.69
USA Federal Standard	-	2017	4.63

*Comparison of the mean annual concentration of PM10 with Iran national standards in Urmia during 2011-2016.

of PM10 at central limit relative risk for 6 years. The average amount of PM10 concentration in 2015 and 2016 was 2.27-1.85 times higher than the limit compared to the rest. According to the estimated component and the number of hospital admissions attributed to PM10 in Urmia, it can be stated that this city has unfavorable conditions, which could be the result of the continuity of days with a higher concentration of suspended particles or a higher mean of this contaminant (Table 4).

Discussion

This study used the AirQ model to assess the impact of short-term exposure to PM10 concentrations on human health.

According to Table 1, the mean concentration of PM10 in cold seasons was more than the warm seasons in 2014 and 2017. However, it has been higher in the warm season in 2012, 2013, 2015, and 2016. The results of this study showed that the number of hospitalizations due to respiratory disease was 8404, 8505, 8611, 8706, 8807, and 8908, so that 486, 535, 459, 453, 684, and 552 were attributed to PM10 during 2011-2016. Also, the number of hospitalization due to cardiovascular disease was 2894, 2943, 2967, 3012, 3039, 3074, and 188, 203, 177, 175, 263, and 213 were attributed to PM10.

In total, the number of admitted cases attributed to PM10 due to respiratory and cardiovascular disease was 3159 and 1219 cases, respectively. Assessing a direct relationship between contact with various particles concentrations and their effects on human health is quite difficult due to the interaction between atmospheric pollutants and other components. However, the AirQ model is one of the most promising models of the WHO that can be utilized to estimate the effects of air pollutants on human's health.

According to the study performed by Kermani et al, in which the health effects of exposure to airborne particulate matter in Tehran from 2004-2015 was evaluated, the total hospitalization cases due to cardiovascular and respiratory diseases were 20 990 and 54 352 cases, respectively, which were attributable to PM10. Finally, they concluded that health effects of exposure to suspended particles in Tehran was very severe and increased the mortality and cardiovascular and respiratory diseases in the citizens (24).

According to the study by Kamarehie et al, on the morbidity and mortality attributed to PM10 and PM2.5 exposure in city of Bukan during 2015-2016, the total mortality rates were 49.8, and 33.3 deaths were attributed to PM2.5 and PM10, respectively. Also, 3.79% of the total mortality was related to PM10. In Bukan, cardiovascular mortality accounts for 2% of total deaths. The Air Quality model was

used to predict the deaths of 92.2 people dealing with hospitalization due to respiratory disease (25).

In a study of Kianisadr et al, on the air quality index (PM₁₀ and PM_{2.5}) by Arc-GIS in city of Khorramabad, the results indicated that continuous dust storms, particularly in recent years, led to unhealthy air condition in Khorramabad that can adversely affect the health of residents (26). In the study performed by Kosha et al, there was an important linkage between hospitalization due to respiratory and cardiovascular diseases and particles concentration in Tabriz. They showed that high concentration of the particles increased the frequency of hospitalization due to respiratory and cardiovascular diseases (27).

According to the study of Khorsandi et al, in 2014 in Urmia, the annual mean of PM10 was 83 micrograms in cubic meters and hospitalized patients due to respiratory and cardiovascular diseases were 482 and 187, respectively, determined by the AirQ2.2.3 model (28). While in the present study, it was 459 cases due to respiratory and 177 due to cardiovascular cases in 2013. This difference may be due to the numerical difference in geographic distribution, population at risk (recorded population census, taking into account the growth rate) or the difference in the mean daily pollutant record. According to another study of Khorsandi et al in 2011, suspended particles, CO and so₂, had the highest contribution as the pollutants responsible for air pollution in Urmia in nonstandard conditions (2).

Similar studies have shown that the effects of PM10 on total mortality were responsible for 2194 deaths in Tehran in 2012 (22). Other studies have shown that the highest number of deaths caused by air pollution was related to PM10 particles (100 deaths) (29).

A survey conducted in a number of American and European cities and in a number of Asian countries showed that short-term contact with suspended particles of less than 10 microns in developed and non-developed countries is in contradiction with Iran (30-32).

In a study by Nadafi et al, entitled "quantifying the health effects of air pollutants in Tehran in 2012", the results showed that the highest share of health effects attributed to suspended particles was 2.5 and 10 microns (22). This software does not consider a causal relationship among the encounter and the message and the confounders (33).

One limitation of this study was exposure assessment, which shows the average exposure of the residents in Urmia. However, because the data used in this study were aggregate data, we could not interpret it at the individual level.

Urmia is exposed to particles due to neighboring with countries in the northwest. The increase in the number of

vehicles in a cold weather causes the inversion of temperature. Therefore, air pollution in Urmia is considered as a serious problem and requires the attention of the policy-makers to take preventive and control measures in this regard. Therefore, it is necessary to continuously monitor the air pollution indicators and take important measures to identify the effective factors.

To reduce the effects of air pollution, there is a need for plan development and collaboration among organizations and even neighboring countries.

The results of this study will be helpful if accompanied by political and economic regulations. Also, considering that air pollution causes mortality and that general health depends on various factors, including industry, engineering, and biostatistics, targeted education is required for environmentalists whose knowledge about new tools is not enough.

Conclusion

Overpopulation causes uncontrolled development of urban areas and more fossil fuels consumption leading to air pollution. Regarding the attributed health effects of PM10, the necessary measures should be taken to identify the causative mechanisms of these processes and to correct them. Thus, the policymakers, and specialists in the field of interest should focus on the reduction of air pollution.

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Conflict of Interests

The authors declare that they have no competing interests.

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