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ESTIMATION OF LUNG CANCER MORTALITY ATTRIBUTED TO LONG-TERM EXPOSURE TO $PM_{2.5}$ IN 15 IRANIAN CITIES DURING 2015 - 2016; AN AIRQ+ MODELING

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ABSTRACT:

Introduction: Long-term exposure to particulate matter with an aerodynamic diameter less than 2.5 µm is associated with lung cancer incidence. This study aimed to estimate the number of lung cancer deaths attributed to lung-term exposure to $PM_{2.5}$ among people older than 30 years in 15 cities of Iran during 2015- 2016 using AirQ+ modelling approach.

Materials and methods: Validation of monitoring stations was done according to WHO's criteria for health impact assessment of air pollution. As AirQ+ needs, 24-h concentrations of $PM_{2.5}$ during a year, total population and at-risk population, baseline incidence of lung cancer, and cut-off value of 10 µg/m^3 for $PM_{2.5}$ concentration were prepared and entered into the model.

Results: Annual concentrations of particulate matter in all cities were 1.8 to 6.7 times higher than WHO's guideline. The most and least cases of lung cancer deaths due to $PM_{2.5}$ were estimated to be in Karaj and Birjand, respectively. Total mortality of lung cancer attributed to $PM_{2.5}$ in these 15 cities were 120 cases.

Conclusions: Since air pollution's health impacts impose financial losses to countries, results of this study can be useful for decision-makers to highlight areas requiring urgent action.

INTRODUCTION

World Bank has introduced air pollution as the fourth risk factor for human health [1]. In a report by World Health Organization (WHO), about 7 million annual deaths were attributed to indoor and outdoor air pollution [2]. There are several criteria air pollutants that can affect human health such as different fractions of particulate matter, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), etc. [3]. Particulate matter with a diameter of 2.5 µm or smaller ($PM_{2.5}$) is a fraction of particles that is able to enter the alveolar region in lung, as a place for blood exchange. $PM_{2.5}$ represents the high-risk fraction of particulate matter in air [4].

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Many epidemiological studies have shown a positive relationship between short- or/and long-term exposure to $PM_{2.5}$ and different adverse health effects [5]. $PM_{2.5}$'s short-term exposure is associated with ischemic heart disease (IHD) and chronic obstructive pulmonary disease (COPD). Its long-term exposure is related to lung cancer, and respiratory and cardiovascular diseases [4]. It is shown that lung cancer incidence increases per each 10 μg/m^3 $PM_{2.5}$ [6]. International Agency for Research on Cancer (IARC) has introduced particulate matter as Group 1 carcinogen (carcinogenic to humans) [7].

Several cities of Iran are experiencing high concentrations of air pollutants, especially $PM_{2.5}$ [8]. Southern and western cities are affected by Middle Eastern dust storm, which even reach Tehran in central Iran [9, 10]. Tehran as the capital of Iran is mainly affected by mobile sources of air pollution [11]. Annual concentrations $PM_{2.5}$ are reported to be 3 - 4 times higher than those in WHO's guideline. These extremely high concentrations cause large numbers of deaths and hospital admissions [12].

Modelling approaches are developed to estimate the number of deaths (or hospital admissions) that are caused by a specific air pollutant in a particular area [13]. Determining the number of health effects attributed to air pollution can be useful for management purposes. Authorities and policy-makers benefit from these results to allocate financial resources in a more important way. It is because each death, hospitalization or medication forces a financial burden to health-care systems [14, 15].

Many studies have been carried out in Iran to estimate the health effects of air pollution [16-19]. However, no study has conducted to estimate the number of lung cancer deaths in Iran. On the other hand, all of these studies have used AirQ software, which is developed by WHO several years ago. Although, WHO released a newer tool for health impact assessment that is known as AirQ+ (AirQ plus). This software is based on recent epidemiological findings regarding the relationship between air pollution and health. AirQ+ was developed in 2016 to quantify the health effects and calculate the burden of disease attributed to outdoor air pollutants, including $PM_{2.5}$, PM_{10}, NO_2, O_3 and black carbon (BC). The software takes account of both short- and long-term cause-specific morbidity and mortality of mentioned air pollutants. In addition, it assesses the health impacts of household air pollution related to solid fuel use (SFU) [20, 21].

This study aimed to estimate the number of lung cancer deaths attributed to lung-term exposure to $PM_{2.5}$ among people older than 30 years in 15 cities of Iran during March 2015-March 2016 using AirQ+ modelling approach.

MATERIALS AND METHODS

Location and time

Fifteen cities of Iran were chosen to assess the health impacts of exposure to $PM_{2.5}$. These cities were Karaj, Kermanshah, Boushehr, Yazd, Urmia, Yasuj, Hamadan, Kerman, Ghazvin, Shahr-e Kord, Birjand, Varamin, Shahriar, Shahre Ghods, and Pakdasht. The period of interest was 21 March 2015 to 19 March 2016, which is one year in Persian calendar.

AirQ+

Estimation of health impacts in AirQ+ needs some input data such as $PM_{2.5}$ daily concentrations during a year, total population and at-risk population, baseline incidence of selected disease in the interest population, a cut-off value of concentration, and relative risks (RRs). This model estimates the number of lung cancer deaths due to long-term exposure to air pollution for individuals older than 30 years old. This is based on the recent findings of epidemiological studies and systematic reviews [21, 22].

Preparation of input data

Hourly concentrations of particulate matter were obtained from Department of Environment (DOE) of Iran. After removing zero and negative values, daily concentrations were calculated just in monitoring stations that met WHO's criteria for health impact assessment of air pollution [23].

According to these criteria, only stations are valid that have more than 50% valid data in a year. In addition, the ratio of valid data in summer to winter or winter to summer should not exceed 2 [24]. Daily concentrations of $PM_{2.5}$ in the selected year was prepared to enter the AirQ+ model. In case of days with PM_{10} measurements and without $PM_{2.5}$ concentrations, $PM_{2.5}$ levels were calculated based on a city-specific ratio of $PM_{2.5}/PM_{10}$ obtained from other days with complete $PM_{2.5}$ and PM_{10} data. Otherwise, a WHO's approved conversion factor of 0.33 was used [8]. There are some more recent criteria for validation of monitoring stations [23], but they require 75% or 90% of valid data in each year, that is not available in many studied cities of Iran.

Age-specific population of each city was received from Statistical Centre of Iran. At-risk population (>30 years old) was calculated. Table 1 presents total population and at-risk population of each city. Total population and population of individuals older than 30 years in all the 15 cities were more than 9 and 4.6 million, respectively.

Baseline incidence (BI) for lung cancer mortality was obtained from Ministry of Health and Medical Education [25]. Due to lack of valid precise city-by-city information, the baseline incidence for all the 15 cities was assumed to be the similar. Integrated exposure-response (IER) function was used for relative risk (RR) values. This function generates RR values depending on a non-standard curve and the level of pollution. So, there is no fixed value of RR [26].

RESULTS AND DISCUSSION

Table 2 presents the average concentrations of $PM_{2.5}$ during 21 March 2015 to 19 March 2016 period. The highest and lowest concentrations of particulate matter were observed in Shahr-e Kord and Birjand, respectively. In addition, the ratio of this annual concentration to WHO's guideline value for annual average of $PM_{2.5}$ (10 μg/m^3) was calculated, and is presented in Table 2. All the yearly concentrations were higher than WHO's guideline value. Fig.1 also shows the geographical distribution of $PM_{2.5}$ concentrations in Iran. According to this Figure, Western and Southern areas have higher concentrations of $PM_{2.5}$ rather than other areas.

The number of lung cancer deaths due to long-term exposure to $PM_{2.5}$ among individuals older than 30 years in 15 cities of Iran was estimated using AirQ+ modelling software. The number of lung cancer deaths due to long-term exposure to $PM_{2.5}$ are presented in Table 2. According to this Table, the most cases of lung cancer deaths due to $PM_{2.5}$ were estimated to be in Karaj. In addition, the least cases of deaths caused by $PM_{2.5}$ were observed in Birjand and Yasuj. The total mortality of lung cancer attributed to $PM_{2.5}$ concentrations in these 15 cities were 120 cases. Fig. 2 illustrates the geographical distribution of lung cancer mortality attributed to air pollution. The red areas are associated with higher mortality. The red areas in this Figure are different from those in Fig. 1.

Table 1. Total population and at-risk population (> 30 years) of each city

City	Total population	Population > 30 year	City	Total population	Population > 30 year
Karaj	2181150	1170125	Ghazvin	533120	269360
Kermanshah	913250	467350	Shahr-e Kord	315280	152320
Boushehr	264860	126480	Birjand	245700	104220
Yazd	595200	281600	Varamin	472800	266040
Urmia	786220	381900	Shahriar	602820	339201
Yasuj	135800	58450	Shahr-e Ghods	342780	192879
Hamadan	588500	306350	Pakdasht	295500	166275
Kerman	738400	334800	***Total***	**9011380**	**4617350**

Table 2. Annual average concentrations (± standard deviation) of $PM_{2.5}$ and attributable deaths due to lung cancer among people older than 30 years

City	Average concentrations (±SD), μg/m^3	Conc./WHO guideline	Deaths (CI 95%)
Karaj	32.85 (±18.76)	3.3	31 (7-47)
Kermanshah	36.31 (±30.11)	3.6	13 (3-20)
Boushehr	53.96 (±178.01)	5.4	5 (1-7)
Yazd	41.63 (±78.96)	4.2	9 (2-13)
Urmia	28.4 (±14.14)	2.8	9 (2-14)
Yasuj	49.69 (±57.17)	5.0	2 (1-3)
Hamadan	18.85 (±9.91)	1.9	5 (1-8)
Kerman	24.5 (±14.38)	2.5	7 (2-11)
Ghazvin	18.44 (±12.47)	1.8	4 (1-7)
Shahr-e Kord	66.65 (±44.81)	6.7	7 (2-9)
Birjand	17.69 (±13.97)	1.8	2 (0.5-3)
Varamin	34.45 (±15.95)	3.4	7 (2-11)
Shahriar	36.1 (±17.58)	3.6	10 (3-15)
Shahr-e Ghods	26.5 (±18.32)	2.7	4 (1-7)
Pakdasht	34.63 (±15)	3.5	5 (1-7)
Total	-	-	120 (29.5-182)

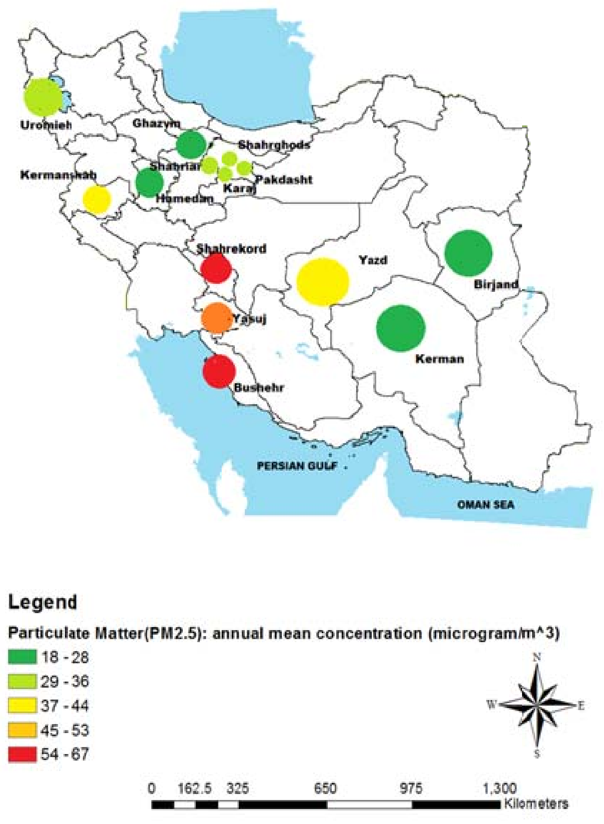

Fig. 1. Geographical distribution of $PM_{2.5}$ concentrations in Iran

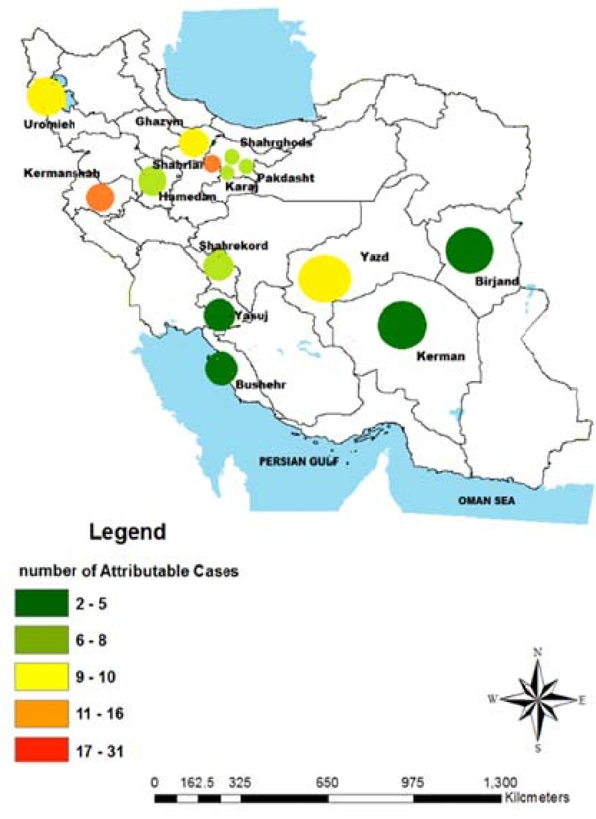

Fig. 2. Geographical distribution of lung cancer mortality attributed to air pollution in Iran

According to the results, yearly concentrations of particulate matter were 1.8 to 6.7 times higher than 10 μg/m^3, which is set by WHO as the annual guideline value for $PM_{2.5}$ concentrations. This value is the lowest level at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to $PM_{2.5}$ [27]. Averages of $PM_{2.5}$ concentrations in urban areas of North America, Europe, Africa and Asia are 17, 15-20, 15-30 and 30-60 μg/m^3, respectively. About 90% of United States' monitoring stations records $PM_{2.5}$ concentrations lower than 16 μg/m^3 [4].

High concentrations of particulate matter are very conventional in Asian cities, and Iran, in particular [10, 28, 29]. According to a database provided by WHO, Iranian cities are among the most polluted cities in the world [30]. A major source of air pollution in Iran is mobile sector, which have mainly poor quality in engine combustion and air pollution control mechanisms [31]. Another notable source of air pollution is Middle Eastern dust storms that are affecting Southern and Western cities of the country [32, 33]. These episodes raise average TSP and PM_{10} concentrations to 1548.7 (± 1965.1) and 1152.4 (± 1510.3) μg/m^3, respectively [10]. This can be due to unsustainable development of water resources in Middle Eastern countries, which has led to extensive desertification [34].

Karaj had the highest mortality of lung cancer due to fine particulate matter. This is not the same city that had the highest $PM_{2.5}$ concentrations. This difference is quietly clear in Figs. 1 and 2. The reason relies on the high population of Karaj that has increased attributed mortality. This is the case for some other cities such as Kermanshah, Urmia and Shahriar. On the other hand, some cities with high concentrations of $PM_{2.5}$ showed lower lung cancer mortality, since their population is less than others. This is important from the point of view of burden of disease or the economic losses that will be imposed to the societies and health-care systems [35].

No study has carried out in Iran to estimate lung cancer mortality that is caused by air pollution. However, WHO has studied about global lung cancer mortality and burden of disease attributed to $PM_{2.5}$ concentrations in 2012. WHO's report contains country-specific number of deaths, years of life lost (YLLs), and disability-adjusted life years (DALYs). According to this report, number of deaths, YLLs and DALYs of lung cancer attributed to $PM_{2.5}$ in Iran during 2012 were 1460, 37894 and 38258, respectively [36]. Even so, WHO's report faces a number of limitations. For instance, $PM_{2.5}$ concentrations have been calculated from PM_{10} measurements, not direct measurements of $PM_{2.5}$.

Lung cancer mortality caused by $PM_{2.5}$ in 23 European cities with 36 million people estimated, and the results showed that 1296 and 1901 lung cancer deaths could be prevented each year if $PM_{2.5}$ concentrations were reduced to 20 and 15 μg/m^3, respectively [37]. Years of life lost (YLLs) due to exposure to $PM_{2.5}$ for people older than 30 years were calculated using AirQ 2.2.3 in an Italian industrial area. The authors reported that for lung cancer, about 433 and 1204 years of life lost can be attributed to $PM_{2.5}$ concentrations higher than 10 μg/m^3 during the first year and the next 10 years, respectively. The yearly average concentration of $PM_{2.5}$ was 42 μg/m^3 [38].

Health impacts of air pollution force economic losses to each country. These losses are either direct and indirect (15). According to the World Bank group evaluation, total welfare losses (TWL) and total forgone labor (TFL) output caused by $PM_{2.5}$ in Iran were about 31 and 1.5 billion USD in 2013, respectively. These values contribute to 2.48% and 0.12% of gross domestic product (GDP) of the country, respectively. In 1990, the TWL and the TFL output caused by $PM_{2.5}$ are announced 14 and 2.5 billion USD, respectively [1]. Thus, reducing concentrations of air pollutants to below guideline values not only decreases mortality or hospitalization rate, but also has positive influences on national economies.

CONCLUSIONS

AirQ+ model was used for estimation of lung cancer deaths due to long-term exposure to fine particulate matter ($PM_{2.5}$). Target population was people with more than 30 years old. High concentrations of $PM_{2.5}$ were observed in Western and Southern cities. Annual concentrations of $PM_{2.5}$ in all cities were much more than the WHO's guideline. However, Karaj – as a city in Central areas- showed highest lung cancer mortality due to $PM_{2.5}$. That was mainly due to its higher population, in comparison to other cities. Beside the number of lung cancer deaths, the burden of disease (i.e. DALY) and also economic losses can be significant. Results of this study are interesting for authorities and decision-makers who are responsible for public health and also allocation of financial resources. They can raise the budget for air pollution reduction strategies and plans. Any reduction in air pollution's level, and attributed mortality and hospitalization reduces the number of years lost due to illness, disability or early death, and cost of illness (COI).

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COMPETING INTERESTS

The authors declare that they have no conflict of interest.

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ETHICAL CONSIDERATIONS

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

REFERENCES

[1] World Bank. The cost of air pollution : strengthening the economic case for action. Washington, D.C.: World Bank Group, 2016.

[2] WHO. Seven million premature deaths annually linked to air pollution. Geneva, World Health Organization: 2014.

[3] Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV, et al. Ambient PM2.5, O3, and NO2 Exposures and Associations with Mortality over 16 Years of Follow-Up in the Canadian Census Health and Environment Cohort (CanCHEC). Environ Health Perspect. 2015;123(11):1180-6.

[4] Traversi D, Gilli G. Mutagenicity of PM2. 5. 2011.

[5] Khamutian R, Najafi F, Soltanian M, Shokoohizadeh MJ, Poorhaghighat S, Dargahi A, et al. The association between air pollution and weather conditions with increase in the number of admissions of asthmatic patients in emergency wards: a case study in Kermanshah. Medical journal of the Islamic Republic of Iran. 2015;29:229.

[6] Pope CA, 3rd, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Jama. 2002;287(9):1132-41.

[7] Cancer IAfRo. Outdoor air pollution a leading environmental cause of cancer deaths. Lyon/Geneva. 2013.

[8] WHO. WHO's Urban Ambient Air Pollution Database. 2016 Update 2016.

[9] Sharafi K, Khosravi T, Moradi M, Pirsaheb M. Air quality and variations in PM10 pollutant concentration in Western Iran during a four-year period (2008–2011), Kermanshah–a case study. J Eng Sci Technol. 2015;10(1):47-56.

[10] Shahsavani A, Yarahmadi M, Hadei M, Sowlat MH, Naddafi K. Elemental and carbonaceous characterization of TSP and PM10 during Middle Eastern dust (MED) storms in Ahvaz, Southwestern Iran. Environmental monitoring and assessment. 2017;189(9):462.

[11] Hossein Shahbazi MB, Hossein Afshin, Vahid Hosseini. Tehran's air pollution emission inventory for the year 2013- Volume II: mobile sources [In Persian]. Tehran, Iran: Tehran Air Quality Control Company, 2015 QM/94/04/03/(U)/02.

[12] Hadei M, Hopke PK, Hashemi Nazari SS, Yarahmadi M, Shahsavani A, Alipour MR. Estimation of Mortality and Hospital Admissions Attributed to Criteria Air Pollutants in Tehran Metropolis, Iran (2013-2016). Aerosol and Air Quality Research.
[13] Conti GO, Heibati B, Kloog I, Fiore M, Ferrante M. A review of AirQ Models and their applications for forecasting the air pollution health outcomes. Environmental Science and Pollution Research.1-20.
[14] Clabaugh G, Ward MM. Cost-of-Illness Studies in the United States: A Systematic Review of Methodologies Used for Direct Cost. Value in Health. 2008;11(1):13-21.
[15] Byford S, Torgerson DJ, Raftery J. Cost of illness studies. BMJ: British Medical Journal. 2000;320(7245):1335.
[16] Asl FB, Kermani M, Aghaei M, Karimzadeh S, Arian SS, Shahsavani A, et al. Estimation of Diseases and Mortality Attributed to NO2 pollutant in five metropolises of Iran using AirQ model in 2011-2012. J Mazandaran Univ Med Sci. 2015;25(121):239-49.
[17] Kermani M, Dowlati M, Jafari AJ, Kalantari RR. Health risks attributed to particulate matter of 2.5 microns or less in Tehran air 2005-2015. Journal of Kermanshah University of Medical Sciences (J Kermanshah Univ Med Sci). 2016; 20 (3).
[18] Kermani M, Dowlati M, Jonidi Jafari A, Rezaei Kalantari R, Sadat Sakhaei F. Effect of Air Pollution on the Emergency Admissions of Cardiovascular and Respiratory Patients, Using the Air Quality Model: A Study in Tehran, 2005-2014. Health in Emergencies and Disasters Quarterly. 2016;1(3):137-46.
[19] Goudarzi GG, Sahar; Salmanzadeh, Shokrolah; Mohammadi, Mohammad Javad; Zallaghi, Elahe. The Number of Myocardial Infarction and Cardiovascular Death Cases Associated with Sulfur Dioxide Exposure in Ahvaz, Iran. Archives of Hygiene Sciences. 2014;3(4):112-9.
[20] Pierpaolo Mudu CG, Maria Dunbar. AirQ+ 1.0 example of calculations. World Health Organization, 2016.
[21] WHO Regional Office for Europe. AirQ+: key features. WHO Regional Office for Europe, 2016.
[22] Organization WH. Health risks of air pollution in Europe—HRAPIE project recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. World Health Organization Regional Office for Europe Geneva, Switzerland: World Health Organization. 2013.
[23] EC Directive. Council Directive 2008/50/EC on ambient air quality and cleaner air for Europe. Official Journal of the European Communities, L. 2008;151:1-44.
[24] World Health Organization. Monitoring ambient air quality for health impact assessment. 1999.
[25] Khosravi AA, Saeedeh; Kazemi, Elaheh; Kalantari, Naser;. The outlook of mortality in 30 provinces of Iran during 2011-2012. Ministry of Health and Medical Education, Tehran, Iran2016.
[26] AirQ plus. Germany: WHO Regional Office for Europe, European Centre for Environment and Health (ECEH), Bonn office; 2016.
[27] WHO. Air quality guidelines: global update 2005: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide: World Health Organization; 2006.
[28] Shahsavani A, Naddafi K, Jafarzade Haghighifard N, Mesdaghinia A, Yunesian M, Nabizadeh R, et al. The evaluation of PM10, PM2.5, and PM1 concentrations during the Middle Eastern Dust (MED) events in Ahvaz, Iran, from april through september 2010. Journal of Arid Environments. 2011.
[29] Shahsavani A, Naddafi K, Haghighifard NJ, Mesdaghinia A, Yunesian M, Nabizadeh R, et al. Characterization of ionic composition of TSP and PM10 during the Middle Eastern Dust (MED) storms in Ahvaz, Iran. Environmental monitoring and assessment. 2012;184(11):6683-92.
[30] WHO. Ambient (outdoor) air pollution in cities database. Geneva, World Health Organization: 2014.
[31] Shahbazi HB, Mahdi; Afshin, Hossein; Hosseini, Vahid. Tehran's air pollution emission inventory for the year 2013- Volume II: mobile sources [In Persian]. Tehran, Iran: Tehran Air Quality Control Company, 2015 QM/94/04/03/(U)/02.
[32] Sowlat MH, Naddafi K, Yunesian M, Jackson PL, Shahsavani A. Source apportionment of total suspended particulates in an arid area in southwestern Iran using positive matrix factorization. Bulletin of environmental contamination and toxicology. 2012;88(5):735-40.
[33] Sowlat MH, Naddafi K, Yunesian M, Jackson PL, Lotfi S, Shahsavani A. PM10 source apportionment in Ahvaz, Iran, using positive matrix factorization. CLEAN–Soil, Air, Water. 2013;41(12):1143-51.
[34] Moghaddam VK, Changani F, Mohammadi A, Hadei M, Ashabi R, Majd LE, et al. Sustainable development of water resources based on wastewater reuse and upgrading of treatment plants: a review in the Middle East. DESALINATION AND WATER TREATMENT. 2017;65:463-73.
[35] Jo C. Cost-of-illness studies: concepts, scopes, and methods. Clinical and molecular hepatology. 2014;20(4):327-37.
[36] WHO. Ambient air pollution: A global assessment of exposure and burden of disease. Geneva, Switzerland: 2016.

[37] Boldo E, Medina S, Le Tertre A, Hurley F, Mücke H-G, Ballester F, et al. Apheis: Health Impact Assessment of Long-term Exposure to PM2.5 in 23 European Cities. European Journal of Epidemiology. 2006;21(6):449-58.

[38] Fattore E, Paiano V, Borgini A, Tittarelli A, Bertoldi M, Crosignani P, et al. Human health risk in relation to air quality in two municipalities in an industrialized area of Northern Italy. Environ Res. 2011;111(8):1321-7.