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Association of Particulate Matter Impact on Prevalence of Chronic Obstructive Pulmonary Disease in Ahvaz, Southwest Iran during 2009–2013

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ABSTRACT

Air pollutants produced in environments have many detrimental impacts on human health. Chronic obstructive pulmonary disease (COPD) is a common worldwide respiratory disease. The aim of this study was to estimate the association between the load of particulate matters and the prevalence of COPD in Ahvaz, southwest of Iran, during 2009–2013. This epidemiological and used-model study was performed in Ahvaz. Particulate matter equal or less than 10 micro meters (PM_{10}) was monitored by Ahvaz Environmental Protection Agency (AEPA). Sampling was performed hourly during the study period in 4 stations. In this study, 175200 (4 × 24 × 365 × 5) samples of air were taken and collected. Sampling and analysis were performed according to EPA guideline. We utilized the relative risk values and baseline incidence measures by the WHO (Middle East) drawn from Health Effects Association of Particulate Matter. Finally, prevalence of COPD attributed to particulate matter exposure was calculated by Air Q model. According to our findings, the prevalence of COPD attributed to particulate matters decreased during 2009–2013 and followed a decreasing trend. Accordingly, the yearly prevalence of COPD during the period 2009–2013 were 121, 111, 94, 102, and 98, and the yearly average PM_{10} concentrations during the same period were 313.72, 281.98, 288.38, 278.12, and 242.29 μg m^{-3}, respectively. Although the average of 5-year study was higher than WHO and NAAQS values, a descending trend for COPD indicates that the level of PM_{10} was diminished from 2009 to 2013. Therefore mitigating air pollutant particularly PM_{10} as one of the main hazards could be possibly led to remarkable decrease in the rate of mortality and morbidity particularly COPD attributed to PM_{10}.

Keywords: Chronic obstructive pulmonary disease; Prevalence; Particulate matter; Iran.

INTRODUCTION

In the recent years, effects of air pollutants on human health, their damage to the environment and the rate of death in the public in the world has increased (Hajat *et al.*,

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2014; Geravandi *et al.*, 2015a; Kim *et al.*, 2015; Lin *et al.*, 2016; Taylor *et al.*, 2016; Omidi-Khaniabadi, *et al.*, 2017a). Results from different studies on particulate matters and different pollutants has raised thoughtful concerns regarding public health (Taghavirad *et al.*, 2014; Goudarzi *et al.*, 2015a; Gschwind *et al.*, 2015; Madronich *et al.*, 2015; Mašková *et al.*, 2016; Mohammadi *et al.*, 2016b; Yari *et al.*, 2016). Transportation, urbanization, industries, economic development, domestic fuel burning, and vehicles in megacities are the main sources of generation and emission of particulate matters (Davar *et al.*, 2014; Yan *et al.*, 2014; Hou *et al.*, 2015; Salvador *et al.*, 2015; Soleimani *et al.*, 2016; Omidi-Khaniabadi, *et al.*, 2017b). According to different studies, particles have short-term and long-term effects on human health (Chan *et al.*, 2015; Ostro *et al.*, 2015; Mammi-Galani *et al.*, 2016; Neisi *et al.*, 2016). Previous studies have shown an association between the air pollutant, particularly PM_{10} and diseases (Kloog *et al.*, 2014; Andersen *et al.*, 2015; Mandel *et al.*, 2015; Goudarzi *et al.*, 2016; Maleki *et al.*, 2016). The most important damage from particles is penetration into the respiratory system that can lead to health effects in humans such as inflammation in pulmonary systems resulting in narrowing of the small airways and destruction of lung tissue known as emphysema (Geravandi *et al.*, 2015a; Omlor *et al.*, 2015; Rupf *et al.*, 2015; Salgueiro-González *et al.*, 2015; Naimabadi *et al.*, 2016).

Eighty percent of people 65 years and older have one or more chronic diseases, and about 50% of these groups have activity limitation. Based on the results of studies, COPD observed in 329 million people or nearly 5% of the globe population. It is expected to become the 5th leading cause of the burden of diseases worldwide by 2020 (Fletcher *et al.*, 2011; Lim *et al.*, 2013). In 2011, COPD ranked as the fourth-leading cause of death, killing over 3 million people (Organization, 2014). A study conducted by the World Health Organization showed that an increase of 10 micrograms in the amount of aerosols causes 1 to 3 percent increase in the mortality rate (Mirhosseini *et al.*, 2013). Shortness of breath and cough are the main symptoms COPD (Fishman, 2005; Cazzola *et al.*, 2007; Swadron *et al.*, 2008). In another investigation which was done in Taiwan, there was a relationship between air pollutants concentration and hospital admission rate in patients suffering from ischemic stroke, COPD, and asthma exacerbation (Tsai *et al.*, 2003). Accordingly, a study conducted in six cities in the United States demonstrated a relationship between long-term air pollution and health status. This study indicated that long term exposure to air pollutants was independently association with cardiovascular mortality (Dockery *et al.*, 1993). Moreover, another study in Mexico evaluated the health impact of air pollution. Results of this study showed 82 percent increase in the risk of death with a 20 $\mu g\ m^{-3}$ increase in the concentration of particles (Romieu *et al.*, 2003). In similar works, Mohammadi *et al.* (2009), Zallaghi *et al.* (2010) and Goudarzi *et al.* (2015b) studied the association between COPD and PM_{10} levels in different cities in Iran.

To date, Ahvaz has been well known for environmental concerns such as air pollution, solid waste management, wastewater collection systems, and potable water. In recent decade, Ahvaz has suffered from a Tran's boundary source of dust storm. Different aspects of dust storm have been well documented (Soleimani *et al.*, 2013; Goudarzi *et al.*, 2014b; Mohammadi *et al.*, 2015). The aim of this study was to assess the potential effects of particulate matter exposure on human health (COPD) in Ahvaz city (southwest of Iran) during 2009 to 2013.

METHODS

The present study is an epidemiological study which correlate concentration of PM_{10} to chronic obstructive pulmonary disease (COPD). We processed PM_{10} data by the use of Excel software and Air Q model. This study was aimed to assess the potential effects of PM_{10} exposure on prevalence of COPD. This estimation was based on calculating relative risk (RR) and attributable proportion (AP). The present study has two main stages including measurement of PM_{10} and using the model. Sampling was conducted in 4 stations by AEPA. The AEPA used beta attenuation method for PM_{10} concentration in ambient air. This is a direct reading method which provide a quick and precise reading for concentration of particulates specially PM_{10} (Maleki *et al.*, 2016). In this study, data was processed in a VBA program of excel to reach to daily mean, maximum, minimum, standard deviation and 98 percentiles. Finally, data were adjusted as compatible as input file for Air Q model (Geravandi *et al.*, 2016; Marzouni *et al.*, 2016). It was defined as the fraction of the health outcome in a certain population attributable to exposure to a given atmospheric pollutant. Obtained value then was multiplied by population (10^6) (Geravandi *et al.*, 2015b; Mohammadi *et al.*, 2016a). AP is proven causative correlation between outcomes and given air pollutant. To find out excess cases, we could calculate distribution of cases attributed to pollutants in terms of concentration intervals (Geravandi *et al.*, 2015b). Relative risk (RR) is the ratio of the probability of the outcome happening in the exposed population versus a non-exposed group (Goudarzi *et al.*, 2015a; Dobaradaran *et al.*, 2016). It is a very useful to know the association between a disease and an environmental factor under study (Goudarzi *et al.*, 2015a). Relative risk is computed by dividing the incidence rate among individuals exposed to given pollutant by the incidence rate among people not exposed to that certain pollutant (Dobaradaran *et al.*, 2016). Population Prevented Fraction (PPF) is related to circumstances where exposure to a given pollutant is protective (Goudarzi *et al.*, 2014a).

The primary and secondary standard of particulate matter concentration according to National Ambient Air Quality Standard (NAAQS) 24-hour is 150 $\mu g\ m^{-3}$ (Krutilla *et al.*, 2015). The standard of particulate matter concentration according to European Air Quality Standards (EUAQS) 24-hour is 50 $\mu g\ m^{-3}$ and 1 year is 40 $\mu g\ m^{-3}$ (Beelen *et al.*, 2014).

Geographical Features of Ahvaz

Ahvaz, the capital city of Khuzestan Province, has suffered from dust storm during this and last decade. It is also famous in view of particulate matter concentration, in which

most of researchers announced Ahvaz as the most polluted city overall the world (Goudie, 2014). Many industries such as steel, gas and petroleum have activity inside the city. Ahvaz, with an area of 140 square kilometers, is located between 48° and 49°29′ east of the Greenwich meridian and, 31°and 45′ minutes north of the equator, and with a population of approximately 1 million has coped with many environmental problems such as salinity of potable water, lack of wastewater collection systems as well as air pollution (Geravandi *et al.*, 2015b; Goudarzi *et al.*, 2016; Yari *et al.*, 2016). Sampling was performed hourly in four stations where are listed from 1 to 4. The name of each station has written in Fig. 1.

RESULTS

As it has shown in Table 1 from 2009 to 2010 the trend for yearly concentration of PM_{10} was decreased, but from 2010 to 2011 the average concentration for PM_{10} increased. Finally, we observed a mild decrease in the average concentration of PM_{10} from 2011 to 2013. The yearly mean, summer maximum and winter maximum of PM_{10} concentrations have been presented in Table 1. During 2009 to 2013, concentration of PM_{10} was higher in summer than in winter. Also, Number of COPD cases related to PM_{10} concentrations is presented in Table 1. Calculated number of cases related to PM_{10} at central RR (1.0044) during 2009 to 2013 was 121, 111, 94, 102 and 98, respectively. Central RR can be a reasonable indicator of current situation in view of PM_{10} health effects. Overall, Table 1 shows that the trend of the number of COPD cases related to PM_{10} concentration was decreasing during 2009 to 2013.

As Fig. 2 indicates, no day during 2009 to 2013 has seen a PM_{10} concentration below 10 μg m^{-3}. Rising trend of cases of COPD with increasing concentrations of PM_{10} in 30–150 μg m^{-3} has a uniform pattern.

Fig. 3 shows cumulative number of COPD cases attributed to particulate matter during 2009 to 2013. Maximum number of COPD was in year 2009 and minimum number of COPD cures in year 2011.

DISCUSSION

Nowadays air pollution is one of several important issues that threaten the public health. In this study, we estimated COPD of exposure to PM_{10} by using Air Q model in Ahvaz,

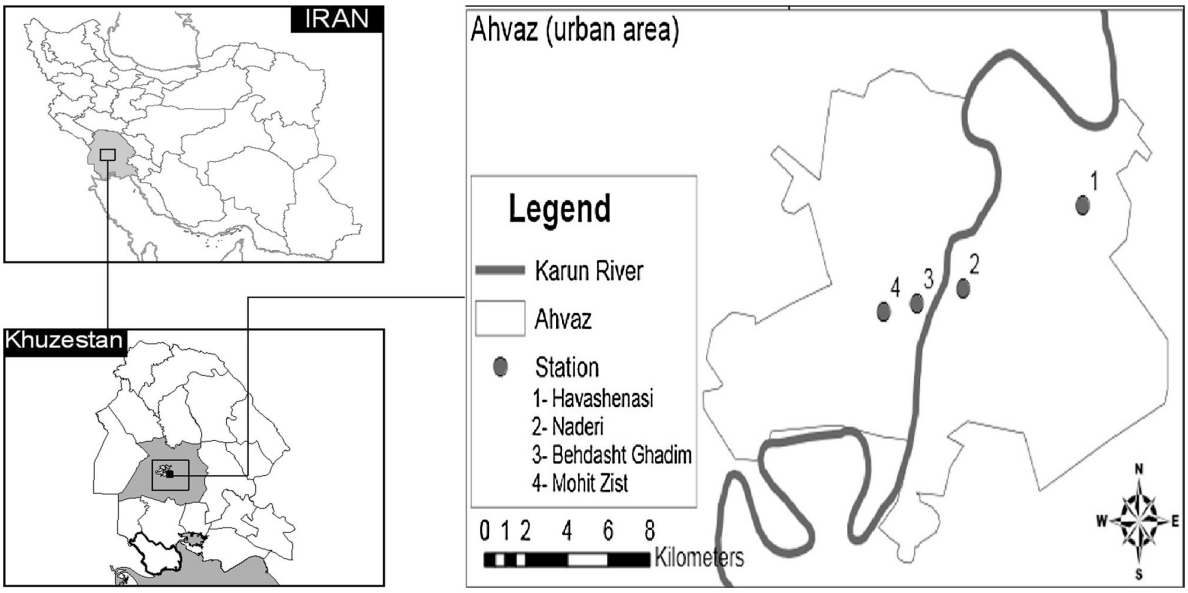

Fig. 1. Location of the study area and sampling stations in Khuzestan Province (Ahvaz city), southwest of Iran.

Table 1. PM_{10} concentrations (μg m^{-3}) and cases of people suffering from COPD assessment of PM_{10} on Ahvaz inhabitants, 2009–2013, (BI = 101.4).

Year	Annual mean	Summer Maximum	Winter Maximum	HACOPD RR = 1.0044 (1–1.0049)
2009	313.72	530	364	121
2010	281.98	489	317	111
2011	288.38	503	306	94
2012	278.12	436	283	102
2013	242.29	355	263	98
Average	280.89	462	306	105

RR: is a ratio of the probability of the event occurring in the exposed group versus a non-exposed group.
AP: is defined as the part of health effects which can be attributed to the pollutant exposure in population.

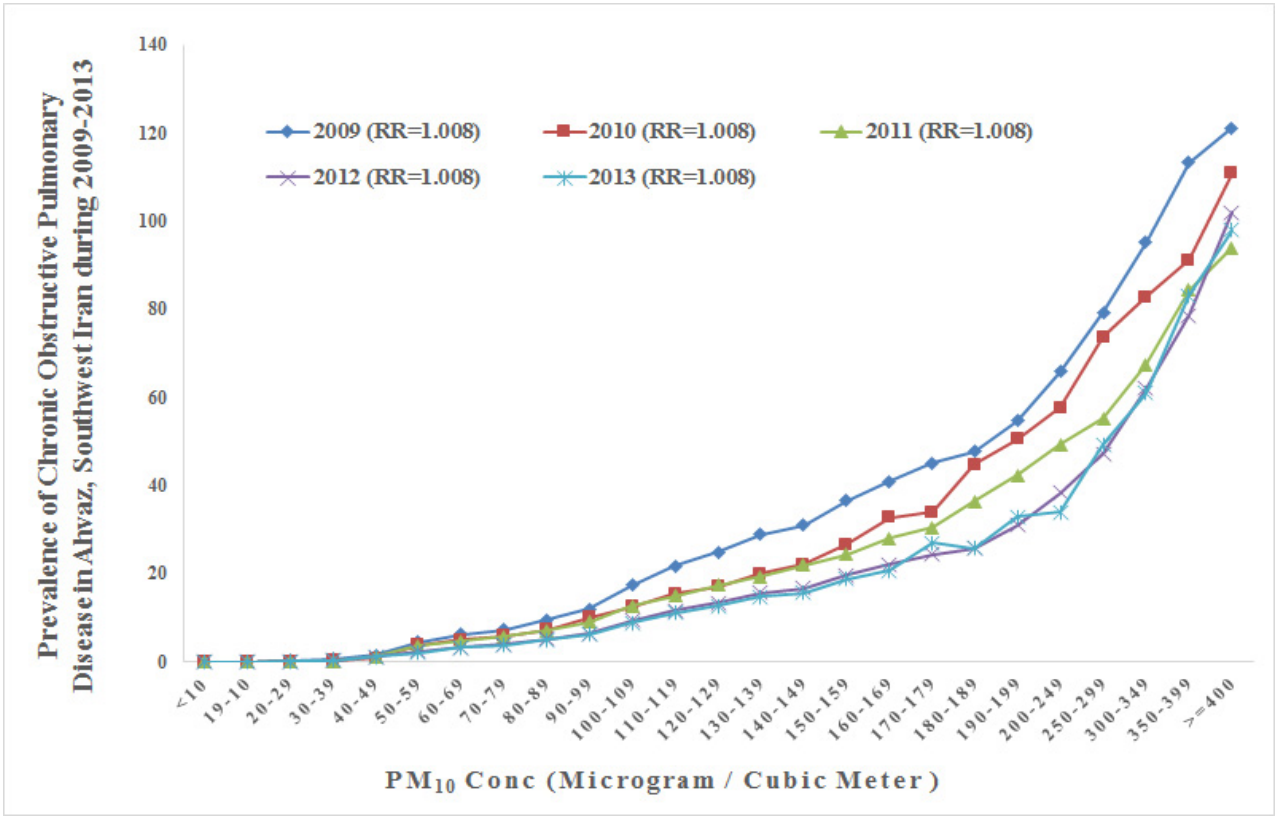

Fig. 2. Relationship between prevalence of COPD and PM_{10} concentration in Ahvaz, southwest of Iran, during 2009–2013.

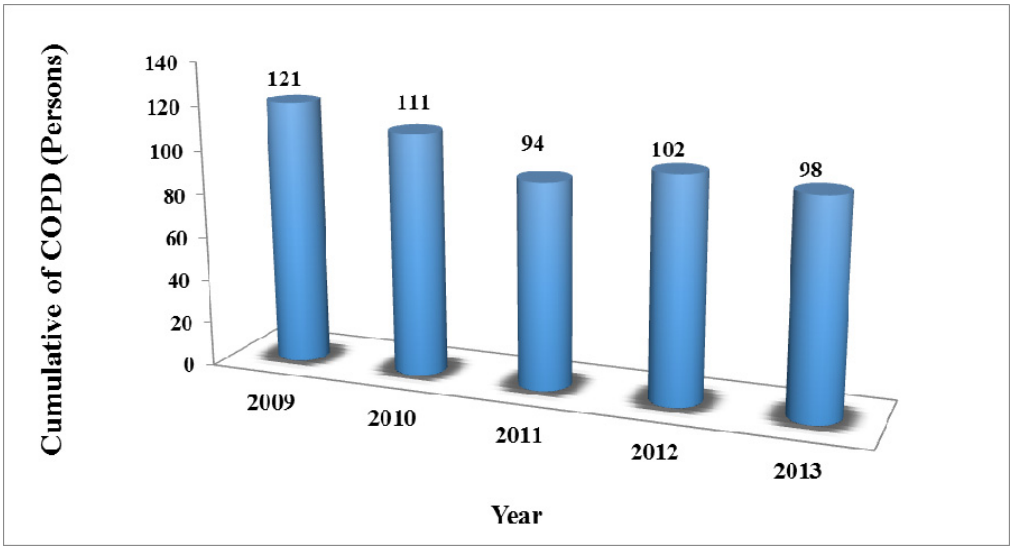

Fig. 3. Cumulative number of COPD cases attributed to particulate matter.

Iran. The result of this study showed that number of COPD in 2009,2010, 2011, 2012 and 2013 was 121, 111, 94, 102 and 98 cases, respectively, in which the maximum was for 2009 due to the highest concentration of PM_{10} among these years. Fig. 2 depicts average PM_{10} levels versus related outcome during 2009 to 2013. The high concentration of PM_{10} can be the result of production of dust storm and development of transportation facilities and industrial processes in recent years. Based on the results of different studies, decreasing PM_{10} concentration decreases the number of COPD cases. Results of our study showed that AP during 2009 to 2013 was decreased, and this can be due to decreases in concentration of PM_{10}. According to WHO report, Ahvaz city has the highest PM_{10} concentration among all cities in the world. Based on our field observations in Khuzestan especially Ahvaz there were many dust event days during these 5-years study that concentration of PM_{10} was above WHO and NAAQS values. Therefore we expect

an increase a burden of disease because of incoming dust.

The lower level of RR may indicate the progress of urban air quality by implementing emission control policies. Therefore the higher RR can imply mismanagement in urban air quality strategies. As a result, three domains of RR based on model's default were considered for estimating outcomes attributed to PM_{10}.

Based on their results, almost 3.6% of all cases of COPD were attributed to PM_{10} concentrations greater than 30 μg m^{-3} (Goudarzi *et al.*, 2007). Results of this study are different compared with ours because of the differences in geographic, demographic, and climate characteristics. Also, an investigation by Geravandi *et al.* (2015a) showed that approximately 4.1 percent of hospital admissions for COPD happened when the PM_{10} concentration was over 20 μg m^{-3}. High percentage of the calculated outcomes in this study was associated with high concentration of measured PM_{10} in Ahvaz. Zalaghi (2010) in their study on health impacts of air pollution in Ahvaz, Bushehr and Kermanshah in 2010 observed that all cases of COPD were 4.8% in Ahvaz, 2.4% in Kermanshah, and 1.7% in Bushehr, approximately. The results of this study showed that concentration of PM_{10} in Ahvaz was higher compared to Kermanshah, and Bushehr.

It is noteworthy to express that chemical and biological contents of aerosols particularly PM_{10} as the representative of dust is at paramount of importance. Previous investigation in Ahvaz revealed that load of bacteria increased during dust events in compared with normal days (Soleimani *et al.*, 2016). Regarding to chemical composition of PM_{10} and its impact on human and animal (Rezaei *et al.*, 2014; Dianat *et al.*, 2016a, b; Naimabadi *et al.*, 2016) many disorders could be posed as detrimental effect of dust pollution on ecosystem. Further research is recommended to clarify long term effects of Ahvaz air pollution especially particulates and attributed diseases to convince authorities to implement practical measures for mitigating air pollutants.

Limitations and Strengths

We used the common coefficient related to COPD. After running long term and successive investigation to localize these coefficient the best policy for such studies is to consider these specific indices which are based on the characteristic our population and very compatible to the pattern of urban air pollution in developing countries. For achieving the reliability and validity of model one of the approach is to observe health end points registries at hospitals, but because of weakness in health registry it was impossible to reach at this time. Keep in mind the results and findings of present study is calculated by using the model which is definitely based on prediction.

CONCLUSION

Models are used to simplify the sophisticated or complicated cases, but in reverse side there is an old belief that, all models are wrong; some models are useful. According to the present research findings, we observed a high prevalence of COPD attributed to PM_{10} in Ahvaz at first year of study (2009) and it was decreased with a slight trend to the end of study (2013). High percentage of the observed COPD cases in 2009 was associated with high concentration of measured PM_{10} and the lowest cases of mentioned outcomes observed in 2011. The major limitations of this study were shortcoming in databases and the lack of local epidemiological parameters, so, in our study, the values of the WHO (Middle East) for estimated health outcomes related to PM_{10} levels were used. Therefore, to assess the health impact of air pollutants on human accurately, epidemiologic studies for accurate calculation of RRs and BIs are needed. Defining policies for decreasing particles in source at neighboring countries, actions to reduce emissions to air in industries, using green fuels such as solar and electrical energy, implementing appropriate health measures, development of green spaces, and environmental monitoring can be effective in reducing PM_{10} concentration. We suppose that for calculating health indicators, epidemiologic studies be done, and rate of exposure to air pollutants and their health effects be measured. Further studies would allow assessing the development in health status more precisely.

CONFLICT OF INTERESTS

Authors have no conflict of interests.

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AUTHORS CONTRIBUTIONS

Study concept, design and critical revision of the manuscript for important intellectual content: Mohammad Javad Mohammadi, Mehran Khaefi, Sahar Geravandi, Ghasem Hassani, Farhad soltani, Sina Dobaradaran, Sasan Moogahi, Nadali Alavi, Ahmad Reza Yari, Mohammad Mahboubi, Majid farhadi and Yusef Omidi Khaniabadi; drafting of the manuscript and advisor; doing experiments Mohammad Javad Mohammadi.

FINANCIAL DISCLOSURE

We have no financial interests related to the materials in the manuscript.

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REFERENCES

Andersen, Z.J., de Nazelle, A., Mendez, M.A., Garcia-Aymerich, J., Hertel, O., Tjønneland, A., Overvad, K., Raaschou-Nielsen, O. and Nieuwenhuijsen, M.J. (2015).

A study of the combined effects of physical activity and air pollution on mortality in elderly urban residents: The Danish Diet, Cancer, and Health Cohort. *Environ. Health Perspect.* 123: 25–32.

Beelen, R., Raaschou-Nielsen, O., Stafoggia, M., Andersen, Z.J., Weinmayr, G., Hoffmann, B., Wolf, K., Samoli, E., Fischer, P., Nieuwenhuijsen, M., Vineis, P., Xun, W.W., Katsouyanni, K., Dimakopoulou, K., Oudin, A., Forsberg, B., Modig, L., Havulinna, A.S., Lanki, T., Turunen, A., Oftedal, B., Nystad, W., Nafstad, P., De Faire, U., Pedersen, N.L., Östenson, C.G., Fratiglioni, L., Penell, J., Korek, M., Pershagen, G., Eriksen, K.T., Overvad, K., Ellermann, T., Eeftens, M., Peeters, P.H., Meliefste, K., Wang, M., Bueno-de-Mesquita, B., Sugiri, D., Krämer, U., Heinrich, J., de Hoogh, K., Key, T., Peters, A., Hampel, R., Concin, H., Nagel, G., Ineichen, A., Schaffner, E., Probst-Hensch, N., Künzli, N., Schindler, C., Schikowski, T., Adam, M., Phuleria, H., Vilier, A., Clavel-Chapelon, F., Declercq, C., Grioni, S., Krogh, V., Tsai, M.Y., Ricceri, F., Sacerdote, C., Galassi, C., Migliore, E., Ranzi, A., Cesaroni, G., Badaloni, C., Forastiere, F., Tamayo, I., Amiano, P., Dorronsoro, M., Katsoulis, M., Trichopoulou, A., Brunekreef, B. and Hoek, G. (2014). Effects of long-term exposure to air pollution on natural-cause mortality: An analysis of 22 European cohorts within the multicentre ESCAPE project. *Lancet* 383: 785–795.

Cazzola, M., Donner, C.F. and Hanania, N.A. (2007). One hundred years of chronic obstructive pulmonary disease (COPD). *Respir. Med.* 101: 1049–1065.

Chan, S.H., Van Hee, V.C., Bergen, S., Szpiro, A.A., DeRoo, L.A., London, S.J., Marshall, J.D., Kaufman, J.D. and Sandler, D.P. (2015). Long-term air pollution exposure and blood pressure in the sister study. *Environ. Health Perspect* 123: 951–958.

Davar, H., Sadat Taghavirad, S. and Mohammadi, M.J. (2014). The investigation of effects of silica on the environment and prevention of release of the silica particles with simulation of gas-solid flow in a gas cyclone. *Res. J. Chem. Environ.* 18: 28–30.

Dianat, M., Radmanesh, E., Badavi, M., Goudarzi, G. and Mard, S.A. (2016a). The effects of PM_{10} on electrocardiogram parameters, blood pressure and oxidative stress in healthy rats: The protective effects of vanillic acid. *Environ. Sci. Pollut. Res. Int.* 23: 19551–19560.

Dianat, M., Radmanesh, E., Badavi, M., Mard, S.A. and Goudarzi, G. (2016b). Disturbance effects of PM_{10} on iNOS and eNOS mRNA expression levels and antioxidant activity induced by ischemia-reperfusion injury in isolated rat heart: Protective role of vanillic acid. *Environ. Sci. Pollut. Res. Int.* 23: 5154–5165.

Dobaradaran, S., Geravandi, S., Goudarzi, G., Idani, E., Salmanzadeh, S., Soltani, F. and Mohammadi, M.J. (2016). Determination of cardiovascular and respiratory diseases caused by PM_{10} exposure in Bushehr, 2013. *J Mazandaran Univ. Med. Sci.* 26: 42–52.

Dockery, D.W., Pope, C.A., Xu, X., Spengler, J.D., Ware, J.H., Fay, M.E., Ferris Jr, B.G. and Speizer, F.E. (1993). An association between air pollution and mortality in six U.S. cities. *N. Engl. J. Med.* 329: 1753–1759.

Fishman, A.P. (2005). One hundred years of chronic obstructive pulmonary disease. *Am. J. Respir. Crit. Care Med* .171: 941–948.

Fletcher, M.J., Upton, J., Taylor-Fishwick, J., Buist, S.A., Jenkins, C., Hutton, J., Barnes, N., Van Der Molen, T., Walsh, J.W. and Jones, P. (2011). COPD uncovered: An international survey on the impact of chronic obstructive pulmonary disease [COPD] on a working age population. *BMC Public Health* 11: 612.

Geravandi, S., Goudarzi, G., Vosoughi, M., Mohammadi, M.J., Salmanzadeh, S. and Zallaghi, E. (2015a). Relationship between particulate matter less than 10 microns exposures and health effects on humans in Ahvaz, Iran. *Arch. Hyg. Sci.* 4: 64–72.

Geravandi, S., Goudarzi, G.R., Vousoghi Niri, M., Mohammadi, M.J., Saeidimehr, S. and Geravandi, S. (2015b). Estimation of the cardiovascular and respiratory mortality rate resulted from exposure to sulfur dioxide pollutant in Ahvaz. *J. Environ. Stud.* 41: 341–350.

Geravandi, S., Goudarzi, G., Soltani, F., Salmanzadeh, S., Ghomeishi, A., Zalaghi, E., Aslani, Z. and Mohammadi, M.J. (2016). The cardiovascular and respiratory deaths attributed to sulfur dioxide in Kermanshah. *J. Kermanshah Univ. Med. Sci.* 19: 319–326.

Goudarzi, G., Nadafi, K. and Mesdaghiniya, A. (2007). Quantification of health effects of air pollution in Tehran and determining the impact of a comprehensive program to reduce air pollution in Tehran on the third axis. PhD Dissertation, Tehran University of Medical Sciences, Tehran, Iran.

Goudarzi, G., Geravandi, S., Foruozandeh, H., Babaei, A.A., Alavi, N., Niri, M.V., Khodayar, M.J., Salmanzadeh, S. and Mohammadi, M.J. (2015a). Cardiovascular and respiratory mortality attributed to ground-level ozone in Ahvaz, Iran. *Environ. Monit. Assess.* 187: 1–9.

Goudarzi, G., Geravandi, S., Mohammadi, M.J., Salmanzadeh, S., Vosoughi, M. and Sahebalzamani, M. (2015b). The relationship between air pollution exposure and chronic obstructive pulmonary disease in Ahvaz, Iran. *Chronic Dis. J.* 3: 14–20.

Goudarzi, G., Geravandi, S., Salmanzadeh, S., Mohammadi, M.J. and Zallaghi, E. (2014a). The number of myocardial infarction and cardiovascular death cases associated with sulfur dioxide exposure in Ahvaz, Iran. *Arch. Hyg. Sci.* 3: 112–119.

Goudarzi, G., Shirmardi, M., Khodarahmi, F., Hashemi-Shahraki, A., Alavi, N., Ankali, K.A., Babaei, A.A., Soleimani, Z. and Marzouni, M.B. (2014b). Particulate matter and bacteria characteristics of the Middle East Dust (MED) storms over Ahvaz, Iran. *Aerobiologia* 30: 345–356.

Goudarzi, G., Geravandi, S., Idani, E., Hosseini, S.A., Baneshi, M.M., Yari, A.R., Vosoughi, M., Dobaradaran, S., Shirali, S. Marzooni, M.B. and Mohammadi, M.J. (2016). An evaluation of hospital admission respiratory disease attributed to sulfur dioxide ambient concentration in Ahvaz from 2011 through 2013. *Environ. Sci. Pollut. Res. Int.* 23: 22001–22007.

Goudie, A.S. (2014). Desert dust and human health

disorders. *Environ. Int.* 63: 101–113.

Gschwind, B., Lefevre, M., Blanc, I., Ranchin, T., Wyrwa, A., Drebszok, K., Cofala, J. and Fuss, S. (2015). Including the temporal change in $PM_{2.5}$ concentration in the assessment of human health impact: Illustration with renewable energy scenarios to 2050. *Environ. Impact Assess. Rev.* 52: 62–68.

Hajat, S., Vardoulakis, S., Heaviside, C. and Eggen, B. (2014). Climate Change Effects on Human Health: Projections of Temperature-Related Mortality for the Uk During the 2020s, 2050s and 2080s. *J. Epidemiol. Community Health* 68: 641–648.

Hou, X., Strickland, M.J. and Liao, K.J. (2015). Contributions of regional air pollutant emissions to ozone and fine particulate matter-related mortalities in eastern U.S. urban areas. *Environ. Res.* 137: 475–484.

Kim, K.H., Kabir, E. and Kabir, S. (2015). A review on the human health impact of airborne particulate matter. *Environ. Int.* 74: 136–143.

Kloog, I., Nordio, F., Zanobetti, A., Coull, B.A., Koutrakis, P. and Schwartz, J.D. (2014). Short term effects of particle exposure on hospital admissions in the Mid-Atlantic states: A population. *PLoS One* 9: e88578.

Krutilla, K., Good, D.H. and Graham, J.D. (2015). Uncertainty in the cost-effectiveness of federal air quality regulations. *J. Benefit Cost Anal.* 6: 66–111.

Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H., AlMazroa, M.A., Amann, M., Anderson, H.R. and Andrews, K.G. (2013). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 380: 2224–2260.

Lin, C.C., Tsai, J.H., Huang, K.L., Yeh, C.K.J., Chen, H.L., Chen, S.J., Lee, J.T. and Hsieh, Y.C. (2016). Characteristics of respirable particulate metals emitted by a beehive firework display in yanshuei area of Southern Taiwan. *Aerosol Air Qual. Res.* 16: 2227–2236.

Madronich, S., Shao, M., Wilson, S., Solomon, K., Longstreth, J. and Tang, X. (2015). Changes in air quality and tropospheric composition due to depletion of stratospheric ozone and interactions with changing climate: Implications for human and environmental health. *Photochem. Photobiol. Sci.* 14: 149–169.

Maleki, H., Sorooshian, A., Goudarzi, G., Nikfal, A. and Baneshi, M.M. (2016). Temporal profile of PM_{10} and associated health effects in one of the most polluted cities of the world (Ahvaz, Iran) between 2009 and 2014. *Aeolian Res.* 22: 135–140.

Mammi-Galani, E., Chalvatzaki, E. and Lazaridis, M. (2016). Personal Exposure and dose of inhaled ambient particulate matter bound metals in five European Cities. *Aerosol Air Qual. Res.* 16: 1452–1463.

Mandel, J.H., Wendt, C., Lo, C., Zhou, G., Hertz, M. and Ramachandran, G. (2015). Ambient air pollution and lung disease in china: Health effects, study design approaches and future research. *Fron. Med.* 9: 392–400.

Marzouni, M.B., Alizadeh, T., Banafsheh, M.R., Khorshiddoust, A.M., Ghozikali, M.G., Akbaripoor, S., Sharifi, R. and Goudarzi, G. (2016). A comparison of health impacts assessment for PM_{10} during two successive years in the ambient air of Kermanshah, Iran. *Atmos. Pollut. Res.* 7: 768–774.

Mašková, L., Smolík, J., Travnickova, T., Havlica, J., Ondráčková, L. and Ondráček, J. (2016). Contribution of visitors to the indoor pm in the national library in Prague, Czech Republic. *Aerosol Air Qual. Res.* 16: 1713–1721.

Mirhosseini, S.H., Birjandi, M., Zare, M.R. and Fatehizadeh, A. (2013). Analysis of particulate matter (PM_{10} and $PM_{2.5}$) concentration in Khorramabad City. *Int. J. Environ. Health Eng.* 2: 3.

Mohammadi, A., Azhdarpoor, A., Shahsavani, A. and Tabatabaee, H. (2016a). Investigating the health effects of exposure to criteria pollutants using Airq2. 2.3 in Shiraz, Iran. *Aerosol Air Qual. Res.* 16: 1035–1043.

Mohammadi, M.J. (2009). *National Conference of the Air Pollution*, 2009.

Mohammadi, M.J., Godini, H., Khak, M.T., Daryanoosh, S.M., Dobaradaran, S. and Goudarzi, G. (2015). Association between air quality and COPD in Ahvaz, Iran. *Jundishapur J. Chron. Dis. Care* 4: e26621.

Mohammadi, M.J., Goudarzi, G., Geravandi, S., Yari, A.R., Ghalani, B., Shirali, S., Zallaghi, E. and Esmaili, M. (2016b). Dispersion modeling of nitrogen dioxide in ambient air of Ahvaz city. *Health Scope* 5: e32540.

Naimabadi, A., Ghadiri, A., Idani, E., Babaei, A.A., Alavi, N., Shirmardi, M., Khodadadi, A., Marzouni, M.B., Ankali, K.A. and Rouhizadeh, A. (2016). Chemical composition of PM_{10} and its in vitro toxicological impacts on lung cells during the Middle Eastern Dust (MED) storms in Ahvaz, Iran. *Environ. Pollut.* 211: 316–324.

Neisi, A., Goudarzi, G., Akbar Babaei, A., Vosoughi, M., Hashemzadeh, H., Naimabadi, A., Mohammadi, M.J. and Hashemzadeh, B. (2016). Study of heavy metal levels in indoor dust and their health risk assessment in children of Ahvaz city, Iran. *Toxin Rev.* 35: 16–23.

Omidi-Khaniabadi, Y., Hopke, P.K., Goudarzi, G., Daryanoosh, S.M., Jourvand, M., Basiri, H. (2017a). Cardiopulmonary mortality and COPD attributed to ambient ozone. *Environ. Res.* 152: 336–341.

Omidi-Khaniabadi, Y., Daryanoosh, S.M., Amrane, A., Polosa, R., Hopke, P.K., Goudarzi, G., Mohammadi, M.J., Sicard, P. and Armin, H. (2017b). Impact of middle eastern dust storms on human health. *Atmos. Pollut. Res.* 8: 606–613.

Omlor, A.J., Nguyen, J., Bals, R. and Dinh, Q.T. (2015). Nanotechnology in respiratory medicine. *Respir. Res.* 16: 64.

Organization, W.H. (2014). The 10 leading causes of death in the world, 2000 and 2011. Fact sheet N 310.

Ostro, B., Hu, J., Goldberg, D., Reynolds, P., Hertz, A., Bernstein, L. and Kleeman, M.J. (2015). Associations of mortality with long-term exposures to fine and ultrafine particles, species and sources: Results from the California Teachers Study Cohort. *Environ. Health Perspect.* 123: 1–31.

Rezaei, M., Salimi, A., Taghidust, M., Naserzadeh, P., Goudarzi, G., Seydi, E. and Pourahmad, J. (2014). A

comparison of toxicity mechanisms of dust storm particles collected in the southwest of Iran on lung and skin using isolated mitochondria. *Toxicol. Environ. Chem.* 96: 814–830.

Romieu, I., Aguilar, M.R., Macias, H.M., Villarreal, A.B., Cadena, L.H. and Arroyo, L.C. (2003). Health impacts of air pollution on morbidity and mortality among children of Ciudad Juarez, Chihuahua, Mexico. Commission for Environmental Cooperation of North America, Montreal, PQ, Canada.

Rupf, S., Berger, H., Buchter, A., Harth, V., Ong, M.F. and Hannig, M. (2015). Exposure of patient and dental staff to fine and ultrafine particles from scanning spray. *Clin. Oral Investi.* 19: 823–830.

Salgueiro-González, N., de Alda, M.L., Muniategui-Lorenzo, S., Prada-Rodríguez, D. and Barceló, D. (2015). Analysis and occurrence of endocrine-disrupting chemicals in airborne particles. *TrAC, Trends Anal. Chem.* 66: 45–52.

Salvador, P., Artíñano, B., Viana, M., Alastuey, A. and Querol, X. (2015). Multicriteria approach to interpret the variability of the levels of particulate matter and gaseous pollutants in the Madrid metropolitan area, during the 1999–2012 period. *Atmos. Environ.* 109: 205–216.

Soleimani, Z., Goudarzi, G., Naddafi, K., Sadeghinejad, B., Latifi, S.M., Parhizgari, N., Alavi, N., Babaei, A.A., Akhoond, M.R., Khaefi, M., Rad, H.D., Mohammadi, M.J. and Shahsavani, A. (2013). Determination of culturable indoor airborne fungi during normal and dust event days in Ahvaz, Iran. *Aerobiologia* 29: 279–290.

Soleimani, Z., Goudarzi, G., Sorooshian, A., Marzouni, M.B. and Maleki, H. (2016). Impact of middle eastern dust storms on indoor and outdoor composition of bioaerosol. *Atmos. Environ.* 138: 135–143.

Swadron, S., FACEP, F., DeBlieux, P. and Nelson, B. (2008). The acute presentation of chronic obstructive pulmonary disease in the emergency department: A challenging oxymoron. *Emergency Med. Pract.* 10: 1–28.

Taghavirad, S., Davar, H. and Mohammadi, M.J. (2014). The a study on concentration of BETX vapors during winter in the department of ports and shipping located in one of the southern cities of Iran. *Int. J. Curr. Life Sci.* 4: 5416–5420.

Taylor, M., Retalis, A. and Flocas, H.A. (2016). Particulate matter estimation from photochemistry: A modelling approach using neural networks and synoptic clustering. *Aerosol Air Qual. Res.* 16: 2067–2084.

Tsai, S.S., Goggins, W.B., Chiu, H.F. and Yang, C.Y. (2003). Evidence for an association between air pollution and daily stroke admissions in Kaohsiung, Taiwan. *Stroke* 34: 2612–2616.

Yan, F., Winijkul, E., Bond, T.C. and Streets, D.G. (2014). Global emission projections of particulate matter (PM): II. Uncertainty analyses of on-road vehicle exhaust emissions. *Atmos. Environ.* 87: 189–199.

Yari, A.R., Goudarzi, G., Geravandi, S., Dobaradaran, S., Yousefi, F., Idani, E., Jamshidi, F., Shirali, S., Khishdost, M. and Mohammadi, M.J. (2016). Study of ground-level ozone and its health risk assessment in residents in Ahvaz City, Iran during 2013. *Toxin Rev.* 35: 201–206.

Zalaghi, E. (2010). *Survey of Health Effects of Air Pollution Ahvaz, Bushehr and Kermanshah with Use of Airq Model*, MSc Thesis, Islamic Azad University, Science and Research Branch, Ahvaz.

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