



# Estimation of PM<sub>2.5</sub> Pollutant and Risk of Chronic Obstructive Pulmonary Disease (COPD) in Ahvaz, Iran

Elahe Zallaghi<sup>1</sup>, Gholamreza Goudarzi<sup>1,2</sup>, Sima Sabzalipour<sup>1,\*</sup> and Alireza Zarasvandi<sup>1,3</sup>

<sup>1</sup>Department of Environmental Sciences, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

<sup>2</sup>Environmental Technologies Research Center (ETRC), Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

<sup>3</sup>Department of Geology, Shahid Chamran University, Ahvaz, Iran

\*Corresponding author: Department of Environment, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran. Email: sabzalipoursima@gmail.com

Received 2020 June 07; Revised 2020 July 11; Accepted 2020 July 29.

## Abstract

**Background:** Urban air pollution was known to be one of the most important environmental problems due to its serious impact on human and environmental health. Among air pollutants, PM<sub>2.5</sub> was the most common pollutant emitted by vehicles and dust and had negative consequences for human health, including chronic obstructive pulmonary disease (COPD).

**Objectives:** This study aimed to assess the change levels of PM<sub>2.5</sub> pollutants and their effect on COPD outcomes in ten years (2008 - 2017) in Ahvaz.

**Methods:** Data were taken from the Ahvaz Department of Environment (ADoE). Data validation was performed using WHO criteria. The average time of PM<sub>2.5</sub> was computed, and its health effects were obtained by entering its annual data and population at risk, baseline incidence (BI), and relative risk index for COPD outcomes in AirQ + software. The PM<sub>2.5</sub> concentration average in total time changes in Ahvaz city was higher than the standard concentration set by WHO. The AQI index indicated that the city of Ahvaz did not have a good day in total during the ten-year time.

**Results:** The result of time changes and AQI index indicated that 2010 was the most polluted year with 47 unhealthy days and 27 dangerous days. Also, with the enhancement in the PM<sub>2.5</sub> annual concentrations, the mortality attributed to this pollution has increased as a consequence of the COPD outcome. The highest and lowest average cases COPD were 24 people in 2010 and 18 people in 2014, respectively.

**Conclusions:** According to the results of this study, the air quality of Ahvaz city was in an unfavorable condition in terms of PM<sub>2.5</sub> pollutions and the authorities should take the necessary measures to control and reduce pollution in the metropolis of Ahvaz for PM<sub>2.5</sub> and reduce the mortality for the COPD health outcome.

**Keywords:** Chronic Obstructive Pulmonary Disease, Urban Air Pollution, Relative Risk, Ahvaz

## 1. Background

Outdoor air pollution is one of the main concerns that have a serious impact on human health and the environment. Understanding how air pollution affects health and its role in disease progression shows the motivation and necessity of reforming environmental health policies, re-assessing economic decisions, and, most importantly, improving the health and quality of life of residents (1). Motor vehicles and industrial processes play an important role in air pollution. Today, the unfavorable state of air quality has become one of the most important environmental problems in many major cities around the world due to its harmful consequences. Harmful air pollutants are also produced in environments that can be harmful to hu-

man health (2, 3). Many epidemiological studies have examined the effect of air pollution on human health (4-6). Amongst air pollutants, PM<sub>2.5</sub> has been identified as the most prevalent pollutant emitted from vehicles. PM<sub>2.5</sub> is related to negative human health consequences due to the sorption of toxic matters at the level of PM<sub>2.5</sub> particles such as volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) (7, 8). Chronic obstructive pulmonary disease (COPD) is a major reason for complications and mortality in both high- and low-income countries. Although smoking is the most important risk factor in the world, outdoor and indoor air pollutants can exacerbate COPD (9). Many epidemiological studies have consistently shown that PM<sub>2.5</sub> is related to an increased risk of

COPD outcomes. Cortez-Lugo et al. (10) investigated the impact of personal exposure  $PM_{2.5}$  on respiratory health in a panel of Mexican patients with COPD. All participants stayed in Mexico City and were monitored during follow-up,  $PM_{2.5}$  personal exposure, medications, respiratory sign, and daily activities. It has been estimated that an increase in  $10 \mu g/m^3$  on average per day of two-day personal exposure to  $PM_{2.5}$  is associated with an increase in respiratory symptoms in adults with COPD (10). Huang et al. (11) examined the association of COPD and  $PM_{2.5}$  in non-smokers in Taiwan. The population-based study included 3,941 unauthorized Taiwanese adults employed between 2008 and 2015 in the Taiwan Biobank project. Exposure to  $PM_{2.5}$  at concentrations above  $38.98 \mu g/m^3$  increases the susceptibility to COPD in Taiwanese non-smokers. Conflict with COPD involves combining tobacco control and pollution management strategies (11).

Therefore, based on the above, it can be said that it is very important to study the time changes of  $PM_{2.5}$  pollutants in urban air quality and its effects on human health. Many models, including BenMAP-CE, AirQ+, TM5-FASST, and IOMLIFET have been studied to health effects assessment of air pollution. AirQ+ software is developed by the World Health Organization (WHO). The software distinguishes hospital reception and mortality from various air pollutants, including  $PM_{2.5}$ , carbon black,  $PM_{10}$ ,  $O_3$ , and  $NO_2$  (12). The air quality index (AQI) and  $PM_{2.5}$  are two significant indexes amongst air pollution indices. AQI is an index of air quality that reflects and assesses the city's air quality, which simplifies the concentration of several air pollutants, including  $PM_{2.5}$ , in a numerical form (13). Ahvaz is one of the most polluted cities in Iran due to its many sources of pollution, including vehicles, factories, and industrial sites. Therefore, there is a need to assess the air quality in this city (14).

## 2. Objectives

Therefore, the purpose of this study was to estimate the estimation of COPD outcomes attributed to  $PM_{2.5}$  pollutants in the air of Ahvaz city. Also, based on the AQI index, we will assess the air quality of Ahvaz for  $PM_{2.5}$  pollutants.

## 3. Methods

In this descriptive cross-sectional study, estimating the time changes of pollutants, epidemiological, and using the model during the ten-year period (2008 - 2017) in Ahvaz for

$PM_{2.5}$  pollutants. Ahvaz is a city as the capital of Khuzestan Province and the largest city in Southwestern Iran. The city is located at 31 degrees 19 minutes north and 48 degrees 40 minutes east and is about 20 meters above sea level (15). The geographical location of Ahvaz is shown in Figure 1.

### 3.1. Data Analysis

$PM_{2.5}$  data from organizations of environmental protection and meteorology and mortality data attributed to COPD outcomes for adults over 30 years were gathered from the Deputy of Health of Khuzestan Province. COPD outcomes of exposure with  $PM_{2.5}$  were surveyed by the AirQ+ model. Data validation was investigated by WHO criteria. Based on this, four stations (Naderi, Mohit Zist, Behdasht Ghadim, and Havashenasi) were elected, including more than 50% of the valid data per year and index of population exposure. After validating the  $PM_{2.5}$  pollutant data, the average of hourly, daily, weekly, monthly, seasonal, and annual for  $PM_{2.5}$  changes was calculated and by entering the annual  $PM_{2.5}$  pollutant data and attributed to population contact, the COPD outcome in AirQ+ software has been applied for ten-years in connection with its health effects. Population contact data per 100,000 population, including the population at risk, BI, and RR for COPD outcomes are shown in Table 1 for the study period. Attributable proportion, the number of cases attributable per 100,000 people at-risk (BE), and the total number of cases attributable to the exposure (NE) are amongst the most important cases in the software output table. Also, their calculation method for COPD outcomes is shown in Equations 1 to 4 (16, 17).

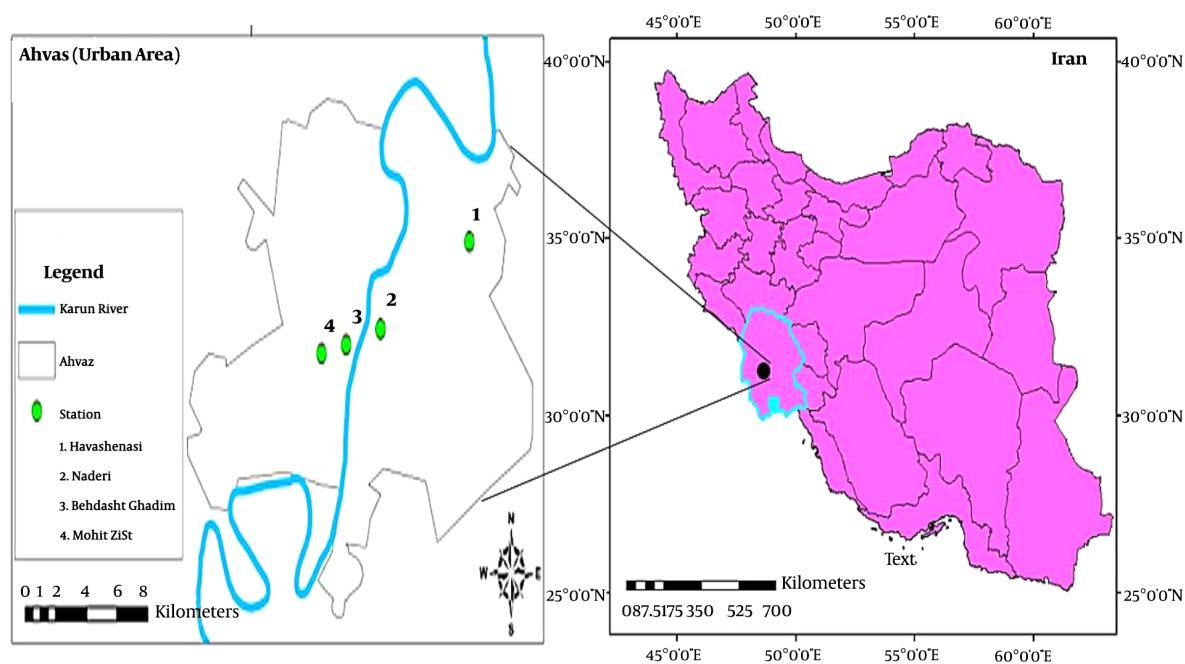
$$AP = \frac{SUM \{ [RR(c) - 1] \times p(c) \}}{SUM [RR(c) - 1 \times p(c)]} \quad (1)$$

$$RR(X) = e^{\beta(X - X_0)} \quad (2)$$

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

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

Where AP is the equivalent attributable proportion or proportion of the population in the exposure of pollutants at a certain time; RR (c) is the relative risk of the health effect on the purpose population in the contact category c (Equation 2); and p (c) is the equivalent of the population proportion of the exposure group c.



**Figure 1.** Location of sampling stations in Ahvaz megacity

**Table 1.** Population of At-Risk, BI, and RR for Health Outcome of COPD

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
<b>Population of at-risk</b>	545640	550460	544340	560034	564446	570857	574731	578295	571881	585185
<b>BI</b>	20	20	20	20	20	20	20	20	20	20
<b>RR</b>										
Lowest	1.09	1.12	1.13	1.10	1.11	1.09	1.08	1.09	1.09	1.09
Average	1.22	1.27	1.29	1.23	1.25	1.22	1.19	1.21	1.21	1.21
Highest	1.37	1.44	1.46	1.37	1.40	1.36	1.32	1.36	1.36	1.36

RR, the elective health outcome, was obtained by contact-response functions from the same epidemiological researches. In this research, we will use the default values of RR in the AirQ+ model.

Where  $X$ ,  $X_0$ , and  $\beta$  demonstrate the  $PM_{2.5}$  average concentration in Ahvaz city. Knowing the BI rate and elective health outcome (B), BE is calculated by Equation 3.

Where B demonstrates the number of incidence of health outcomes per 100,000 population at risk, owing to the inability to access hospitals' data of COPD outcomes, BI values were applied in other same researches. Also, its values were not accessible for the last year, the year that these values were accessible was applied. Finally, NE to the population at risk (N) in the ten-years studied (Table 1), was calculated by Equation 4.

### 3.2. Mechanisms of $PM_{2.5}$ on the Human Respiratory System

The effects of ambient  $PM_{2.5}$  on mortality in China and other countries have been investigated for decades (18). Current epidemiological data have revealed a robust correlation between fine particle pollutants and respiratory diseases.  $PM_{2.5}$  is known to exacerbate chronic inflammatory lung conditions, including pulmonary hypertension, 31 cardiovascular, and autoimmune diseases. There are several proposed mechanisms of the impact of  $PM_{2.5}$  on human respiratory physiology (18). These include the release of molecular mediators [i.e., extracellular regulated protein kinases (ERK)/protein kinase B (Akt), mitogen-activated protein kinase (MAPK), signal transducers and activators of transcription (STAT)-1] that affect the cells, tissue, and system after PM exposure, and the binding of pathogenic antibodies to pro-inflammatory cell recep-

tors, leading to an exacerbation of chronic inflammation (Figure 2).

#### 4. Results

In this research, the PM<sub>2.5</sub> time changes and its health effect on COPD outcomes were surveyed by the AirQ+ model in Ahvaz City. The average time of hourly, daily, weekly, monthly, seasonal, and annual for PM<sub>2.5</sub> concentrations according to air quality guidelines of WHO was computed, and their results are indicated in Figure 3. The hourly changes average of PM<sub>2.5</sub> in Ahvaz was indicated that the maximum concentration was in 2010 (83.35  $\mu\text{g}/\text{m}^3$ ) at 23:00, and the minimum was in 2014 (39.08  $\mu\text{g}/\text{m}^3$ ) at 4 pm. The maximum daily average of PM<sub>2.5</sub> concentration was dependent on 2009 (234.19  $\mu\text{g}/\text{m}^3$ ), and the minimum was in 2017 (18.15  $\mu\text{g}/\text{m}^3$ ). According to the average of the weekly change for PM<sub>2.5</sub> in Ahvaz City, the maximum concentration of dependent in 2010 (72.85  $\mu\text{g}/\text{m}^3$ ) and the minimum was in 2014 (41.33  $\mu\text{g}/\text{m}^3$ ). The monthly changes average of PM<sub>2.5</sub> in Ahvaz were indicated that the maximum monthly concentration of PM<sub>2.5</sub> was in February 2010 (97.26  $\mu\text{g}/\text{m}^3$ ), and the minimum was in April 2016 (35.5  $\mu\text{g}/\text{m}^3$ ). According to the average of the seasonal change of PM<sub>2.5</sub> in Ahvaz city, the maximum seasonal concentration of PM<sub>2.5</sub> was in the winter of 2010 (94.64  $\mu\text{g}/\text{m}^3$ ), and the minimum was in the fall of 2014 (44.439  $\mu\text{g}/\text{m}^3$ ). Also, the average of annual changes of PM<sub>2.5</sub> indicated that the maximum annual concentration of PM<sub>2.5</sub> was in 2010 (70.72  $\mu\text{g}/\text{m}^3$ ), and the minimum was in 2014 (41.97  $\mu\text{g}/\text{m}^3$ ).

In Table 2 the health effects of PM<sub>2.5</sub> pollutants for COPD outcomes are specified in the city of Ahvaz, including attributable proportion, the number of cases attributable per 100,000 people at risk (BE), and the total number of cases attributable to the exposure (NE) the ten-year period by the AirQ+ software. Based on these results, the maximum average of AP was 22.48% in 2010 and the minimum was 7.41% in 2014. The maximum average of BE was 4.5 people in 2010, and the minimum was 3.2 people in 2014. Also, the maximum and minimum average NE were 24 people in 2010 and 18 people in 2014, respectively.

#### 5. Discussion

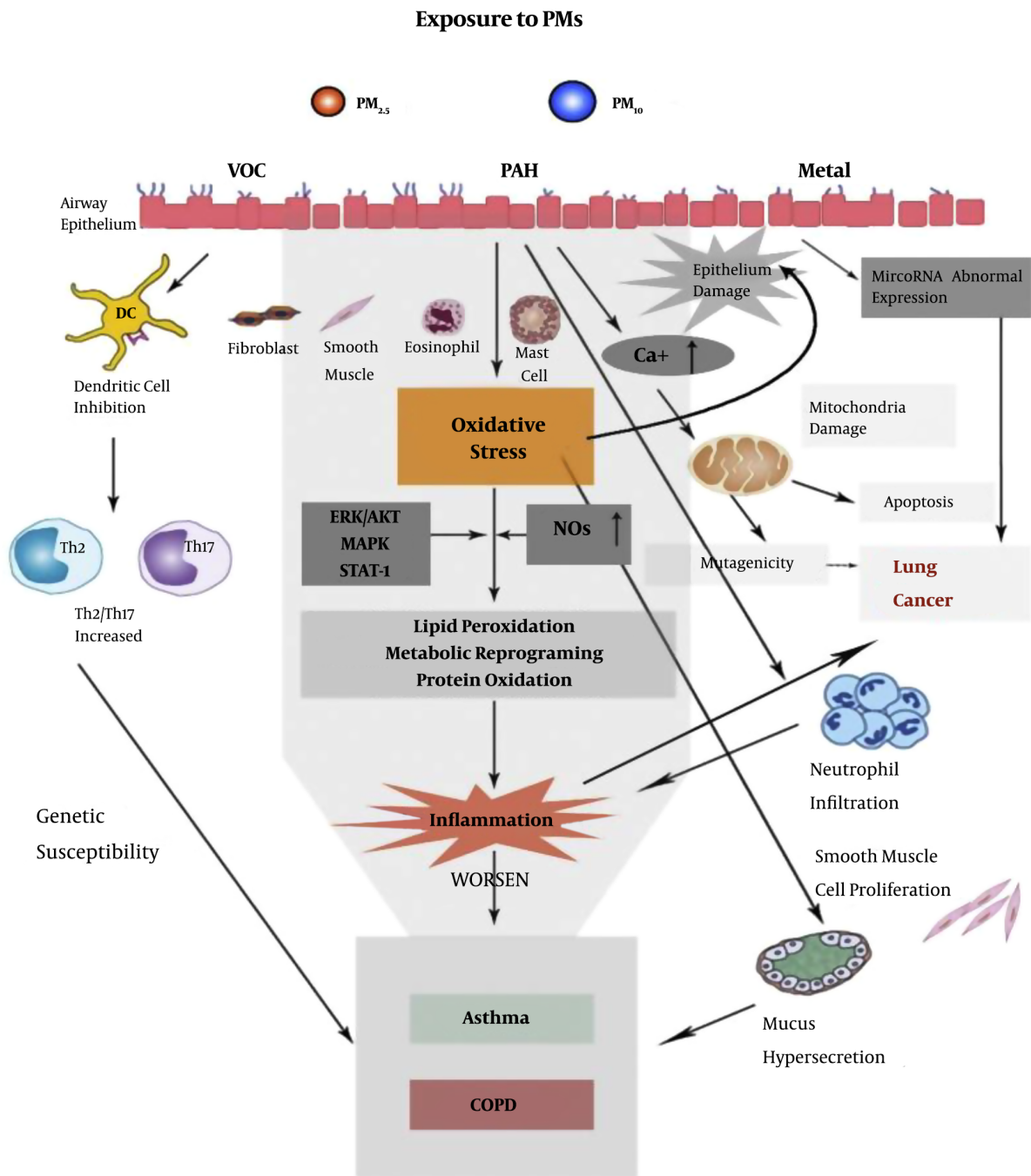
In many developing countries, the concentration of air pollutants is much higher than the WHO's guidelines. In addition, it has been widely suggested that urban air pollution can cause a diversity of diseases. In recent years, despite good measures to control and prevent air pollution,

this issue remains a serious threat to human health and the environment (19). Considering the significance of air pollution on human health, in this research, hourly, daily, weekly, monthly, seasonal, and annual changes for PM<sub>2.5</sub> pollutants and its effect on the COPD health outcome by the AirQ+ model in Ahvaz city in a period of ten-years was applied.

The average PM<sub>2.5</sub> concentration in total time changes studied in the air of Ahvaz City was higher than the standard set (10  $\mu\text{g}/\text{m}^3$ ) by WHO (20). Dust phenomenon is one of the main causes of air pollution due to PM<sub>2.5</sub> pollution in Ahvaz City. The city of Ahvaz is close to Iraq, Kuwait, and Saudi Arabia, which are important sources of desert dust, especially in the summer, which is constantly affected by north winds and cyclones. Ahvaz is also affected by dust from the north wind and strong northwest winds, which prevail in the spring and carry large amounts of dust from southern Iraq. The dust has caused considerable problems in multiple aspects of urban life and has also caused economic and environmental problems (including soil turmoil, increased drought, and reduced vegetation cover). Thus, industrial and educational centers have led to the hospitalization of thousands of patients with cardiovascular and respiratory diseases in hospitals (21, 22). Therefore, urban air pollution has been reported by some researchers due to the phenomenon of dust and PM<sub>2.5</sub> pollutants in Ahvaz city and many regions of Iran and the world (23, 24). There was a significant relationship between PM<sub>2.5</sub>, proportion, and cases of attributable to health outcomes of COPD using the AirQ+ model. Accordingly, with increasing annual concentration of PM<sub>2.5</sub> over the ten years studied, mortality attributed to this pollutant has increased as a result of the outcome of COPD. In the same research by Jo et al. (25), the epidemiological status of PM<sub>2.5</sub> and the risk of COPD-related hospital exposure to particulate matter in Chuncheon, Korea, were investigated. The results indicated that increasing the PM<sub>2.5</sub> concentrations and its compounds caused an increase in hospital visitation for COPD in Chuncheon.

##### 5.1. Limitations and Strengths

The major limitations of this study include the limitations of ecological studies, which is the use of aggregated data. Observed trends may not be representing a wider population because of this study had a small sample size. It should be noted that future larger studies are required to verify the observed trends to perform sub-group analyses and further period.



**Figure 2.** The principal route of damage on the human respiratory system after PM<sub>2.5</sub> exposures. PM, particulate matter; VOC, volatile organic compounds; PAH, polycyclic aromatic hydrocarbon; ERK, extracellular regulated protein kinases; MAPK, mitogen-activated protein kinase; STAT-1, signal transducers and activators of transcription-1; COPD: chronic obstructive pulmonary disease (18).

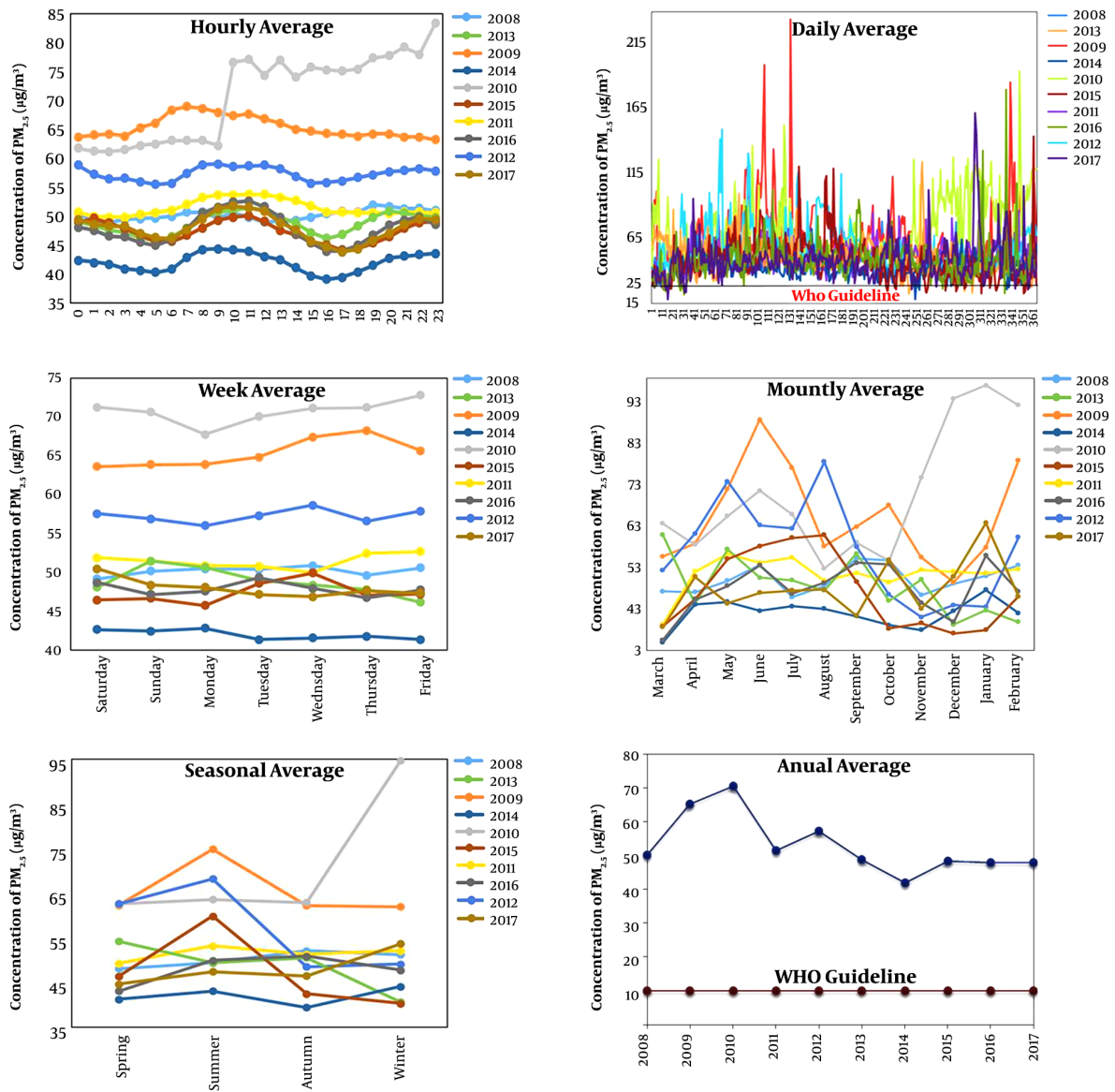


Figure 3. The average time of hourly, daily, weekly, monthly, seasonal, and annual for PM<sub>2.5</sub> concentrations in Ahvaz City.

### 5.2. Conclusions

According to the results of PM<sub>2.5</sub> pollutant time changes and health outcomes of COPD in Ahvaz City in the ten-year period, it can be said that the city of Ahvaz needs more attention for reducing the adverse effects of air pollution. As a result, using AirQ+ software to study the health effects of PM<sub>2.5</sub> on human health is a safe, useful, and simple way. The results indicate that the authorities should seriously, using short-term and long-term plans,

make the necessary efforts to control and reduce the pollution of metropolises and ensure the health of the residents of this city.

### Acknowledgments

The authors are thankful to the Islamic Azad University, Ahvaz Branch, Meteorological Organizations, Department of Health and cure, and Environmental Protection Agency

**Table 2.** Attributable Proportion and Cases Attributed to PM<sub>2.5</sub> in COPD

Year	Attributable proportion (AP)			Attributable cases number per 100000 population of at-risk (BE)			Attributable cases total (NE)		
	Lowest	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest
2008	8.41	18.15	27.01	1.7	3.6	3.6	9	20	29
2009	10.71	21.26	30.74	2.1	4.2	4.2	12	23	34
2010	11.5	22.48	31.85	2.3	4.5	4.5	13	24	53
2011	9.09	18.70	27.24	1.8	3.7	3.7	10	21	31
2012	9.91	20	28.73	2.5	4	4	11	23	32
2013	8.26	18.03	26.89	1.6	3.6	3.6	9	21	31
2014	7.41	15.97	24.80	1.5	3.2	3.2	9	18	29
2015	8.26	17.62	26.47	1.6	3.5	3.5	10	20	31
2016	8.26	17.95	26.47	1.6	3.6	3.6	10	21	31
2017	8.26	18.02	26.47	1.6	3.6	3.6	10	21	31

of Khuzestan Province for their cooperation in obtaining the required data.

#### Footnotes

**Authors' Contribution:** Conception and design of study: Elahe Zallaghi, Gholamreza Goudarzi, Sima Sabzalipour, and Alireza Zarasvandi. Acquisition of data: Elahe Zallaghi and Sima Sabzalipour. Analysis and/or interpretation of data: Elahe Zallaghi. Drafting the manuscript: Elahe Zallaghi, Gholamreza Goudarzi, Sima Sabzalipour, and Alireza Zarasvand. Revising the manuscript for important intellectual contents: Elahe Zallaghi, Gholamreza Goudarzi, Sima Sabzalipour, and Alireza Zarasvandi.

**Conflict of Interests:** There are no conflicts of interest to declare.

**Funding/Support:** Funding is provided by the Islamic Azad University, Ahvaz Branch.

#### References

- Ghorani-Azam A, Riahi-Zanjani B, Balali-Mood M. Effects of air pollution on human health and practical measures for prevention in Iran. *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences*. 2016;**21**. doi: [10.4103/1735-1995.189646](https://doi.org/10.4103/1735-1995.189646). [PubMed: [27904610](https://pubmed.ncbi.nlm.nih.gov/27904610/)].
- Goudarzi G, Mohammadi MJ, Ahmadi AK, Neisi A, Babaei AA, Mohammadi B, et al. Estimation of health effects attributed to no2 exposure using airq model. *Arc Hygiene Sci*. 2012.
- Kermani M, Aghaei M, Gholami M, Asl FB, Karimzadeh S, Jokandan SF, et al. Estimation of mortality attributed to PM2. 5 and CO exposure in eight industrialized cities of Iran during 2011. *Iran Occupational Health*. 2016;**13**(4):49-61. doi: [10.17795/jhealthscope-38736](https://doi.org/10.17795/jhealthscope-38736).
- Ito K, Xue N, Thurston G. Spatial variation of PM2. 5 chemical species and source-apportioned mass concentrations in New York City. *Atmospheric Environment*. 2004;**38**(31):5269-82. doi: [10.1016/j.atmosenv.2004.02.063](https://doi.org/10.1016/j.atmosenv.2004.02.063).
- Rovira J, Domingo JL, Schuhmacher M. Air quality, health impacts and burden of disease due to air pollution (PM10, PM2. 5, NO2 and O3): Application of AirQ+ model to the Camp de Tarragona County (Catalonia, Spain). *Science of The Total Environment*. 2020;**703**:135538. doi: [10.1016/j.scitotenv.2019.135538](https://doi.org/10.1016/j.scitotenv.2019.135538). [PubMed: [31759725](https://pubmed.ncbi.nlm.nih.gov/31759725/)].
- Yitshak-Sade M, Bobb JF, Schwartz JD, Kloog I, Zanobetti A. The association between short and long-term exposure to PM2. 5 and temperature and hospital admissions in New England and the synergistic effect of the short-term exposures. *Science of the Total Environment*. 2018;**639**:868-75. doi: [10.1016/j.scitotenv.2018.05.181](https://doi.org/10.1016/j.scitotenv.2018.05.181). [PubMed: [29929325](https://pubmed.ncbi.nlm.nih.gov/29929325/)].
- Dabass A, Talbott EO, Venkat A, Rager J, Marsh GM, Sharma RK, et al. Association of exposure to particulate matter (PM2. 5) air pollution and biomarkers of cardiovascular disease risk in adult NHANES participants (2001-2008). *International journal of hygiene and environmental health*. 2016;**219**(3):301-10. doi: [10.1016/j.ijheh.2015.12.002](https://doi.org/10.1016/j.ijheh.2015.12.002). [PubMed: [26725170](https://pubmed.ncbi.nlm.nih.gov/26725170/)].
- Nabizadeh R, Yousefian F, Moghadam VK, Hadei M. Characteristics of cohort studies of long-term exposure to PM 2.5: a systematic review. *Environmental Science and Pollution Research*. 2019:1-17. doi: [10.1007/s11356-019-06382-6](https://doi.org/10.1007/s11356-019-06382-6).
- Liu Y, Lee K, Perez-Padilla R, Hudson NL, Mannino DM. Outdoor and indoor air pollution and COPD-related diseases in high-and low-income countries [State of the Art Series. Chronic obstructive pulmonary disease in high-and low-income countries. Edited by G. Marks and M. Chan-Yeung. Number 2 in the series]. *The international journal of tuberculosis and lung disease*. 2008;**12**(2):115-27.
- Cortez-Lugo M, Ramirez-Aguilar M, Pérez-Padilla R, Sansores-Martínez R, Ramírez-Venegas A, Barraza-Villarreal A. Effect of personal exposure to PM2. 5 on respiratory health in a Mexican panel of patients with COPD. *International journal of environmental research and public health*. 2015;**12**(9):10635-47. doi: [10.3390/ijerph120910635](https://doi.org/10.3390/ijerph120910635). [PubMed: [26343703](https://pubmed.ncbi.nlm.nih.gov/26343703/)].
- Huang H, Lin FC, Wu M, Nfor ON, Hsu S, Lung C, et al. Association between chronic obstructive pulmonary disease and PM2. 5 in Taiwanese nonsmokers. *International journal of hygiene and environmental health*. 2019;**222**(5):884-8. doi: [10.1016/j.ijheh.2019.03.009](https://doi.org/10.1016/j.ijheh.2019.03.009). [PubMed: [30962144](https://pubmed.ncbi.nlm.nih.gov/30962144/)].

12. Manojkumar N, Kumar MM, Somwanshi SK, Raj MM, Srimuruganandam B. Estimation of PM<sub>2.5</sub>-Related Hospital Admissions and Its Monetary Burden in Hyderabad, India. *Advances in Geotechnical and Transportation Engineering*. Springer; 2020. p. 1-10. doi: [10.1007/978-981-15-3662-5\\_1](https://doi.org/10.1007/978-981-15-3662-5_1).
13. Kumar A, Goyal P. Forecasting of daily air quality index in Delhi. *Science of the Total Environment*. 2011;**409**(24):5517-23. doi: [10.1016/j.scitotenv.2011.08.069](https://doi.org/10.1016/j.scitotenv.2011.08.069). [PubMed: [21962560](https://pubmed.ncbi.nlm.nih.gov/21962560/)].
14. Goudarzi G, Geravandi S, Salmanzadeh S, Zallaghi E. The number of myocardial infarction and cardiovascular death cases associated with sulfur dioxide exposure in Ahvaz, Iran. *Archives of Hygiene Sciences*. 2014;**3**(3):112-9.
15. Effatpanah M, Effatpanah H, Jalali S, Parseh I, Goudarzi G, Barzegar G, et al. Hospital admission of exposure to air pollution in Ahvaz megacity during 2010-2013. *Clinical Epidemiology and Global Health*. 2019. doi: [10.1016/j.cegh.2019.12.001](https://doi.org/10.1016/j.cegh.2019.12.001).
16. 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 PM<sub>2.5</sub>, NO<sub>2</sub>, and O<sub>3</sub> in ambient air of Ahvaz city, Iran (2014-2017). *Ecotoxicology and environmental safety*. 2019;**180**:542-8. doi: [10.1016/j.ecoenv.2019.05.026](https://doi.org/10.1016/j.ecoenv.2019.05.026). [PubMed: [31128552](https://pubmed.ncbi.nlm.nih.gov/31128552/)].
17. Khaniabadi YO, Polosa R, Chaturkova RZ, Daryanoosh M, Goudarzi G, Borgini A, et al. Human health risk assessment due to ambient PM<sub>10</sub> and SO<sub>2</sub> by an air quality modeling technique. *Process safety and environmental protection*. 2017;**111**:346-54. doi: [10.1016/j.psep.2017.07.018](https://doi.org/10.1016/j.psep.2017.07.018).
18. Li T, Hu R, Chen Z, Li Q, Huang S, Zhu Z, et al. Fine particulate matter (PM<sub>2.5</sub>): The culprit for chronic lung diseases in China. *Chronic diseases and translational medicine*. 2018;**4**(3):176-86. doi: [10.1016/j.cdtm.2018.07.002](https://doi.org/10.1016/j.cdtm.2018.07.002). [PubMed: [30276364](https://pubmed.ncbi.nlm.nih.gov/30276364/)].
19. Sun Z, Zhu D. Exposure to outdoor air pollution and its human health outcomes: A scoping review. *PLoS one*. 2019;**14**(5). doi: [10.1371/journal.pone.0216550](https://doi.org/10.1371/journal.pone.0216550). [PubMed: [31095592](https://pubmed.ncbi.nlm.nih.gov/31095592/)].
20. World Health Organization. *WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: global update 2005: summary of risk assessment*. Geneva: World Health Organization; 2006.
21. Shahsavani A, Tobías A, Querol X, Stafoggia M, Abdolshahnejad M, Mayvaneh F, et al. Short-term effects of particulate matter during desert and non-desert dust days on mortality in Iran. *Environment international*. 2020;**134**:105299. doi: [10.1016/j.envint.2019.105299](https://doi.org/10.1016/j.envint.2019.105299). [PubMed: [31751828](https://pubmed.ncbi.nlm.nih.gov/31751828/)].
22. Khodarahmi F, Soleimani Z, Yousefzadeh S, Alavi N, Babaei AA, Mohammadi MJ, et al. Levels of PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1</sub> and Impacts of Meteorological Factors on Particle Matter Concentrations in Dust Events and non Dusty Days. *International Journal of Health Studies*. 2016;**1**(3):7-12.
23. Jaafari J, Naddafi K, Yunesian M, Nabizadeh R, Hassanvand MS, Ghozikali MG, et al. Study of PM<sub>10</sub>, PM<sub>2.5</sub>, and PM<sub>1</sub> levels in during dust storms and local air pollution events in urban and rural sites in Tehran. *Human and Ecological Risk Assessment: An International Journal*. 2018;**24**(2):482-93. doi: [10.1080/10807039.2017.1389608](https://doi.org/10.1080/10807039.2017.1389608).
24. Lall R, Thurston GD. Identifying and quantifying transported vs. local sources of New York City PM<sub>2.5</sub> fine particulate matter air pollution. *Atmospheric Environment*. 2006;**40**:333-46. doi: [10.1016/j.atmosenv.2006.04.068](https://doi.org/10.1016/j.atmosenv.2006.04.068).
25. Jo YS, Lim MN, Han Y, Kim WJ. Epidemiological study of PM<sub>2.5</sub> and risk of COPD-related hospital visits in association with particle constituents in Chuncheon, Korea. *International journal of chronic obstructive pulmonary disease*. 2018;**13**:299. doi: [10.2147/COPD.S149469](https://doi.org/10.2147/COPD.S149469). [PubMed: [29391787](https://pubmed.ncbi.nlm.nih.gov/29391787/)].