Journal of Air Pollution and Health (Summer 2020); 5(3): 171-180

Original Article

Available online at http://japh.tums.ac.ir

# Quantification of mortality and morbidity in general population of heavily-industrialized city of Abadan: Effect of long-term exposure

*Akram Ghorbanian[1], Ahmad Jonidi Jafari[2,3], Abbas Shahsavani[4], Ali Abdolahnejad[5], Majid Kermani[2,3,*] Farzad Fanaei[6,*]*

[1] Department of Environmental Health Engineering, School of Public Health, Mashhad University of Medical Sciences, Mashhad, Iran
[2] Research Center of Environmental Health Technology, Iran University of Medical Sciences, Tehran, Iran
[3] Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran
[4] Environmental and Occupational Hazards Control Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[5] Department of Public Health, School of Nursing and Midwifery, Maragheh University of Medical Sciences, Maragheh, Iran
[6] Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

**ARTICLE INFORMATION**

*Article Chronology:*
Received 01 August 2020
Revised 02 September 2020
Accepted 10 September 2020
Published 29 September 2020

*Keywords:*
Air pollution; AirQ+; Burden of disease; Long-term; $PM_{2.5}$

**CORRESPONDING AUTHOR:**

farzadfanaei37@gmail.com
Tel: (+98 21) 88622707
Fax: (+98 21) 88622707
Kermani.m@iums.ac.ir
Tel: (+98 21) 88622707
Fax: (+98 21) 88622707

**ABSTRACT:**

**Introduction:** In the 21st century, air pollution has become a global and environmental challenge. The increase in cases of illness and mortality due to air pollution is not hidden from anyone. Therefore, in this study, we estimated the mortality rate due to cause by air pollution agents ($PM_{2.5}$) in the southernmost city of Khuzestan province (Abadan city) at 2018-2019.

**Materials and methods:** To estimate the mortality duo to air pollution, data related to $PM_{2.5}$ particles daily concentrations was received from the Abadan Environmental Protection Organization. The average 24-h concentrations of $PM_{2.5}$ were calculated using Excel. Then, mortality data were obtained from the Vice Chancellor for Health, Abadan University of Medical Sciences. Finally, by AirQ+ software, each of the mortality in 2018-2019 in Abadan was estimated.

**Results:** The obtained data indicated that the concentration of $PM_{2.5}$ particles within the one-year period was higher than the value set by WHO guideline and EPA standard. Which caused the citizens of Abadan to be exposed to $PM_{2.5}$ more than 8.23 times than the guidelines of the WHO and 5.34 times more than the standard of the EPA. The output of the model used in this study was as follows: natural mortality (462 cases, AP: 38.25%), mortality duo to LC (6 cases, AP: 32.18%), mortality duo to COPD (8 cases, AP: 26.64%), mortality duo to Stroke (86 cases, AP: 71.26%), mortality duo to IHD (183 cases, AP: 68.34%) and mortality duo to ALRI (2 cases, AP: 32.9%).

**Conclusion:** Planning appropriate strategies of air pollution control to reduce exposure and attributable mortalities is important and necessary.

## Introduction

Today, air pollution has expanded beyond the boundaries of cities and changed into a global plight, such that the modern life is interwoven with air pollution [1]. Therefore, it can be said that air pollution is one of the factors disrupting life in the present age in developed, especially developing countries [2]. So, it can be said that there is no clean and healthy air. In October 2013, outdoor air pollution classified as group 1 carci-

Please cite this article as: Ghorbanian A, Jonidi Jafari A, Shahsavani A, Abdolahnejad A, Kermani M, Fanaei F. Quantification of mortality and morbidity in general population of heavily-industrialized city of Abadan: Effect of long-term exposure. Journal of Air Pollution and Health. 2020; 5(3):171-180.

nogenic to humans by the IARC, and now it is one of the 5 top causes of death in the world [3]. As a result, it can be said that air pollution have a one of the hazard agent for human life continuity [5 ,4]. On the other hand, exposure to causes of air pollution can be endanger human health [6]. Air pollutants contain carcinogenic and dangerous compounds [8 ,7]. particulate matter with a diameter of less than 2.5 μm are the causes of air pollution and the impact on human health [9]. About 87% of the People of the world living in countries where the level of air pollution (level of $PM_{2.5}$) is higher than the allowable limit set by regulatory agencies (10 $\mu g/m^3$), including the WHO [10]. Mortality due to exposure of air pollution agents ambient ($PM_{2.5}$) has reached a very high levels [11]. So that, nearly 7 million deaths and 3.7 million premature deaths occur annually in urban and rural areas due to exposure to these fine particles [13 ,12]. In during the recent decade's mortality due to LC, COPD, stroke, IHD and ALRI due to exposure to $PM_{2.5}$ particles has increased [14]. Air pollution in addition to health effects it was increases the negative effects on the economies of countries. In 2016 the costs of air pollution were estimated to be as much as the gross domestic product (GDP) in some countries such as India, Canada, and Mexico [15].

Numerous studies have examined exposure to suspended particles and adverse health effects. In the crouse study, mortality from cardiovascular diseases increased by 10–20% due to an increase in $PM_{2.5}$ particle concentration [16]. Some researchers showed an association among fine particles and fatality from IHD, cardiovascular disease and LC [17]. And also in a study by other researchers, association among fine particles and mortality from IHD, cardiovascular disease and LC it was found [18].

Dust in parts of Iran, especially in Khuzestan province and cities of that province, has disrupted people's lives and severely overshadowed people's quality of life .[19]Continuation and recurrence of this pollution, especially with the prevailing weather conditions in autumn and winter, is a warning sign of an increase in cardiovascular disease, lung disease, cancer and an increase in deaths [20]. Quantifying the health effects of air pollution is an important guide for community decision makers and determines the extent of the health effects of air pollution and prioritizes air pollution control over In comparison with to other hazard agent [21].

Abadan city as one of the industrial cities of Iran because of unsustainable development, incompatible ambient air quality standards along , existence of the largest oil refinery in Iran and in neighboring countries, dust hotspot in the city itself, and most importantly, the dust imported from Iraq and Saudi Arabia, has seriously faced sever ambient air pollution[22]. Since the carcinogenicity of air pollution has been proven, the necessary measures to prevent such diseases and mortality are of great importance. In addition, the chemical properties of fine particles in this city have been studied to some extent, however, the health effects of these pollutants on the residents of this city have not been evaluated so far [23]. Thus, the current research was carried out with the following aim: estimating all naturally mortality cases, lung cancer (LC) in adults (over 30 years), COPD in adults (over 30 years), stroke in adults (over 25 years), IHD in adults (over 25 years), ALRI in childhood (Less than 5 years), and attributed to exposure to $PM_{2.5}$ in the atmosphere of Abadan city from March 2018 to March 2019 using AirQ+.

## Material and methods

### *Description of study area*

Abadan city in Khuzestan province with geographical features of 48 ° 17 'E and 30 ° 20'N and 3 m above sea level is known as one of the most famous cities in the south of Iran. Abadan city borders the cities of Khorramshahr, Shadegan and Mahshahr, so that the south of this city leads to the Persian Gulf. On the other hand, two rivers, Arvand and Bahmanshir, are flowing in this city. (Fig. 1). According to the 2016 enumeration, this city with a population of 300,000 people after Ahvaz and Dezful is the third most populous city in Khuzestan province. This city due to the largest oil refinery in the Middle East and access to open waters, petrochemical plants play a serious pattern in the Iranian economy, and along with the Tehran city (the capital of Iran) and Karaj (the capital of Alborz province) are known as the most industrial cities of Iran. The growth of this city has been based on the principles of urban planning due to the existence of a large oil refinery, something that the center of the province has been deprived of in recent decades. Abadan, like most cities in Khuzestan province, has a hot and humid climate and has hot summers and humid winters with mild weather. The average of annual rainfall, temperature in winter and summer was 350 mm, 5°C and 57°C, respectively. The hottest and coldest months of the year in this city are August and February, respectively [24].

On the other hand, Abadan, like other cities in Khuzestan province, is no exception to air pollution. In a way, in most seasons of the year, we see catastrophic pollution in this city. The source of most pollution in Abadan air can be attributed to fine dust. These dust particles are can be attributed to the destruction of vegetation and drying of wetlands in Khuzestan province, Iraq and also the Saudi desert and phenomenon of climate change. However, the pollution caused by the oil industry refinery should not be ignored. In this city, there is a fixed station for measuring air pollutants, which is owned by the city's environmental protection department. The installation site of Abadan Hilal Barim station is the Environmental Protection Office.

### *Quantification*

To express the effects of air pollutants on humans, several indicators can be used, one of the most important methods is the quantification of effects. In this method, the amount of effects attributed to each pollutant is estimated. Quantification in air pollution in order to measuring the effect of air pollution on public health is done with the aim of is possible by using mathematical and statistical models and relationships. One of the methods of quantifying the effects of air pollution is AirQ + introduced by WHO. The AirQ+ that May 2016 by the European Office of the WHO to quantify of pollutants (which is actually an upgraded version of AirQ2.2.3), is a user-friendly model. Acute and chronic consequences on human health due to contact with various air pollutants, along with mortality and disease can be estimated using this software [26 ,25].

### *Data collection and processing*

Abadan city, there is a one air pollution measuring station which is at the access of the environmental protection organization. Therefore, daily air quality of this city is measured by this station. In order to estimate the mortality due to exposure with $PM_{2.5}$ particles, the average 24-h concentrations of fine particles should be taken into account in the relevant calculations. Therefore, the

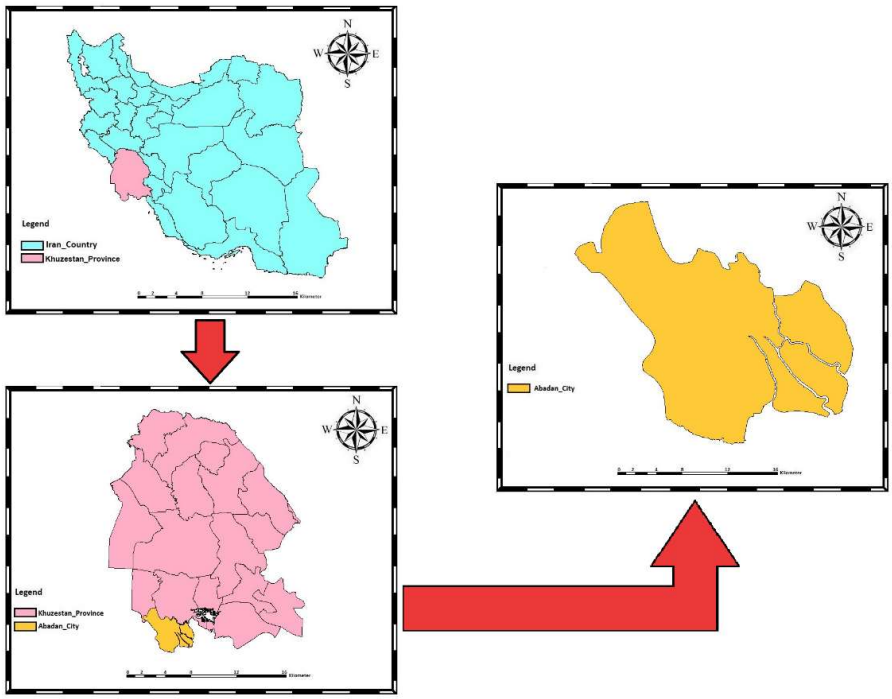


**Fig. 1. The Map of the study area**

hourly level of $PM_{2.5}$ particles were taken from air pollution monitoring stations from March 2018 to March 2019. Data according to the EPA criteria were processed using Excel. The 24 h averages for $PM_{2.5}$ was calculated based on WHO guideline. Afterwards, only valid data measurements were analyzed in current study by AirQ+ to quantify health effects.

***Baseline incidence (BI)***

The population of Abadan city from 2018-2019, in age groups (all ages, ≤5 years of age, ≥25, and ≥30) were obtained from the Statistical Center of Iran. Based on the number of deaths classified by ICD 10 codes in Abadan during 2018-2019 obtained from the Ministry of Health and Medical Education the baseline incidence rates (BI) of natural mortality and other mortality due to COPD, IHD, LC, and stroke were calculated using integrated exposure response (IER) function [27].

***Health risk assessment***

In this study, In order to estimate the health effects of $PM_{2.5}$ that include estimating all naturally mortality cases, acute lower respiratory infections (ALRI) (childhood<5 years old), chronic obstructive pulmonary disease (COPD) (adults 30<years), ischemic heart disease (IHD) (adults 25<years), lung cancer (LC) (adults 30<years) and stroke (adults 25<years)( long and short term), the following parameters were needed [a] annual mean concentration of PM2.5 [b] data for exposed population including the total adults (≥ 30 years of age) [c] epidemiological parameters, such as baseline rates (BR) [d] a cut-off value for studied pollutants (10 μg/m$^3$, according to WHO recommendation) and the values relative risk (RRs). The model is based on the attributable to proportion (AP) defined as the section of the health effect related to exposure air pollution, and is calculated based on the following equation:

$$AP = \left(\frac{\{(RR(c)-1)\times p(c)\}}{\{RR\,(c)\times p(c)\}}\right) \quad (1)$$

Where RR(c) is the relative risk for the health outcome in the Population exposed to air pollutants (c), and p(c) is the proportion of the population in the category of exposure (c). And also, the relative risk is calculated by the Eq. 2:

$$RR = \exp(\beta \ln(x - x.)) \quad (2)$$

β is a confidence interval (95% CI), X is the concentration of air pollutant, Xo the value of the counterfactual. on the other hand, the amount of health effects caused by exposure to fine particles (IE), and the number of cases related to exposure to fine particles (NE), are calculated using the following equations:

$$BE = B \times AP \quad (3)$$

$$NE = BE \times N \quad (4)$$

B: baseline incidence of the health outcome (per 100000 people). N: number of the at-risk population

## Results and discussion

### *Air pollution situation in Abadan*

As mentioned, there is one air pollution measuring station in Abadan. A total of 301 days of measuring $PM_{2.5}$ were found that in this city 10% of the total days of 2018-2019 have healthy air, 38% of days have unhealthy for sensitive groups, 10% of days have unhealthy, 9% of days have very bad Unhealthy and 8% of the days the quality was dangerous. This indicates that the citizens of Abadan are seriously exposed to various diseases caused by air pollution. Furthermore, the results of measuring station showed that 280 times in 1397, the 24-h concentration of $PM_{2.5}$ was more than the guideline of WHO. (Guideline for 24-h average concentration: 25μg/m$^3$). Also, concentration of $PM_{2.5}$ in Abadan was 230 times more than the EPA standard. (EPA standard for 24-h average concentration: 35 μg/m$^3$). The results show that $PM_{2.5}$ particles are the most important pollutants in Abadan urban air. Average concentration of this pollutant in 2018-2019 was 80.023 μg/m$^3$, which 8.23 times more than the WHO guideline for annual concentration (10 μg/m$^3$) and 5.34 times higher than the EPA standard for annual concentration (15 μg/m$^3$). In a study by Fanai et al. In 2020, the annual particle concentration $PM_{2.5}$ particles was 4 times higher than his WHO guide ]28[. On the other hand, other researchers estimated the mean annual concentration $PM_{2.5}$ particles as 68.98 μg/m$^3$ [29].Finally, a researcher in Hong Kong obtained the mean annual concentration $PM_{2.5}$ particles as 57.40 μg/m$^3$ [30].Table 1 compares the $PM_{2.5}$ particle concentrations obtained in the studies with our study.

**Table 1. Concentration of PM2.5 in Abadan and comparison with data from other countries**

| Country | Year | $PM_{2.5}$ concentration |
|---|---|---|
| Italy | 2001 | 45 |
| Pakistan | 2009 | 75 |
| Turkey | 2005 | 64 |
| Iran (Urmia city) | 2013 | 30 |
| Iran (Bushehr city) | 2017 | 65.77 |
| Iran (Abadan city) | 2018-2019 (present study) | 80.32 |

### *Potential health effects*

The Potential health risk attributed to long-term exposure of ambient $PM_{2.5}$ concentrations above 10 µg/m$^3$ in Abadan city at 2018-2019 obtained by the proposed model of the World Health Organization (AirQ +) are given in Table 2. Based on the results, the attributable to proportion estimated for the natural mortality related to $PM_{2.5}$ concentrations was 38.25% (95% CI: 26.12-44.39) and the excess cases of death 462 (312-584) cases with RR (1.53) were estimated. Comparison of the number of natural mortality in our study was different from other studies. In one of the industrial cities of Iran (Karaj), this amount of 948 deaths was achieved [17[. In a study, over a 10-year period, 5895 cases mortality occurred due to natural causes [31]. Other researchers 4061 numeral of death due to long-term exposure to $PM_{2.5}$ in Ahvaz city during of 2006-2015 was estimated [18]. On the other hand, Some researchers 4336 numeral of death due to exposure of $PM_{2.5}$ to natural causes for 10 cities in Iran country was estimated [32]. Also, the numbers of causes related to long-term exposure of $PM_{2.5}$ in capital of Iran during 2015-2016 and 2017-2018 were 5070 and 6710 cases, respectively [33 ,32] A study of the United States found that 130,000 deaths from 2005 to 2018 were related to long term exposure to $PM_{2.5}$ [34]. The reason for the increase in the number of deaths due to long term exposure to $PM_{2.5}$ in Tehran and United States compared to the present study can be attributed to the high population at risk in these studies. In a study of Ahvaz, it was found that approximately 40% of deaths were due to natural causes [18]. Accordingly, in our study at Abadan city in 2018-2019, 35% of the total number of deaths attributed to long term exposure to $PM_{2.5}$. Which was similar to study of researchers in Ahvaz and Tehran [35 ,18].

### *LC attributable cases*

Non-communicable diseases (NCD) by air pollution caused that becomes the main factors of death in the world. So that the AIRC has classified air pollution as a dangerous and carcinogenic substance. Undoubtedly, one of these non-communicable diseases caused by exposure to $PM_{2.5}$ particles is lung cancer. Studies have shown that air pollutants can greatly cause lung cancer. Researchers have predicted that mortality from lung cancer worldwide to increase by about 12 million due to air pollution by 2030 [36]. In this study, total mortality of lung cancer related to exposure of

**Table 2. BL, RR, AP, Excess cases and attributable cases for residents of Abadan city**

| Exposure | Pollutant | Health Outcome | BL | RR | AP (%) | Excess cases | Attributable cases per100000 |
|---|---|---|---|---|---|---|---|
| Long-term | $PM_{2.5}$ | Natural Mortality | 827.12 | 1.44 | 38.25 (26.12-44.39) | 462 (312-584) | 936.31 |
| | | LC | 14.16 | 1.44 | 32.18 (13.28-46.37) | 6 (9-21) | 16.52 |
| | | COPD | 11.25 | 1.44 | 25.64 (14.06-35.97) | 8 (6-13) | 10.27 |
| | | Stroke | 64.82 | 3.27 | 71.26 (42.56-72.31) | 86 (44-92) | 67.81 |
| | | IHD | 112.26 | 2.63 | 68.34 (52.68-86.49) | 183 (146-225) | 150.32 |
| | | ALRI | 6.89 | 1.19 | 32.19 (20.54-40.29) | 2 (1-3) | 6.53 |

$PM_{2.5}$ particles for Abadan city in 2018-2019 for a population over 30 years were estimated using AirQ+. (Table 2). As can be seen that the mortality of Lung cancer duo to long term exposure of $PM_{2.5}$ with AP 32.18% (95% Cl: 13.28-46.37%) in 2018-2019 was estimated 6 (9-21) cases. Numerous studies, have examined the significant relevance between air pollution and lung cancer [39 ,38 ,37 ,4]. In similar studies were obtained the number of deaths due to LC in Tabriz were 7 cases [40]. But in Karaj (2012-2016) and Tehran city that 139 and 427 cases was reported [17]. The incidence of baseline mortality may be one of the reasons for the difference in lung cancer mortality due to contact with $PM_{2.5}$ particles in these two studies with our study. A study by Parascandola in 2016 at Poland also found that lung cancer was the most important destructive effect of fine particles [41]. The European Union is working to control deaths from lung cancer due to contact with $PM_{2.5}$ particles by reducing particulate matter in the air. Also, a researcher showed in Taiwan that between 2008 and 2015, deaths due to LC decreased nearly by 16% [42]. The differences in baseline mortalities can be considered as the key reason for the differences in the values in the previous studies and the present study in the number of attributable deaths from LC.

***COPD attributable cases***

Among the deaths related to exposure of $PM_{2.5}$ particles, COPD is a great importance. Because they are also the most vulnerable group. So that in 2016, it accounted for almost 5% of all deaths [43]. In our study, the total mortality of COPD attributable to $PM_{2.5}$ during 2018-2019 with AP 25.64% (95% Cl: 14.06-35.97%) was estimated 8 (6-13) cases (Table 2). Researchers in Tehran [32], Karaj (2012-20126) [17], Rom[44] and Ahvaz [18]reported the COPD mortality duo to long term exposure of $PM_{2.5}$ respectively158, 124, 279 and 75. The differences in baseline mortalities can be considered as the key reason for the differences in the values in the previous studies and the present study in the number of attributable deaths from COPD.

***Stroke attributable cases***

As mentioned, air pollution have several effects on humans. The correlation between air pollution and stroke due to exposure with airborne particles has attracted the attention of many researchers. With increasing every 5 $\mu g/m^3$ at a particle concentration of $PM_{2.5}$ can cause to increase of hazard ratio about 1.15 (95% CI: 1.05, 1.23) mortality of stroke. The number of mortality due to stroke in Abadan city at period of this study with AP 71.26% (95% Cl: 42.56-72.31%) was estimated to be 86 (44-92) cases (Table 2). In a study, 34% of the population exposed to air pollution suffered a stroke [45]. Also, in Tehran city, 1500 cases of mortality duo to strokes in 2015 and in 2017, during a similar study in the same city, 1145 deaths were estimated [46 ,33[. For the city of Karaj, due to the existence of many industries and factories that exist, the death rate due to stroke in period of 2012 -2016 was estimated at 1834 cases [17]. The differences in baseline mortalities can be considered as the key reason for the differences in the values in the previous studies and the present study in the number of attributable deaths from Stroke.

***IHD attributable cases***

In a report by World Health Organization Categorized IHD (the first), stroke (The second) and COPD (Third) as cause of mortality related to exposure of $PM_{2.5}$ particles in ambient air [47]. In

our study, the highest mortality rates were related to IHD, stroke, and COPD, respectively (Table 2). In a study of Karaj, It was found that with every 10 μg/m$^3$ increase in the concentration of $PM_{2.5}$ particles, the cardiovascular admissions increases by 0.35 times [17]. Table 2 showed that the total mortality of IHD related to $PM_{2.5}$ in 2018-2019 at Abadan city with AP 68.34% (95% Cl: 52.68-86.49%) was estimated 183 (146-225) cases, respectively. Mortality due to IHD attributable cases in this study were different from other studies. Including they can be referred to a study by some researchers, which reported number of 3797 cases deaths related to IHD [46]. The differences in baseline mortalities can be considered as the key reason for the differences in the values in the previous studies and the present study in the number of attributable deaths from IHD.

### *ALRI attributable cases*

The effects of fine particles are not limited to adults and the aged, but in all ages it has its effects in various forms. One of these effects is ALR in children under 5 years of age. As there is no research about this issue in Abadan city, in this study we evaluate the effect of exposure to $PM_{2.5}$ on ALR-related mortality in children population (<5 years old) the city of Abadan and findings are shown in Table 2. Since the population at risk to $PM_{2.5}$ particles is lower, so we will see less mortality duo to ALR. As you can see in Table 2, the total mortality of ALR related to $PM_{2.5}$ in 2018-2019 at Abadan city with AP 32.19% (95% Cl: 20.54-40.29%) was estimated 2 (3-1) cases, respectively. In similar studies conducted by other researchers at tehran, tehran and karaj city, 27, 21 and 13 cases mortality duo to ALR in children population (<5 years old) respectively, was estimated [33, 17, 31]. The differences in baseline mortalities can be considered as the key reason for the differences in the values in the previous studies and the present study in the number of attributable deaths from ALR.

## Conclusion

The current study describes and analyzes the air of Abadan during 2018-2019 in terms of particle index of $PM_{2.5}$ and also assess the health risk of long exposure to ambient air pollutants. In this study, total natural mortality, mortality due to lung cancer, chronic obstructive pulmonary disease, stroke, ischemic heart disease, and Acute Lower Respiratory Infections (ALRI) was estimate using AirQ+. Citizens of Abadan in 2018-2019 approximately 8.23 times more than the amount guideline of the WHO will be exposed to air pollution especially $PM_{2.5}$. In other words, that citizens of Abadan during 2018-2019 in almost 280 days of a year were exposed to $PM_{2.5}$ more than the guidelines of WHO. The number of deaths due to natural mortality, LC, COPD, stroke, IHD ALRI associated with ambient $PM_{2.5}$ were 462, 6, 8, 86, 188 and 2, respectively. Based on our study estimation, 38.25% of the natural mortality, 32.18% of LC, 25.64% of COPD, 71.26 % of Stroke, 68.34% of IHD, and 32.19% of ALRI mortalities in Abadan was duo to long-term exposure of ambient $PM_{2.5}$. The current study indicates the mortality have a direct and indirect effects especially in terms of economic aspects for the city. The results from this research recommend that suitable controlling policies should be regulated to reduce ambient air $PM_{2.5}$ and its adverse health endpoints in Abadan.

## Financial supports

This study was funded by Iran University of

Medical Sciences, Tehran, Iran, and the Code of Ethics (IR.IUMS.REC.1399.129)

## Competing interests

The authors declare they have no actual or potential competing interests.

## Acknowledgements

This article is the result of Research project No 16758. Thus the authors are thankful for the funding provided by the Department of Environmental Health Engineering and Research Center of Environmental Health Technology, IUMS.

## Ethical considerations

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

## References

1. Mohammadi A, Ghassoun Y, Löwner M-O, Behmanesh M, Faraji M, Nemati S, et al. Spatial analysis and risk assessment of urban BTEX compounds in Urmia, Iran. Chemosphere. 2020;246:125769.
2. Laumbach RJ, Kipen HM. Respiratory health effects of air pollution: update on biomass smoke and traffic pollution. Journal of allergy and clinical immunology. 2012;129(1):3-11.
3. Cancer IAfRo. IARC: Outdoor air pollution a leading environmental cause of cancer deaths: International Agency for Research on Cancer; 2011.
4. Mohammadi A, Faraji M, Conti GO, Ferrante M, Miri M. Mortality and morbidity due to exposure to particulate matter related to drying Urmia Lake in the NW Iran. European journal of internal medicine. 2019;60:e14-e5.
5. Heydari G, Taghizdeh F, Fazlzadeh M, Jafari AJ, Asadgol Z, Mehrizi EA, et al. Levels and health risk assessments of particulate matters (PM2.5 and PM10) in indoor/outdoor air of waterpipe cafés in Tehran, Iran. Environmental Science and Pollution Research. 2019;26(7):7205-15.
6. Abdolahnejad A, Jafari N, Mohammadi A, Miri M, Hajizadeh Y. Mortality and Morbidity Due to Exposure to Ambient NO2, SO2, and O3 in Isfahan in 2013–2014. International journal of preventive medicine. 2018;9.
7. Hajizadeh Y, Jafari N, Mohammadi A, Momtaz SM, Fanaei F, Abdolahnejad A. Concentrations and mortality due to short-and long-term exposure to PM2.5 in a megacity of Iran (2014–2019). Environmental Science and Pollution Research. 2020;27(30):38004-14.
8. Nabizadeh R, Yousefi M, Azimi F. Study of particle number size distributions at Azadi terminal in Tehran, comparing high-traffic and no traffic area. MethodsX. 2018;5:1549-55.
9. Vahidi MH, Fanaei F, Kermani M. Long-term health impact assessment of PM2.5 and PM10: Karaj, Iran. International Journal of Environmental Health Engineering. 2020;9(1):8.
10. Guo C, Zhang Z, Lau AK, Lin CQ, Chuang YC, Chan J, et al. Effect of long-term exposure to fine particulate matter on lung function decline and risk of chronic obstructive pulmonary disease in Taiwan: a longitudinal, cohort study. The Lancet Planetary Health. 2018;2(3):e114-e25.
11. Lipsett MJ, Ostro BD, Reynolds P, Goldberg D, Hertz A, Jerrett M, et al. Long-term exposure to air pollution and cardiorespiratory disease in the California teachers study cohort. American journal of respiratory and critical care medicine. 2011;184(7):828-35.
12. 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. 2017;24(7):6426-45.
13. Dehghani MH, Jarahzadeh S, Hadei M, Mansouri N, Rashidi Y, Yousefi M. The data on the dispersion modeling of traffic-related PM10 and CO emissions using CALINE3; A case study in Tehran, Iran. Data in brief. 2018;19:2284-90.
14. Xie W, Li G, Zhao D, Xie X, Wei Z, Wang W, et al. Relationship between fine particulate air pollution and ischaemic heart disease morbidity and mortality. Heart. 2015;101(4):257-63.
15. Hosseini V, Shahbazi H. Urban air pollution in Iran. Iranian Studies. 2016;49(6):1029-46.
16. Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV, et al. HystadPerryPublicHealthHumanSciAmbientPM2. 5NO2Exposures. pdf. 2017.
17. Kermani M, Arfaeinia H, Masroor K, Abdolahnejad A, Fanaei F, Shahsavani A, et al. Health impacts and burden of disease attributed to long-term exposure to atmospheric PM10/PM2.5 in Karaj, Iran: effect of meteorological factors. International Journal of Environmental Analytical Chemistry. 2020:1-17.
18. Karimi A, Shirmardi M, Hadei M, Birgani YT, Neisi A, Takdastan A, et al. Concentrations and health effects of short-and long-term exposure to PM2.5, NO2, and O3 in ambient air of Ahvaz city, Iran (2014–2017). Ecotoxicology and Environmental Safety. 2019;180:542-8.
19. Neisi A, Goudarzi G, Akbar Babaei A, Vosoughi M, Hashemzadeh H, Naimabadi A, et al. Study of heavy metal levels in indoor dust and their health risk assessment in children of Ahvaz city, Iran. Toxin reviews. 2016;35(1-2):16-23.
20. Ghanavati N, Nazarpour A, Watts MJ. Status, source, ecological and health risk assessment of toxic metals and polycyclic aromatic hydrocarbons (PAHs) in street dust of Abadan, Iran. Catena. 2019;177:246-59.

21. Héroux M-E, Anderson HR, Atkinson R, Brunekreef B, Cohen A, Forastiere F, et al. Quantifying the health impacts of ambient air pollutants: recommendations of a WHO/Europe project. International journal of public health. 2015;60(5):619-27.
22. Radmanesh E, Maleki H, Goudarzi G, Zahedi A, Kalkhajeh SG, Hopke PK, et al. Cerebral ischemic attack, epilepsy and hospital admitted patients with types of headaches attributed to PM10 mass concentration in Abadan, Iran. Aeolian Research. 2019;41:100541.
23. Momtazan M, Geravandi S, Rastegarimehr B, Valipour A, Ranjbarzadeh A, Yari AR, et al. An investigation of particulate matter and relevant cardiovascular risks in Abadan and Khorramshahr in 2014–2016. Toxin reviews. 2018.
24. Ahmady-Birgani H, McQueen KG, Mirnejad H. Characteristics of mineral dust impacting the Persian Gulf. Aeolian Research. 2018;30:11-9.
25. Asl FB, Leili M, Vaziri Y, Arian SS, Cristaldi A, Conti GO, et al. Health impacts quantification of ambient air pollutants using AirQ model approach in Hamadan, Iran. Environmental research. 2018;161:114-21.
26. Organization WH. Evolution of WHO air quality guidelines: past, present and future. Copenhagen: WHO Regional Office for Europe. 2017;39.
27. Organization WH. Ambient air pollution: A global assessment of exposure and burden of disease. 2016.
28. Kermani M, Jafari AJ, Gholami M, Fanaei F, Arfaeinia H. Association between meteorological parameter and PM2.5 concentration in Karaj, Iran. International Journal of Environmental Health Engineering. 2020;9(1):4.
29. Tai AP, Mickley LJ, Jacob DJ. Correlations between fine particulate matter (PM2.5) and meteorological variables in the United States: Implications for the sensitivity of PM2. 5 to climate change. Atmospheric Environment. 2010;44(32):3976-84.
30. Ho K, Lee S, Chan CK, Jimmy CY, Chow JC, Yao X. Characterization of chemical species in PM2.5 and PM10 aerosols in Hong Kong. Atmospheric Environment. 2003;37(1):31-9.
31. Faridi S, Shamsipour M, Krzyzanowski M, Künzli N, Amini H, Azimi F, et al. Long-term trends and health impact of PM2.5 and O3 in Tehran, Iran, 2006–2015. Environment international. 2018;114:37-49.
32. Yarahmadi M, Hadei M, Nazari SSH, Conti GO, Alipour MR, Ferrante M, et al. Mortality assessment attributed to long-term exposure to fine particles in ambient air of the megacity of Tehran, Iran. Environmental science and pollution research. 2018;25(14):14254-62.
33. Ansari M, Ehrampoush MH. Meteorological correlates and AirQ+ health risk assessment of ambient fine particulate matter in Tehran, Iran. Environmental research. 2019;170:141-50.
34. Dedoussi IC, Eastham SD, Monier E, Barrett SR. Premature mortality related to United States cross-state air pollution. Nature. 2020;578(7794):261-5.
35. Bayat R, Ashrafi K, Motlagh MS, Hassanvand MS, Daroudi R, Fink G, et al. Health impact and related cost of ambient air pollution in Tehran. Environmental research. 2019;176:108547.
36. Martín-Sánchez JC, Lunet N, González-Marrón A, Lidón-Moyano C, Matilla-Santander N, Clèries R, et al. Projections in breast and lung cancer mortality among women: a Bayesian analysis of 52 countries worldwide. Cancer research. 2018;78(15):4436-42.
37. Zhang C, Guo Y, Xiao X, Bloom MS, Qian Z, Rolling CA, et al. Association of breastfeeding and air pollution exposure with lung function in Chinese children. JAMA network open. 2019;2(5):e194186-e.
38. Zhai T, Li S, Hu W, Li D, Leng S. Potential micronutrients and phytochemicals against the pathogenesis of chronic obstructive pulmonary disease and lung cancer. Nutrients. 2018;10(7):813.
39. Yang B-Y, Qian ZM, Li S, Fan S, Chen G, Syberg KM, et al. Long-term exposure to ambient air pollution (including PM1) and metabolic syndrome: The 33 Communities Chinese Health Study (33CCHS). Environmental research. 2018;164:204-11.
40. Mehmood T, Tianle Z, Ahmad I, Li X, editors. Integration of AirQ+ and particulate matter mass concentration to calculate health and ecological constraints in Islamabad, Pakistan. 2019 16th International Bhurban Conference on Applied Sciences and Technology (IBCAST); 2019: IEEE.
41. Parascandola M. Ambient air pollution and lung cancer in Poland: research findings and gaps. Journal of Health Inequalities. 2018;4(1):3-8.
42. Luong LTM, Dang TN, Huong NTT, Phung D, Tran LK, Thai PK. Particulate air pollution in Ho Chi Minh city and risk of hospital admission for acute lower respiratory infection (ALRI) among young children. Environmental Pollution. 2020;257:113424.
43. Organization WH. Chronic obstructive pulmonary disease (COPD). 2017. Available on: http://www who int/respiratory/copd/en. 2018.
44. De Marco A, Amoatey P, Khaniabadi YO, Sicard P, Hopke PK. Mortality and morbidity for cardiopulmonary diseases attributed to PM2.5 exposure in the metropolis of Rome, Italy. European Journal of Internal Medicine. 2018;57:49-57.
45. Knezovic M, Pintaric S, Jelavic MM, Kes VB, Nesek V, Bogovic S, et al. The role of weather conditions and normal level of air pollution in appearance of stroke in the region of Southeast Europe. Acta Neurologica Belgica. 2018;118(2):267-75.
46. Hadei M, Nazari SSH, Eslami A, Khosravi A, Yarahmadi M, Naghdali Z, et al. Distribution and number of ischemic heart disease (IHD) and stroke deaths due to chronic exposure to PM2.5 in 10 cities of Iran (2013-2015); an AirQ+ modelling. Journal of air pollution and health. 2017;2(3):129-36.
47. Organization WH. WHO guidelines for indoor air quality: household fuel combustion: World Health Organization; 2014.