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Original Article

Total number of deaths and respiratory mortality attributed to particulate matter (PM_{10}) in Ahvaz, Iran during 2009

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ABSTRACT

Aims: This study was conducted to assess health-effects of exposure particulate matter (PM_{10}) in Ahvaz city (located in South-Western Iran), during 2009.
Materials and Methods: The adverse health effects of PM_{10} were calculated by relative risk (RR) and baseline incidence related to health end point PM_{10}. A specialized model, the air quality health impact assessment tool (AirQ2.2.3), was used to assess the potential impacts of PM_{10} exposure on human health in Ahvaz city during 2009. PM_{10} data was taken from Ahvaz Department of Environment. These data were in volumetric base. Health effects are being related to the mass of pollutants inhaled and should convert on the gravimetric basis. Conversion between volumetric and gravimetric units (correction of temperature and pressure), coding, processing (averaging), and filtering are implemented for solving such problem.
Results: The results revealed that approximately 3% of total numbers of deaths and respiratory mortality happened when the PM_{10} concentration was over 50 $\mu g/m^3$. Sum of total number of deaths attributed to PM_{10} was 1165 cases in 2009. Based on the results of this study, 13% of all respiratory mortality were attributed to PM_{10} concentration over 20 $\mu g/m^3$ in Ahvaz city during 2009. High percentage of the observed health endpoints was associated with a high concentration of measured PM_{10}.
Conclusion: Year comparison of PM_{10} concentration with standard was revealed particle matter concentration in summer and winter season were higher than standard. Although total mean of particle matter was higher than the standard concentration. The higher percentage of deaths perhaps could be the result of higher average PM_{10} or because of sustained high concentration days in Ahvaz.

Key words: Baseline incidence, health effects, relative risk, respiratory mortality

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INTRODUCTION

Anthropogenic air pollution has been effects harmful on human health. Its seriousness lies in the fact that high, potentially harmful pollutant levels are produced in environments which can be harmful to human health.

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According to World Health Organization (WHO) estimations, 8,00,000 people were died each year due to cardiovascular and respiratory diseases, which are attributed to air pollution, in all over the world. Approximately, 1,50,000 of this death occur in south of Asia. The result of studies about short- and long-term effects of air pollution were estimated in the form of hospital admissions excess cases, increasing in number of consultation with physician, asthma attacks, cardiopulmonary disease, death, and years of life lost.[1-7] Particulate matter (PM) air pollution is an air-suspended mixture of solid and liquid particles that vary in number, size, shape, surface area, chemical composition, solubility, and origin.[8] PM is produced in the combustion process which takes place mostly in transportation, power stations, heating plants, and industrial processes. The major sources of PM_{10} are resulting from human intervention particulate road traffic, stationary combustion, and industrial processes. PM_{10} emissions are defined as PM emissions that are $<10\ \mu m$ in diameter. PM_{10} are designated as the upper limit of the reparable fraction, the mass fraction of inhaled particles which penetrate the airways of the lung and as such are thought to be a major health hazard.[10-13] In recent years, numerous epidemiological studies have shown a relationship between the concentration of particle matter in urban air and respiratory diseases, pulmonary damage, and mortality among the population.[14-17] The extent to which airborne particles penetrate into the human respiratory system is determined mainly by their size, with possible health effects.[18] WHO study showed that increased by 10 μg of aerosols, the mortality rate of 1-3% increases.[16] The annual population-weighted average concentration of PM_{10} was estimated at 46.9 $\mu g/m^3$ and $PM_{2.5}$ at 26.6 $\mu g/m^3$ for all urban areas in South Africa.[19] Among infants 1 month to 1 year of age, a 20 $\mu g/m^3$ increase in PM_{10} 24-h average on the previous day was associated with a 62% increase in respiratory mortality. Isabelle evaluated the health impact assessment of air pollution in México. Based on the results of this study, when an increase of 20 $\mu g/m^3$ was observed, the risk of death was increased by 82%.[20] In another study, estimated health effects attributed to PM_{10} in the eight major Italian cities, in 1998. Result showed that about 3500 deaths and many more cases of the disease were attributable to levels of PM_{10} over 30 $\mu g/m^3$.[21] Over the last two decades, a large number of epidemiological studies have been conducted around the world to highlight the health significance of ambient PM.[22] In similar work, Goudarzi *et al*. estimation of health effects using AirQ Model.[23] Furthermore, Zallaghi *et al*. evaluated the health impact using AirQ model in Tabriz.[24] The health impact of chronic exposure from 1998 through 2002 was estimated at 168 deaths. Acute exposure led to 26 deaths and 43 hospital admissions during this period. A 10% daily decrease in pollution would reduce the number of expected deaths from short-term exposure by 19% while achieving compliance with European Union regulations would reduce them by <3%.[25] It should be noted that the cells of the respiratory system become remedied or replaced more slowly than those of other organs of the body. If the inflammation and swelling occur in the nasal organ or bronchus, they are called rhinitis and bronchitis. If the inflammation pervades the lung parenchyma, it will be known as pneumonia. Ultimately, the chronic inflammation of the lungs could result in fibrosis.[26] AirQ2.2.3 software was proved to be a valid and reliable tool to estimate the potential short-term effects of air pollution, predicts health endpoints attributed to criteria pollutants, and allows the examination of various scenarios in which emission rates of pollutants are varied.[27] This model is a valid and reliable WHO-proved tool to estimate the potential short term effects of air pollution. This model includes four screen inputs (Supplier, AQ data, Location, Parameter) and two output screens (Table and Graph). [4] The purpose of this study was to assess the potential effects of PM_{10} exposure on human health in Ahvaz city (located in South-Western Iran) during year 2009.

MATERIALS AND METHODS

A specialized model, the air quality health impact assessment tool ($AirQ_{2.2.3}$), was used to assess the potential impacts of PM_{10} exposure on human health in Ahvaz city during 2009. PM_{10} data was taken from Ahvaz Department of Environment. Stations were Naderi, Behdasht Ghadim, Havashenasi, and Mohitzist. Hence, the mortality and morbidity of PM in Ahvaz city at 2009 were calculated by $AirQ_{2.2.3}$ utilizing relative risk (RR) and baseline incidence (BI) from WHO data. The primary and secondary standard of PM according to National Ambient Air Quality Standards (NAAQS) 24-h is 150 $\mu g/m^3$.[27] The standard of PM according to European Air Quality Standards (EU AQS) 24-h is 50 $\mu g/m^3$ and 1 year is 40 $\mu g/m^3$.[28]

Geographical features of Ahvaz

Ahvaz city, the capital of Khuzestan Province, is located between 48° and 49°29′ east of Greenwich meridian, and between 30° and 32°45′ to the north of the equator. It has a semi-humid and sweltering climate. Ahvaz is located in the dry area of Iran, and its average yearly rainfall is about 250 mm. In 2009, its population was 1 million people.[29] Recently, Ahvaz has been exposed to the inadvertent dust which has made the living difficult and unbearable to the citizen. Figure 1 shows the location of the study area in the Khuzestan Province (Ahvaz city). [30]

Data analysis

To make the file, the following steps were taken in a row: These data were in volumetric base. Health effects are being related to the mass of pollutants inhaled, and this is why the AirQ model was on the gravimetric basis. Hence, there was a conflict between AirQ model and ADoE data. Conversion between volumetric and gravimetric units includes: Correction of temperature and pressure (when the temperature and pressure change the volume of the gas changes but it still contains the same mass of material),

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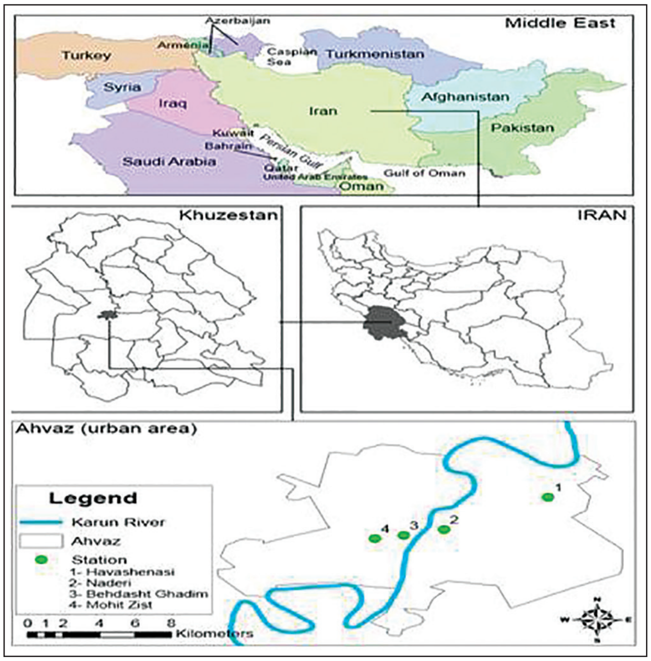

Figure 1: Location of the study area and sampling station in the Khuzestan Province (Ahvaz city), in the South-West of Iran

conformity of the unit with the model, coding, processing (averaging), and filtering are implemented for solving such problem. Calculating daily mean based on codification, condition modification, primary filtering, and secondary filtering. Thereafter, 24-h means were calculated for PM_{10} pollutant. For estimated of health impact attributable to the exposure of air pollution on the target population using AirQ model that estimate the this impacts to specific air pollutants on a resident population in a certain area and period. AirQ model is based on statistical equations. Sample community was Ahvaz city which was considered 1 million persons approximately. Data capture was collected for criteria air pollutants. Attributable proportion (AP) is fraction of health consequences in a specific population that can be attributed to a specific air pollutant exposure with this notion that there is proven causative correlation between health consequences and air pollutant exposure. AP was calculated as following formula:

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

where $p(c)$ is the population of city and RR denotes the relative risk for a given health endpoint.

The rate attributable to the exposure can be calculated as the following equation if the baseline frequency of the health endpoint is known in the population:

$$IE = I \times AP$$

where AP is the fraction of health impacts which can be attributed to the exposure in a given population for a certain time period.[31] In statistics and mathematical epidemiology, RR is the risk of an event (or of developing the disease) relative to exposure. RR is the ratio of the probability of an event occurring in the exposed group versus a nonexposed group. I is the BI attributed to selected health effects.[32]

$$RR = \frac{\text{Probability of event when exposed}}{\text{probability of event when nonexposed}}$$

The number of cases attributable to the exposure can be estimated as the following equation knowing the size of the population:

$$NE = IE \times N$$

where NE denotes the number of cases attributed to the exposure. N denotes the size of the population investigated.

Attributable proportion was multiplied at BI and divided to 10^5. Obtained value should be multiplied at population (10^6). The results will be the excess cases of mortality or morbidity attributed to given pollutant (PM_{10}). In order to verify and compare the results with the actual results were referred to the registration center for disease. But, unfortunately, due to lack and was not database quantities we used values of parameters required calculated by the WHO (in Middle East).

RESULTS

In view of PM_{10} concentrations, head office of ADoE and downtown were the highest and the lowest stations during this year, respectively. The yearly average, summer mean, winter mean, and 98 percentile of PM_{10} concentrations in these stations has presented in Table 1. Table 1 shows that annual mean of PM_{10} in Ahvaz was 277 μg/m^3 in 2009, which is higher than EU AQS and also much higher than NAAQS.

Figure 2 shows that summer 24-h average of PM_{10} in Ahvaz in 2009 was higher than NAAQS and also much higher than EU AQS standards. In view of PM_{10} concentrations, shows that winter 24-h average was the highest concentrations during this year respectively.

Relative risk and estimated AP percentage for a total number of deaths were estimated in Table 2. According to model's default, the BI of this health endpoint for PM_{10} was 1013/10^5 so the number of estimated number of excess cases were estimated 1165 at centerline of RR (RR = 1.0074 and AP = 11. 8569%).

Figure 3 shows the cumulative total number of deaths versus PM_{10} concentrations. Cumulative cases of this health endpoint were estimated by model which was 1165 in 2009. Furthermore, shows that despite the RR of health effects of PM_{10} concentrations below 20 μg/m^3 due to lack of contact with the population concentration is zero in other words,

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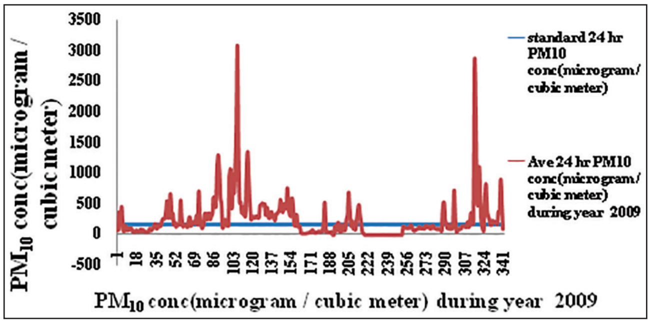

Figure 2: Relationship between standard 24 h average particulate matter (PM_{10}) concentrations and 24 h average PM_{10} concentrations in Ahvaz during year 2009

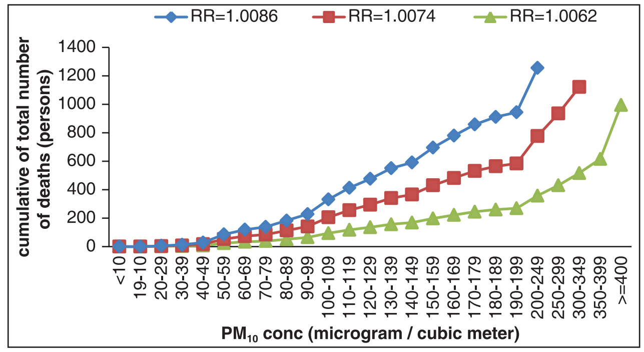

Figure 3: Relationship between cumulative of the total number of deaths versus particulate matter (PM_{10}) concentration in Ahvaz during 2009

no 1 day in 2009 has been reaches the PM_{10} concentration below 20 μg/m³. About 70% of this number has occurred in the days with concentrations lower than 200 μg/m³. It should be noted that 84% of the above number are corresponded to the days with concentrations below 350 μg/m³.

Relative risk and estimated AP percentage were estimated in Table 3 for respiratory mortality. BI of this health endpoint is 66/10⁵, the estimated number of excess cases were 114 at centerline of RR (RR = 1.012 and AP = 17. 9075%).

Respiratory mortality versus PM concentration has shown in Figure 4. Estimated cases which attributed to PM_{10} for respiratory mortality at lower, central, and higher of RR were 81, 114, and 257, respectively.

DISCUSSION

In recent decades, air pollution is considered as a serious threat to the environment, quality of life and health of people. In this study, we estimate effects of exposure to PM_{10} air pollution, such as the total number of deaths and respiratory mortality, using AirQ model in Ahvaz, Iran. Figures 3 and 4 illustrate PM_{10} concentrations versus related health endpoint. As it has shown, three ranges of RR based on model's default were considered for assessing health effects of PM_{10}. Furthermore, BI values were also taken from the default of model. For our population of 1 million people and base on BI of 1013/10⁵ people/year, some 1165 total numbers of deaths cases can be expected annually, out of this number, 1165 can be attributed to the PM_{10} concentration above 30 μg/m³. In respiratory mortality, 63% of cases occurred in days with pollutant not exceeding 190 μg/m³. Even in comparison between the total number of deaths and respiratory disease, BI had a paramount of importance than RR. In the interpretation of RR, it should be noted that 1 for this epidemiological parameter implies no impact on human health. In addition, severe effects can be expected when it exceeds from 1. The lower level of RR value might achieve if some control strategies for reducing PM_{10} emission be used. Therefore, the higher RR value can depict mismanagement in urban air quality. Based on the results of this study, 13% of respiratory mortality were attributed to PM_{10} concentrations over 20 μg/m³. A higher percentage of these deaths perhaps could be the result of higher average PM_{10} or due to sustained high concentration days in Ahvaz. The reason Ahvaz has got the highest rate became of higher concentration and further duration of the dusty air in

Table 1: Highest and lowest concentrations of PM_{10} (μg/m³) corresponding to stations in Ahvaz during 2009

Parameter	Stations		
	Average Ahvaz	Lowest stations (Mohitzist)	Highest stations (Naderi)
Annual mean	277.64	147.2	261
Summer mean	373.55	182	376
Winter mean	348.55	132.47	170
98 percentile	2104.77	802.66	1268
Annual maximum	4496.2	2475	4324
Summer maximum	4496.2	1283	4324
Winter maximum	3084.33	2475	2810

PM: Particulate matter

Table 2: RRs, APs, and the number of people suffering from the total number of deaths due to PM_{10} exposure in Ahvaz during 2009

Estimate	Indicator		
	RR (medium)	Estimated AP (%)	Number of persons
Down	1.0062	10.1289	995.3
Mean	1.0074	11.8569	1165.1
Up	1.0086	13.5196	1328.5

RRs: Relative risks, AP: Attributable proportions, PM: Particulate matter

Table 3: RRs, APs, and the number of people suffering from respiratory mortality due to PM_{10} exposure in Ahvaz during 2009

Estimate	Indicator		
	RR (medium)	Estimated AP (%)	Number of persons
Down	1.0080	12.6992	81.3
Mean	1.0120	17.9075	114.6
Up	1.0370	40.2125	257.4

RRs: Relative risks, APs: Attributable proportions, PM: Particulate matter

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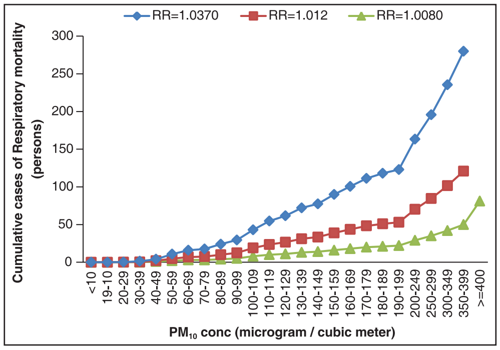

Figure 4: Relationship between cumulative of respiratory mortality versus particulate matter (PM_{10}) concentration in Ahvaz during 2009

the city. A study commissioned its cooperation on North American was conducted to among infants aged 1 month to 1 year 20 μg/m³ increase in average 24-h PM_{10} the risk of death was increased by 82%. However, these estimates were based on only 41 deaths.[33] An epidemiological study, examined the relationship between daily mortality and daily morbidity from 1996 to 2001, indicated a 10 μg/m³ change in daily PM_{10} is associated with a 0.5% increase in total mortality.[34] Average PM_{10} levels on urban population of 13 large Italian cities for the years 2002-2004 ranged from 26.3 μg/m³ to 61.1 *μg/m*³. The health impact of air pollution in Italian cities is large: 8220 deaths a year, on average, are attributable to PM_{10} concentrations above 20 μg/m³. The impact on short-term mortality, again for PM_{10} above 20 μg/m³, is 1372 deaths, which is 1.5% of the total mortality in the whole population. Schwartz based on a regression model in the study of air pollution in the United States of America in 10 people over 65 years, the RR for each 10 μg/m³ 2% increase in PM_{10} is calculated.[35] Review and meta-analysis were conducted to determine the effects of short-term exposure on mortality that increasing 10 μg/m³ showed estimated by the Bangkok 1/7%, Mexico 1/83%, Santiago 1/1%, Inchoan, 0/8%, Bryson Australia 1/6%.[36-40] Tominz *et al*. to evaluate the health effects of PM_{10} using of AirQ model in Trieste city during 2005, Italy. Based on the results of this study, 1/8% of all respiratory mortality and 2/5% of all deaths were attributed to respiratory concentrations over 20 μg/m³.[41] In similar work, Zallaghi *et al*. to evaluate the health effects of PM_{10} using of AirQ model in South-West of Iran (Ahvaz, Kermanshah, Bushehr) during 2010. Based on the results of this study, in Kermanshah 12% of cardiovascular diseases and 17% respiratory diseases was attributed to PM_{10} concentrations over 30 μg/m³.[42] Furthermore, Zallaghi *et al*. exploited AirQ model to estimate the PM_{10} hygienic effects in Bushehr during 2010. Based on their results, almost 14% of cardiovascular diseases and 19% respiratory diseases was attributed to PM_{10} concentrations over 20 μg/m³.[43] In another similar work, Goudarzi *et al*. to evaluate the health effects of PM_{10} using of AirQ model in Tehran city during 2008. Based on the results of this study, 4% of all respiratory mortality were attributed to PM_{10} concentrations over 20 μg/m³.[23] In another similar work, Zallaghi *et al*. evaluated the health effects of PM_{10} using of AirQ model in Bushehr city during 2011. Based on the results of this study, 15% of cardiovascular diseases and 20% respiratory diseases were attributed to PM_{10} concentrations over 10 μg/m³.[44] Furthermore, Zallaghi *et al*. evaluated the health impact using AirQ model in Tabriz. Based on the results of this study, 6% of all cardiovascular and respiratory mortality were attributed to PM_{10} concentrations over 10 μg/m³.[24]

CONCLUSIONS

High percentage of the observed health endpoints was associated with a high concentration of measured PM_{10}, and as it was mentioned previously, PM_{10} concentration was higher than EU AQS and NAAQS guidelines' values. This study was the first attempt to assess health impacts of air pollution using the AirQ2.2.3 model in Ahvaz, Iran. Although the results of this study are in line with results of other researches around the world, since the geographic, demographic, and climate characteristics are different, there is still high need to further studies to specify local RRs and BIs. Unfortunately, due to lack of databases and the lack of indicators amounts the studied were used the values of the WHO (Middle East) for calculated health effects attribute PM_{10}. Therefore, to estimate the health effects of air pollutants, actually require epidemiologic studies for accurate calculation of RRs and BIs. Accordingly, cost-effective measures and management schemes should be considered to abate air pollution concentrations and/or reduce exposure of the general population to air pollutants. Overall, based on the results obtained in this study PM_{10} concentrations at warm month in the year were higher than the EU AQS and NAAQS and crowded of city. Finally, the survey results show that the implementation of basic actions to the control dust entering to the country by spreading mulch and development of green space is essential.

Limitations of the study

Lack of databases and the lack of epidemiologic studies for accurate calculation of RRs and BIs are an important limitation of this study.

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