ORIGINAL PAPER

Health impact assessment of exposure to PM_{10} in Ilam city using Air Q software

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ABSTRACT

Air pollution is a major environmental issue in the world that can be harmful for human health. The aim of this study was to determine the health impacts of particulate matter with an aerodynamic diameter ≤10µm (PM_{10}) in Ilam in 2013 and 2014. The air pollution data were obtained from the Ilam Department of Environmental Protection. The data were analyzed by Excel software, and the annual mortality and morbidity due to cardiovascular and respiratory diseases attributed to PM_{10} exposure were estimated by Air Q software**.** According to the results, the average of annual, winter, and summer PM_{10} concentration was 68.1, 46.7, and 89.3 µg/m^3, respectively, in 2013. In 2014, the average annual, winter, and summer PM_{10} concentrations were 51.4, 40.3, and 62.6 µg/m^3, respectively. The total mortality, cardiovascular mortality, respiratory mortality, and hospital admissions due to cardiovascular and respiratory diseases in 2013 were estimated at 89, 47, 9, 46, and 119 cases, respectively, and in 2014 they were estimated at 64, 33, 6, 33 and 85 cases, respectively. The results revealed that 9.6% of total mortality in 2013 and 5.8% total mortality in 2014 were associated with concentrations of more than 20 µg/m^3 PM_{10} concentration. Therefore, it is concluded that exposure to PM_{10} can increase morbidity and mortality. Thus, urgent and substantial actions to deal with the adverse effects of particulate matters are found to be necessary.

Keywords: air pollution; health impact assessment; PM_{10}; mortality; Air Q software

Introduction

Air pollution is a serious problem around the world that is growing because of industrialization, urbanization, population growth and climate change, especially in developing countries. Particulate matter in the air, as one of the important pollutants and indicators, has attracted a lot of attention.[1-3]

Several epidemiological studies have demonstrated a relationship between adverse health effects and air pollution and most of these effects include increased mortality and hospitalization of patients attributed to cardiovascular disease.[4,5] The World Health Organization (WHO) reported a mortality of 8.4 million annually worldwide and nearly 865,000 premature mortality as health outcomes of air pollution. In addition, according to WHO estimates, nearly 150,000 premature mortality annually in South Asian countries due to cardiovascular and respiratory diseases and lung cancer can be attributed to air pollutants' exposure.[1, 6]

Particulate matter at high concentrations, in addition to health events, results in economic impacts such as severe erosion of buildings and industrial facilities, land and air travel disruption, crops damage and loss, and social consequences such as increased immigration. Particulate matters in the range of 0.005 to 500 µm are transmitted by air, with the main portion

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of them being in the range of 1.0 to 10 µm. Particles with an aerodynamic diameter of 10 µm and smaller are defined as PM_{10}. This PM_{10} fraction, due to the point of entry and settling down in the lower respiratory system, has the most adverse effects on human health.[7-10]

Exposure to high concentrations of PM_{10} can result in both short and long-term adverse health effects.[11] These particles can aggravate respiratory diseases such as asthma, emphysema, bronchitis, silicosis, and lung cancer.[7,12] Relevant management and also public awareness of adverse health effects of air pollution are considered as the first fundamental step in development of strategic programs to control air pollutants. With quantification of air pollution data, the health effects of air pollution are easily estimated and the priority of control measures is defined by comparison with other risk factors. One of the most valid and reliable tools for estimating the short-term effects of air pollutants is the Air Q model introduced by WHO in 2004. In connection with the estimated mortality associated with PM_{10}, several studies have been conducted around the world, including in New Delhi (India), Qin Yang (China), Trieste (Italy) and South Korea. Furthermore, similar studies have been carried out to estimate the health effects of PM_{10} in cities of Iran including Tehran, Sanandaj, Shiraz, and Tabriz using Air Q models. In the past decade, due to dust storms in the south, south west and west of Iran, these areas have been faced with the phenomenon of the influx of dust and therefore of exposure to high concentrations of PM_{10}.[1,2,13,14,15]

Ilam city, the center of Ilam province, is located in the west of Iran. In recent years, for various reasons, including geographic location and topography in neighboring Khuzestan Province and bordering with Iraq and also being close to other countries known as sources of the dust (Saudi Arabia, Syria, Kuwait, Yemen), Ilam has been affected by major disasters, air pollution, and dust invasion. Therefore, as a consequence, this study has aims to assess the health outcomes assigned to PM_{10} exposure in Ilam using the Air Q model.

Materials and Methods

Area of study

Ilam, the center of Ilam province, is located in western Iran (latitude 3°63', altitude 46°42') and 1,387 m above sea level (Fig.1). The city has a population of over 213,579 and is fenced with mountains and forested highlands with a mountainous temperate. Ilam is also an important source of oil and gas in the country.[16]

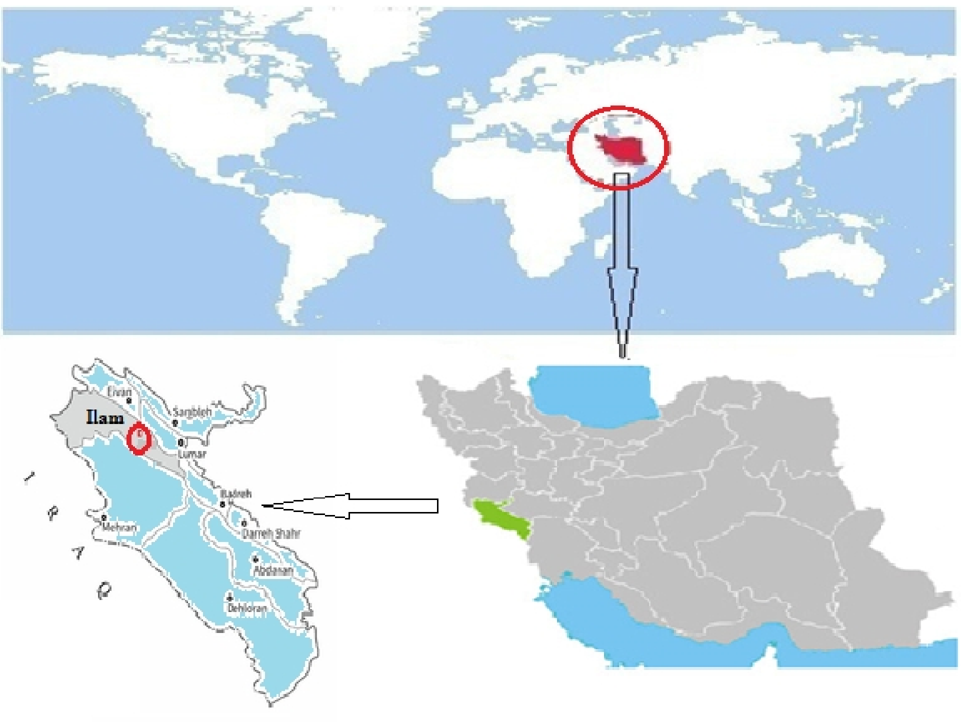

Fig. 1. Ilam location in the world and air quality monitoring stations in 2013 and 2014

Air pollution data collection

PM_{10} data for Ilam was received from the Ilam Department of Environmental Protection between January 1, 2013 and January 1, 2015. Sampling sites based on the location of this department were selected in a way that they covered most areas of the city. After post-processing using Excel software the data were converted to the input file for the Air Q model.

Air Q software

Air Q is a specialized software developed by WHO to assess the health effects of air quality. It can evaluate the potential effects of a criteria pollutant on human health in a given urban area. This model can provide the health effects of pollutants on human health as having such outcomes as mortality, incidence, and prevalence of diseases.[1,2,13,14,17]

In this model, relative risk, attributable portion, and base incidence are the key factors. The relative risk (RR) represents the ratio of the probability of an event occurring in an exposed population to the probability of the event occurring in a non-exposed population. Furthermore, the term "base incidence" in the model is the number of outcomes based on epidemiological studies conducted by WHO as calculated for a year. The term "attributable portion" is also the percentage of health outcomes directly attributed to the pollution. Attributable portion is calculated using Equation 1 as follows:

$$AP=\frac{\sum\{[RR(c)-1]\times P(c)\}}{\sum[RR(c)\times P(c)]} \qquad (1)$$

where AP is the assigned health outcomes, RR (c) represents the health relative risk in Group C, C is the exposed group derived from epidemiological studies, and P (c) is the proportion of Group C or exposed group. The number of cases per population unit (IE) with a base incidence of health consequences (I) is calculated by Equation 2 as follows:

$$IE=I\times AP \qquad (2)$$

$$AP=I\times IE \qquad (3)$$

Also, having a population size (N), the estimated number of cases attributable to exposure (NE) can be estimated by Equation 4 as follows:

$$NE=IE\times N \qquad (4)$$

In this study, Air Q 2.2.3 software was used with input data of PM_{10} in the Ilam population two years (January 1, 2013 to January 1, 2015). The output includes indicators such as RR, attributable portion, etc., for all mortality and morality as a result of cardiovascular and respiratory diseases as well as hospitalized patients for cardiovascular and respiratory diseases.[18]

Results and Discution

The results of average and maximum annual and seasonal (summer and winter) PM_{10} concentrations in 2013 and 2014 for the Keshvari Square Station are presented in Fig. 2. According to the results of this study, the average of annual, winter, and summer concentrations of PM_{10} in 2013 were 68.115, 46.7 and 89.32 μ/m^3, respectively, and in 2014 these values were 51.497, 40.3 and 62.61 μ/m^3, respectively. These values are much higher than the annual average standard for PM_{10} recommended by WHO (20 μ/m^3).[19] The maximum annual, winter, and summer concentrations of PM_{10} in 2013 were 490.63, 165.82 and 490.63 μ/m^3, respectively, and in 2014 they were 521.94, 114.36 and 521.94 μ/m^3, respectively. As it is evident from the results, the maximum concentration of PM_{10} occurred in the summer in both the years.

This situation usually occurs in cities in the south and west of Iran and other studies in Iran have shown similar results. As reported by Shahsavani et al., annual average and maximum concentrations of PM_{10} were 319.6 and 2028 μ/m^3 in Ahvaz in April and September, respectively.[20] Based on the results of other studies, this situation exists also in the neighboring countries. Draxler et al. reported higher values than the standard in Kuwait, Iraq, and Saudi Arabia. They also reported the highest concentrations PM_{10} in June.[21] Accordingly, the increase of PM_{10} concentrations in summer in Ilam can be assigned to the arid climate of the

Iraq, Kuwait, Saudi Arabia, and Middle East dust storms. These storms are the main cause of existence of dust in the west and southwest of Iran.[22]

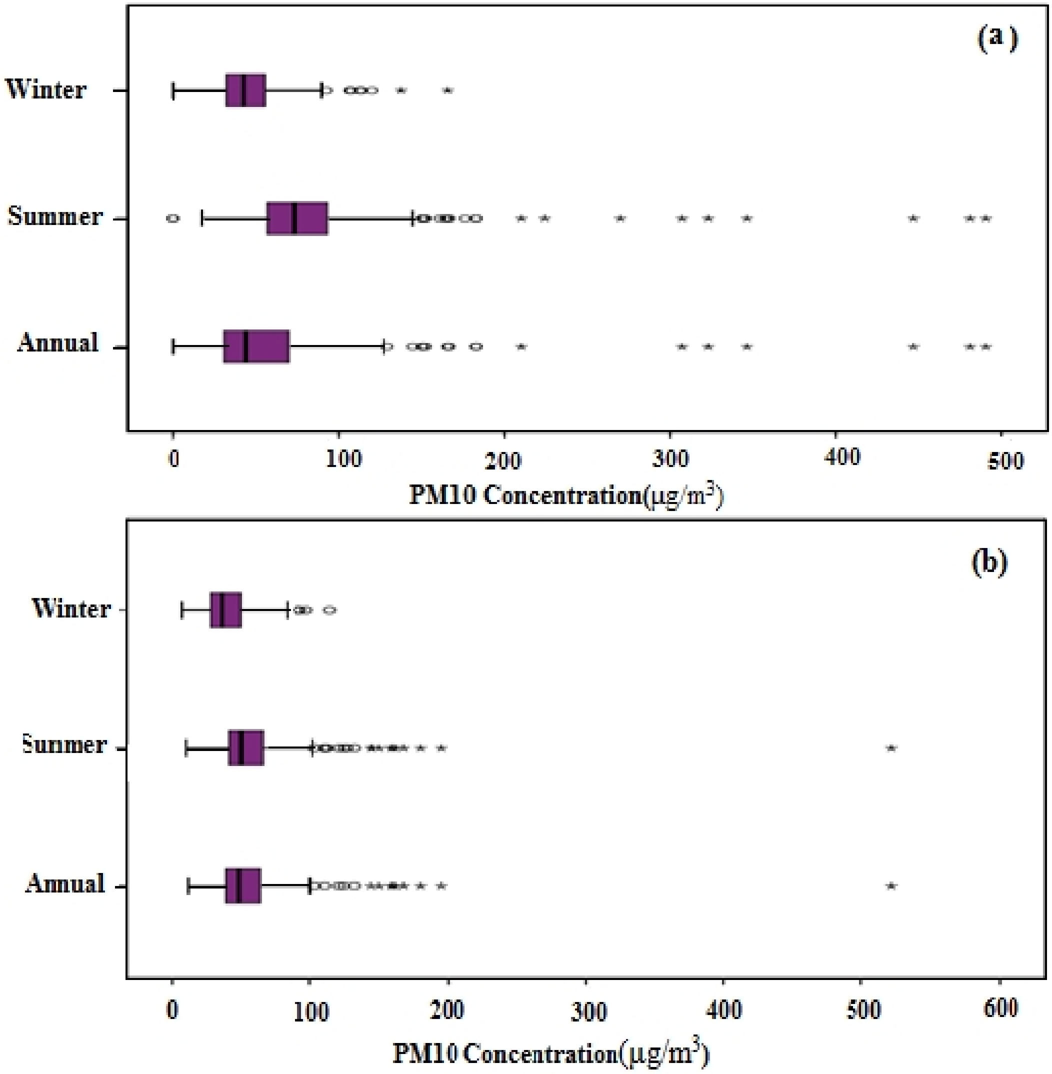

Fig. 2. Descriptive statistics of measured particulate matter with aerodynamic diameters <10 µm concentrations in Ilam, Iran, in 2013 (a), 2014 (b)

Fig. 3 presents the per cent of days that people were exposed to different concentrations of PM_{10}. The highest percentage of days that people were exposed to PM_{10} particles in both 2013 and 2014 were in the range of 40 to 49 μ/m^3. Figure 4 shows the percentage of people who were affected by the short-term effects of various concentrations of PM_{10} in 2013 and 2104, which was 63% and 78%, respectively, attributed to the particle concentration of less than 99 μ/m^3. The highest number of people affected by short-term effects of various concentrations of PM_{10} was in the range of 80-89 μ/m^3 in 2013 and in the range of 40-49 μ/m^3 in 2014.

The number of cases attributable to exposure to PM_{10} of total mortality, mortality from cardiovascular disease, mortality from respiratory diseases, and the number of hospitalized patients of cardiovascular and respiratory diseases are presented in Table 1. The total number of cases of cardiovascular mortality, respiratory mortality and the number of hospitalized patients for cardiovascular disease and respiratory diseases in 2013 as the average RR range, were 9, 46, and 119 cases, respectively, while in 2014, they were 33, 6, 33, and 85 cases, respectively.

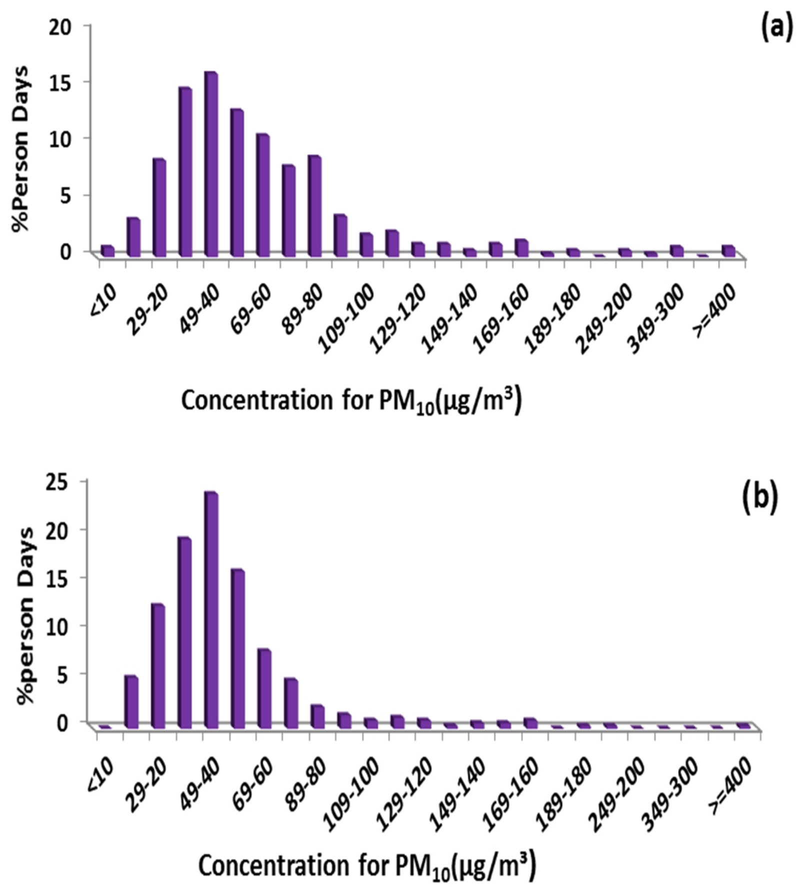

Fig. 3. Percentage of days of exposure to different concentrations of particles with an aerodynamic diameter of residents less than 10 microns in Ilam city in 2013 (a) and 2014 (b)

Table 1. Repeated cases (BI), relative risk (RR), the ratio of attributable (AP) estimated annual number of cases Subject to short-term effects of particles with aerodynamic diameter of less than 10 microns

Health endpoints	Year	BI	RR	Attributable proportion in percent (uncertainty range)	Number of cases excess (uncertainty range)
Total mortality	2013	1013	1.0074 (1.006-1.008)	4.13 (3.4-4.7)	89 (75-102)
	2014	1013	1.0074 (1.006-1.008)	2.9 (2.4-3.43)	64 (53-73)
Cardiovascular mortality	2013	497	1.008 (1.005-1.018)	4.45 (2.82-9.48)	47 (30-100)
	2014	497	1.008 (1.005-1.018)	3.19 (2.02-6.92)	33 (21-73)
Respiratory mortality	2013	66	1.012 (1.008-1.037)	6.53 (4.45-17.73)	9 (6-24)
	2014	66	1.012 (1.008-1.037)	4.72 (3.19-13.25)	6 (4-18)
Hospital admissions due to cardiovascular diseases	2013	436	1.009 (1.006-1.013)	4.98 (3.37-7.03)	46 (31-65)
	2014	436	1.009 (1.006-1.013)	3.5 (2.4-5.09)	33 (22-47)
Hospital admissions due to respiratory diseases	2013	1260	1.008 (1.004-1.011)	4.45 (2.71-6.12)	119 (73-164)
	2014	1260	1.008 (1.004-1.011)	3.19 (1.94-4.42)	85 (52-118)

In Figs. 5 to 9 the cumulative number of cases of mortality, cardiovascular mortality, respiratory mortality, and the annual number of patients hospitalized for cardiovascular disease and respiratory diseases in the range of moderate RR was evaluated for the health effects of PM_{10}.

Based on Figs. 5 to 9, it can be stated that 76% of these cases in 2013 and 83% of cases in 2014 were attributed to PM_{10} concentrations less than 120 μ/m^3. Based on the Air Q model, cumulative number of mortality cases in 2013 and 2014 were 89 and 64, respectively (Fig. 5).

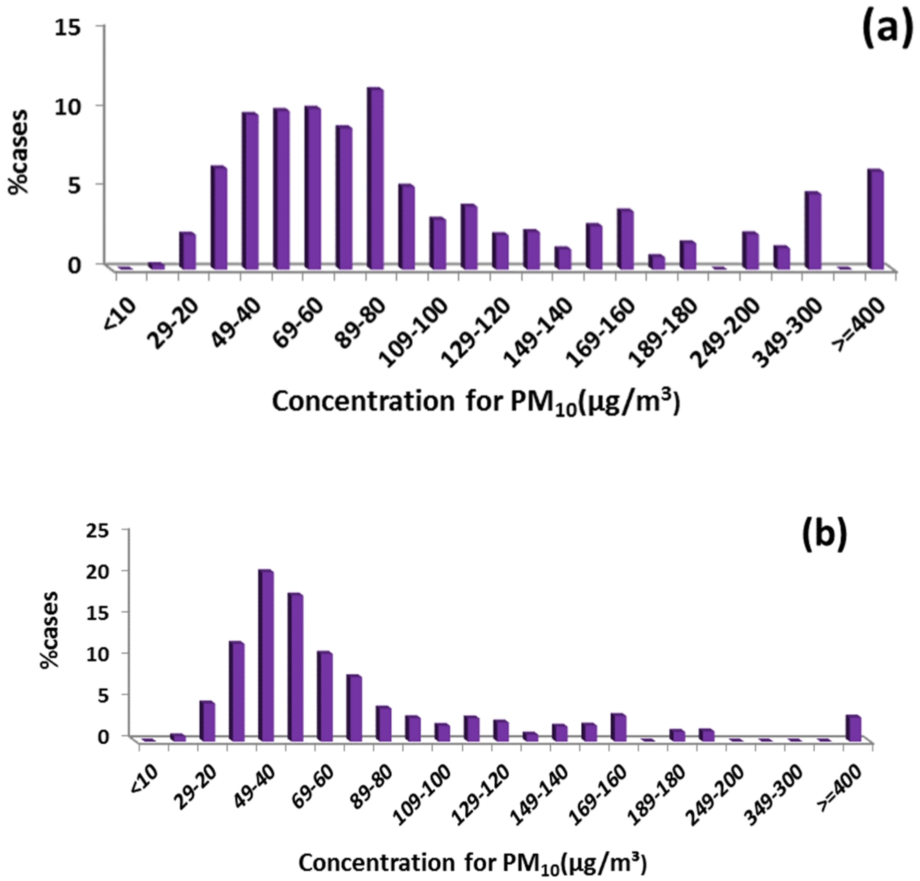

Fig. 4. Percentage of people exposed to different concentrations of particles with an aerodynamic diameter of less than 10 microns in 2013 (a) and 2014 (b)

Now, according to existing reports in Ilam (with a population of over 213, 579 people), the annual death rates in 2013 and 2014 were 982 and 1099 cases, respectively. Based on this model, 5.8% of the mortality cases in 2014 and 9.06% of mortality cases in 2013 are attributable to PM10 particles with higher concentrations than those of the WHO standard. This proportion has also been reported in the provinces neighboring Ilam. Hosseini et al. reported the total number of mortality, cardiovascular mortality, respiratory mortality, and ultimately the number of patients hospitalized for the average relative risk of cardiovascular disease and respiratory disease as 120, 23, 118, and 305, respectively, in Sanandaj in 2013 where 73% was attributed to PM_{10} concentrations of less than 129 μ/m^3. According to the population of Sanandaj, 11.7% of the mortality was related to PM_{10} concentrations which were higher than the WHO standard.[1]

Similarly, other studies have reported different results elsewhere based on the Air Q model. For instance, Tominz et al. in Trieste, Italy showed that 1.8% of mortality from cardiovascular and 2.5% mortality from respiratory diseases were related to PM_{10}

concentrations that were higher than those of the standard WHO guidelines.[23]

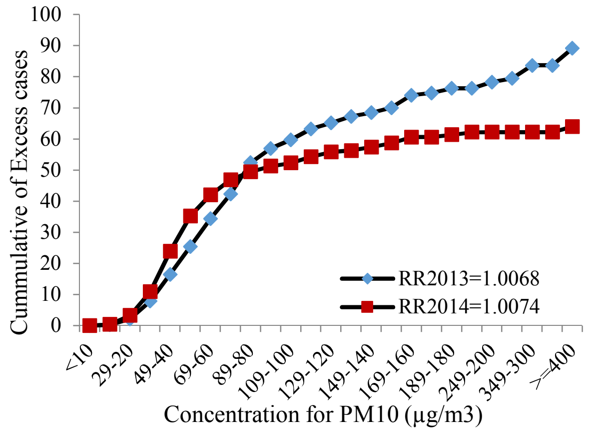

Fig. 5. Estimated cumulative number of mortality related to particles with diameter of less than 10 microns in Ilam Air Q model in the years 2013 and 2014

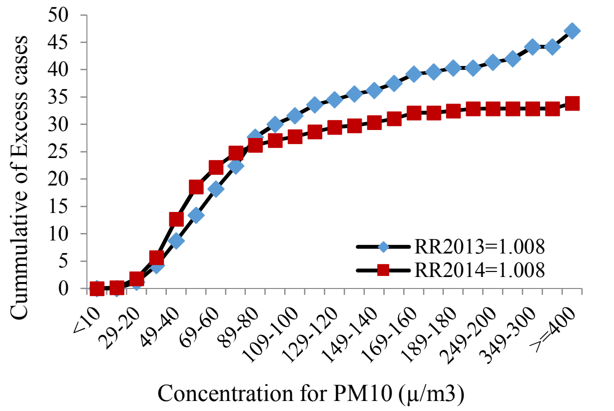

Fig. 6. Estimated cumulative number of mortality caused by cardiovascular diseases related to particles with a diameter less than 10 microns in Ilam using Air Q model in 2013 and 2014

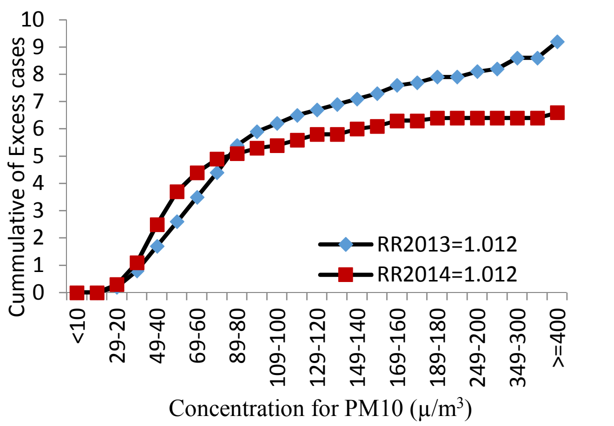

Fig.7. Estimate the total cumulative number of mortality from respiratory diseases related to particles with a diameter less than 10 microns in Ilam using Air Q model in 2013 and 2014

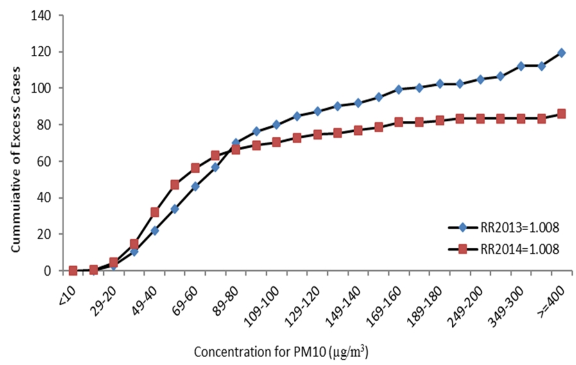

Fig. 8. Estimates total cumulative number of hospital admissions for respiratory disease related to particles with a diameter less than 10 microns in Ilam using Air Q model in 2013 and 2014

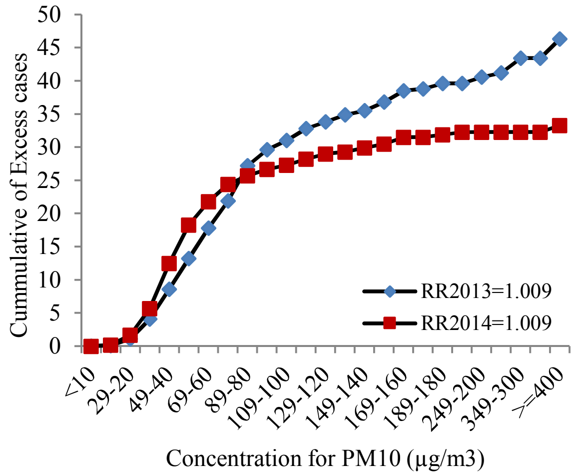

Fig. 9. Estimated total cumulative number of hospital admissions related to cardiovascular patients less than 10 microns in diameter particle model in Ilam using Air Q in 2013 and 2014

Conclusion

The objective of this study was to measure the adverse health effects of PM_{10} in one of Iran's border provinces with Iraq using Air Q software which shows the effects of pollutants on inhabitants of a certain area. Accordingly, from comparison of results of the present study and results of similar studies, high mortality rate in Ilam during the studied period can be attributed to high concentrations of PM_{10} and to the number of days with high PM_{10} concentrations.

Generally speaking, the results of this study indicate that the concentrations of PM_{10} in Ilam are higher than those of the WHO guidelines. As a conclusion, with regard to the adverse effects of PM_{10} on the public health of Ilam and the increase of mortality and cases of hospitalization, we recommend the urgent establishment of necessary policies to reduce exposure to PM_{10} in the city.

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