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Assessment of health impacts attributed to PM_{10} exposure during 2011 in Kermanshah City, Iran

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Original Article

Abstract
The main aim of this study was to evaluate cardiovascular and respiratory outcomes attributed to PM_{10} in Kermanshah, Iran. In order to gather data, an Environmental Dust Monitor instrument was used at 3 stations throughout the city at a height of at least 3 m above the ground. We obtained an input file for the model from crude data and quantified PM_{10} using the AirQ model. Our estimation showed that 80% of cardiovascular deaths occurred on days with PM_{10} concentrations of less than 170 μgm^{-3}. The number of respiratory deaths due to PM_{10} was estimated to be 46 people in 2011, showing a 48% reduction in such deaths compared to 2010. The number of patients with respiratory problems attributed to PM_{10} exposure comprised 5.61% of the total number of patients admitted to hospitals due to respiratory diseases. This lower percentage of morbidity and mortality attributed to suspended particles in Kermanshah in 2011, in comparison with 2010, was due to the higher exposure days with PM_{10} concentration of 200-250 μgm^{-3} in 2010. Every 10 μgm^{-3} increase in the concentration of suspended particles led to a 0.8 and 1.2% rise in the mortality rate due to cardiovascular and respiratory diseases, respectively. Additionally, the rates of heart and respiratory problems increased by 0.9 and 0.8%, respectively.
KEYWORDS: Assessment, Health Impacts, Mortality, Cardiovascular Diseases, Particulate Matter

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Introduction

In the standpoint of human beings and their health, health impact assessment of air quality is of paramount importance. Many studies have been conducted to illustrate mortality and

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morbidity resulting from air pollutants in Iran.[1-4] PM_{10} are particulate matter with aerodynamic diameter of 10 µm or less, which can be an appropriate parameter in terms of health impact assessment. Short-term and long-term epidemiological studies have investigated the relation between suspended particles and adverse effects on health, excess mortality, and the outbreak of cardiovascular and respiratory diseases. There are clear signs indicating that the health effects of particles are mainly attributed to PM_{10} and $PM_{0.1}$.[5] Air-polluting suspended particles, regardless of chemical properties, are presented in figure 1 in terms of size.

High concentrations of suspended particulate matter (SPM) adversely affect human life in a number of ways, including the provocation of a wide range of respiratory and cardiovascular diseases, carcinogenic effects, profound impacts on defensive mechanism, and corrosion and loss of property.[7-10] Important particles in air pollution studies have a size between 0.01 to 100 µm.[8] The average concentration of PM_{10} in the world is about 10-80 µgm^{-3}. In the most polluted cities in Latin America such as Mexico City, the average concentration of PM_{10} could reach 100 µgm^{-3} or even higher. The concentration of suspended particles in developing countries is commonly and traditionally much higher than developed countries.[7] In a report carried out by the World Health Organization (WHO) on urban air pollution in megacities of the world (1994), in which the air quality of 20 cities were compared, it was revealed that most of the cities engaged were among the developing countries.[11] According to this report, suspended particle concentrations in 17 of the total 20 studied cities were about two times higher than the WHO standards. This issue became even more intense with higher concentrations of SO_2. The annual mean range of SPM was 200-600 µgm^{-3}. The maximum concentration was reported to be 1000 µgm^{-3}.[11] The suspended particles enter the human body exclusively through the respiratory tract and immediately disrupt the function of this part of the body. High concentrations of suspended particles are detrimental to human health, especially for those suffering from chronic respiratory diseases. Previous studies have shown that increased level of suspended particles in combination with sulfur oxides is the main cause of the increased number of patients admitted to the hospitals and clinics. The most common health problems caused by suspended particles include the upper respiratory tract infections, cardiac disorders, bronchitis, asthma, pneumonia, lung inflammation, carcinogenic effects, chest discomfort, and adverse effects on defensive mechanisms.[8,12]

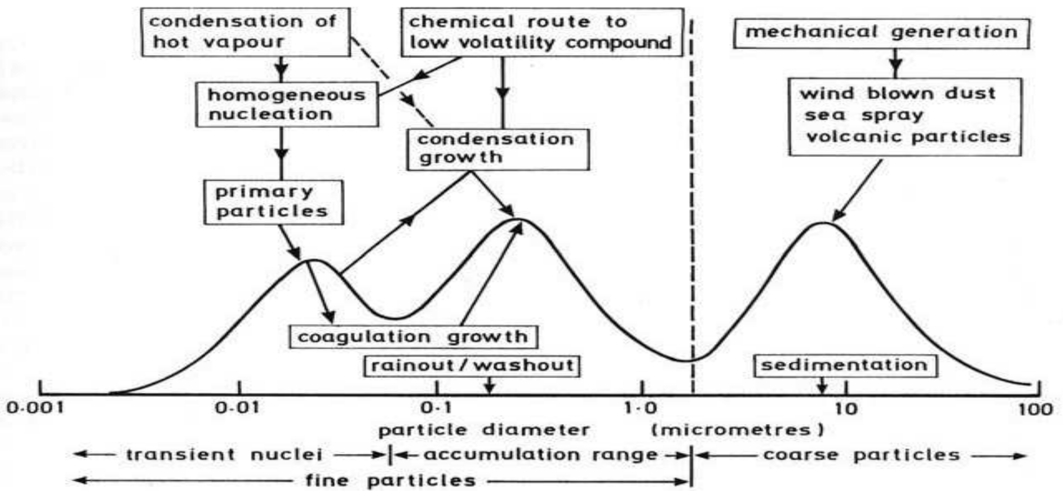

Figure 1. The trimodal size distribution, showing general relationships between the three common size ranges and the particle sources Source: Tiwary, Colls [6]

The capability of the human respiratory tract defense system against inhaled suspended particles depends highly on the size of the particles. The diameter of most suspended particles is in the range of 0.1-10 µm. The smaller particles undergo vibrational and Brownian motions, while the larger particles (> 10µm) precipitate rapidly. Due to the heightened level of dust particles in some regions of Iran in recent years, especially Kermanshah City, it is vital to evaluate the relationship between such particles and the increased number of cardiovascular and respiratory tract diseases.

Kermanshah City, with a population of approximately 843117 people, is located in the Southwest of Iran and currently considered as an industrial center of Iran as well as a source of dust events. As a result, the city is among the most polluted cities in Iran. The main objective of this study was to estimate the health effects of particulate matter (PM_{10}) on mortality due to respiratory and cardiovascular diseases in 2011 and compare the statistical results with those obtained for 2010.

Materials and Methods

Kermanshah, the capital of Kermanshah Province, is located in the Central-West Region of Iran. The geographical location of Kermanshah is 34° 19' N, 47° 7' E and it is 1322 m above sea level. According to the Damartn classification, which is based on average precipitation and average temperature, Kermanshah is placed in the category of cold and semi-arid climate with the annual average precipitation and temperature of 444.7 mm and 14.3°C, respectively. The vegetation cover is steppe with few trees in the ranges. The temperature may drop to 10°C in the winter; however, it rises to 44°C in the summer.[13]

The aim of the present study was the estimation of health endpoints attributed to PM_{10} pollutant using epidemiological indices. The AirQ model that was introduced by the WHO in 2004 provides a valid and reliable tool for estimating the short-term impacts of air pollutants.

The first step: sampling of PM_{10} pollutant: For sampling of PM_{10} particles, 3 sampling stations were selected in the city. A high-volume air samplers (model: Anderson) was used to sample and measure the concentrations of the suspended particles. Sampling, analysis, and selection of the stations were performed according to the EPA 3051A guideline.[14,15] The temperature and pressure parameters were recorded hourly by the weather channel software (www.msn.com).

The second step: data processing and model implementation: The measured PM_{10} concentration data was processed to provide daily average, minimum, maximum, and some statistical parameters. The processed data was entered into the AirQ model to estimate the number of cases of cardiovascular and respiratory morbidity and mortality.

Results and Discussion

Air pollution of Kermanshah attributed to PM_{10} in 2011

The results presented in table 1 show that in all 3 studied stations, the average concentrations of PM_{10} in the summer were higher than the winter, with the observed maximum concentration of 1810.5 μgm^{-3} in the summer. The highest and lowest concentrations were observed in Ziba Park and Ostandari stations, respectively. According to table 1, the annual average concentration of PM_{10} in Kermanshah in 2011 was equal to 89.54 μgm^{-3}, and was117.91μgm^{-3} for the summer, which was higher than the winter. Figures 2, 3, 4, and 5 are presented according to accumulative mortality due to cardiovascular and respiratory tract diseases versus the concentration ranges of the related pollutant. Each figure includes 3 curves in which the middle curve corresponds to the central relative risk, and the upper and lower curves correspond to the relative risks of 95% and 5%, respectively.

Table 1. The required indices of the model for PM_{10} (μgm^{-3}) in 3 studied stations in Kermanshah in 2011

Parameter	Station			
	Ziba Park	Shahrdari	Ostandari	Overall mean
The annual average	90.03	89.34	89.26	89.54
The summer average	118.34	117.76	117.62	117.91
The winter average	60.60	59.80	59.78	60.06
98^{th} annual percentile	330.95	328.36	329.12	329.48
Annual maximum	1810.50	1809.00	1804.00	1807.83
Summer maximum	1810.50	1809.00	1804.00	1807.83
Winter maximum	283.00	283.00	278.00	281.33

Table 2. The estimation of relative risk indices, attributable proportion, and number of cases of cardiovascular disease mortality (Baseline incidence (BI) = 497) in Kermanshah in 2011

Estimation	Epidemiological indices		
	Relative risk (average)	Attributable proportion (%)	Number of cases
Lower	1.005	3.5839	151.6
Average	1.008	5.6135	237.8
Upper	1.018	11.8023	499.2

Table 3. The estimation of relative risk indices, attributable proportion, and number of cases of respiratory tract disease mortality (BI = 66) in Kermanshah in 2011

Estimation	Epidemiological indices		
	Relative risk (average)	Attributable proportion (%)	Number of cases
Lower	1.008	5.6135	31.5
Average	1.012	8.1904	46.0
Upper	1.037	21.5728	121.2

Quantification of the health effects due to PM_{10} exposure

By using results yielded by data processing and registered data from the measurement stations for suspended particles throughout the city, and estimating the population in 2011, we obtained various indices that will be described in the following sections.

According to table 2, by considering the central relative risk, attributable proportion of cardiovascular disease mortality was 5.61% in 2011, which showed a 6.27% reduction in contrast with 2010.[16]

Attributable proportions, in the conditions of the estimation with the lower and upper relative risks, were 3.58 and 11.80%, respectively. By considering a baseline incidence equal to 497 per 100,000 people for cardiovascular diseases, the accumulative number of mortality due to such diseases was 237 people, showing a reduction of 261 people in contrast with 2010.[16] The maximum number of exposure to PM_{10} and mortality due to cardiovascular diseases were observed in the concentration range of 50-60 μgm^{-3}. The corresponding values estimated for mortality due to respiratory tract diseases are presented in table 3. The relative risk indices, attributable proportion, and number of cases of outpatient treatment due to both cardiovascular and respiratory tract diseases were also estimated (Tables 4 and 5).

Indices of mortality due to cardiovascular and respiratory tract diseases attributed to PM_{10} in Kermanshah in 2011

Considering an annual average PM_{10} concentration of 89.54 μgm^{-3} and a population of 851405 people in 2011, and estimation of mortality rate due to cardiovascular and respiratory tract diseases attributed to PM_{10} exposure, we obtained the health impacts based on the number of deaths in every 100,000 people by the following equation:

$$(M_t/P_t) \times 100000$$

where M_t is mortality due to cardiovascular and respiratory tract diseases attributed to PM_{10} exposure, P_t is the total population, and the unit is mortality per 100,000 people.

For cardiovascular disease: 237/851405 = 27.83 deaths in every 100,000 people

The results obtained from the model show that the number of cardiovascular mortality and outpatient cases attributed to PM_{10} in the air of Kermanshah for central or average relative risk were 237 and 233, respectively, in 2011.For respiratory tract disease: 46/851405 = 5.40 deaths in every 100,000 people

The values obtained from the model show that the number of respiratory tract diseases mortality and outpatient cases with respiratory problems attributed to PM_{10} in the air of Kermanshah for central relative risk were 46 and 602, respectively, in 2011.Figure 2 illustrates a steady increase in the mortality rate due to cardiovascular diseases associated with a PM_{10} concentration of 50-100 μgm^{-3}, whereas it shows a steep increase in the concentrations of higher than 350 μgm^{-3}. Indeed, figure 2 shows that 80% of the deaths due to cardiovascular diseases occurred on days with concentrations of less than 170 μgm^{-3}. With every 10 μgm^{-3} increment in the concentration of suspended particles, the risk of deaths due to cardiovascular diseases increased by 0.8%.

According to table 3, and based on the calculated relative risk and the results from figure 3, the accumulative number of deaths due to respiratory tract problems attributed to PM_{10} was estimated to be 46 individuals. This rate, in comparison with 2010, shows a decrease in mortality rate of 48 individuals.[16] Moreover, 80% of such deaths occurred on the days with PM_{10} concentrations of less than 170 μgm^{-3}. The steep phase of the curve in figure 3, corresponding with RR = 1.022, represents the maximum mortality rate (6 people) in the range of 50-60 μgm^{-3}. As can be seen, the slope of the upper and lower curves in the figure is steep in this range. The slight slope in the concentration range of 10-20 μgm^{-3} represents the minimum number of deaths due to respiratory tract problems. Every 10 μgm^{-3} increase in the concentration of suspended particles led to a 1.2% increase in the risk of death due to respiratory tract problems. Figure 3 illustrates a steady increase in mortality due to respiratory tract problems associated with a PM_{10} concentration of 50-100 μgm^{-3}, but it shows a steep increase in the concentrations of higher than 350 μgm^{-3}.

Table 4. The estimation of relative risk indices, attributable proportion, and number of cases of cardiovascular diseases attributed to PM10 (outpatient treatment) (BI = 436) in Kermanshah in 2011

Estimation	Epidemiological indices		
	Relative risk (high)	Attributable proportion (%)	Number of cases
Lower	1.006	4.2701	158.4
Average	1.009	6.2712	232.7
Upper	1.013	8.8128	327.0

Table 5. The estimation of relative risk indices, attributable proportion, and number of cases of respiratory tract diseases attributed to PM10 (outpatient treatment) (BI = 1260) in Kermanshah in 2011

Estimation	Epidemiological indices		
	Relative risk (high)	Attributable proportion (%)	Number of cases
Lower	1.0048	3.4455	369.4
Central	1.008	5.6135	601.9
Upper	1.0112	7.6864	824.2

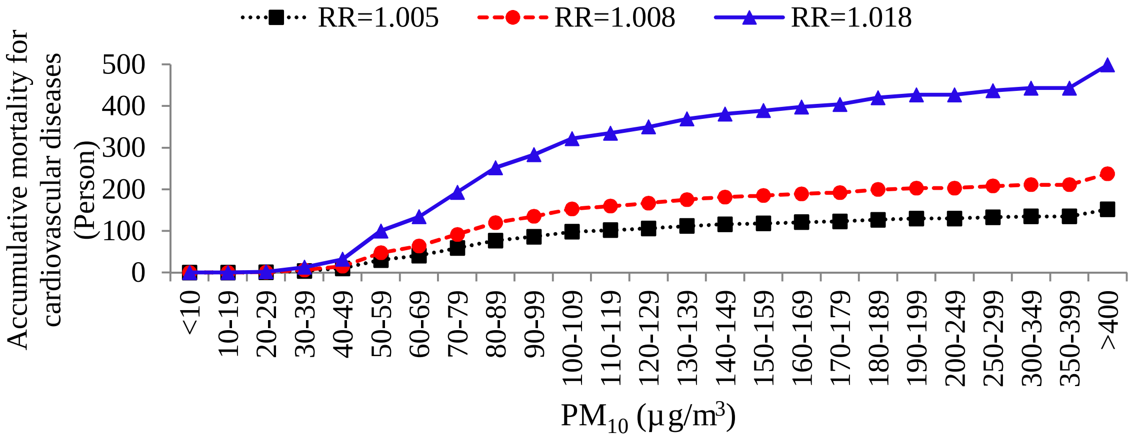

Figure 2. Accumulative mortality due to cardiovascular diseases attributed to PM_{10} based on PM_{10} concentration in Kermanshah in 2011

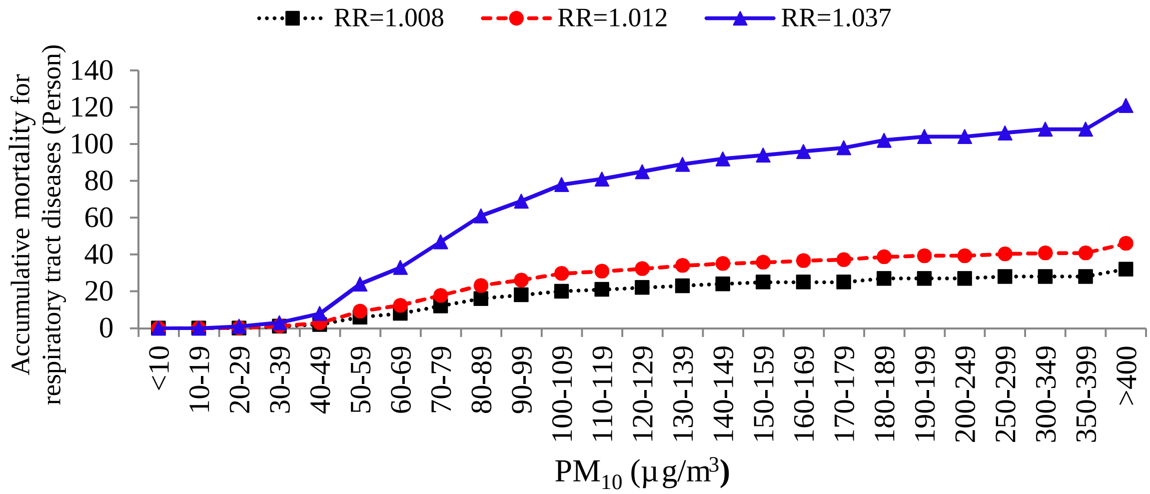

Figure 3. Accumulative mortality due to respiratory tract diseases attributed to PM10 based on PM10 concentration in Kermanshah in 2011

Some studies have utilized the AirQ model to estimate the health effects of particulate matter. For example, Tominz et al. used the AirQ model to estimate the health impacts of PM_{10} in Trieste, Italy, in 2005.[17] The authors reported that 1.8% of natural deaths, 2.2% of cardiovascular deaths, and 2.5% of respiratory deaths were attributable to PM_{10} concentrations of higher than 20 μgm^{-3}. In 2009, Goudarzi used the AirQ model to estimate the health impacts of PM_{10} in Tehran, Iran.[18] The results of the study showed that about 4% of the total number of cardiovascular and respiratory tract diseases was attributed to a PM_{10} concentration of higher than 20 μgm^{-3}. In another study, Yavari et al. demonstrated that about 13% of the total number of cardiovascular and respiratory tract diseases was attributed to a PM_{10} concentration of higher than 20 μgm^{-3}.[19] Ostro et al. analyzed the relationship between PM_{10} and daily mortality rate between 1989 and 1991, and reported a strong association between mortality from either respiratory disease or cardiovascular disease and PM_{10}.[20] Based on a regression model of examining the air pollution in 10 cities of the United States, Schwartz has calculated that the relative risk for adults older than 65 years would be 2% for each 10 µgm[3] increase in PM_{10}.[21]

Indices of cardiovascular and respiratory tract diseases mortalities for outpatient treatment due to PM_{10} in Kermanshah in 2011

According to the results of table 4 and figure 4, accumulative number of cardiovascular disease cases was 233, based on the estimated average relative risk (RR = 1.009) and baseline incidence rate of 436 in 10^5 people. This showed a reduction of 251 people in comparison with 2010. Approximately, 80% of the cases occurred on the days when PM_{10} concentration was higher than 170 μgm^{-3}. The accumulative numbers of such health impacts in the lower (RR = 1.006) and upper (RR = 1.013) relative risks were 158 and 327 individuals, respectively. Every 10 μgm^{-3} increment in the concentration of suspended particles resulted in a 0.9% increase in the risk of cardiovascular diseases.

According to the results of table 5 and figure 5, the accumulative number of respiratory tract disease cases due to PM_{10} exposure, based on the estimated average relative risk (RR = 1.008) and baseline incidence of 1260 in 10^5 people, was 602. This showed a reduction of 660 people in comparison with 2010.[16] Approximately, 80% of the cases occurred on the days when PM_{10} concentration was higher than 170 μgm^{-3}. Thus, the number of referrals to the hospitals due to respiratory tract diseases attributed to exposure to PM_{10} comprised 5.61% of the total referrals. The accumulative numbers of such health impacts in the estimated lower (RR = 1.0048) and upper relative risk (RR = 1.0112) were 369 and 824 individuals, respectively. Every 10 μgm^{-3} increment in the concentration of the suspended particles resulted in a 0.8% increase in the risk of respiratory tract diseases. Figures 4 and 5, respectively, illustrate steady increases in the number of outpatients due to cardiovascular and respiratory tract diseases associated with PM_{10} concentrations of 50-100 μgm^{-3}, but showed steep increases in the concentrations of higher than 350 μgm^{-3}.

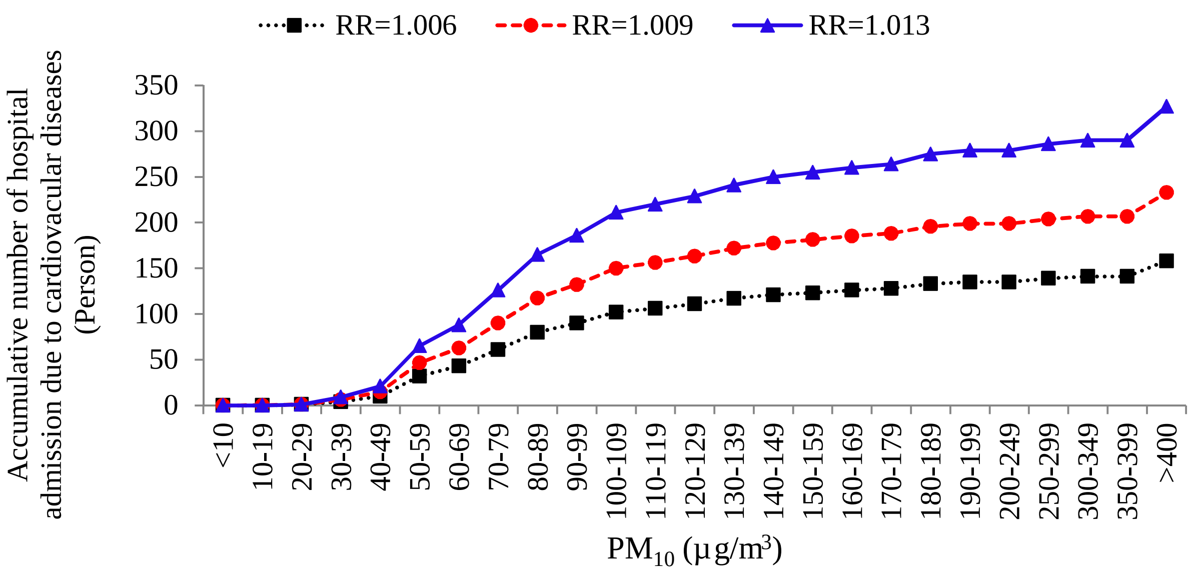

Figure 4. Accumulative number of hospital admission due to cardiovascular diseases attributed to PM10 based on PM10 concentration in Kermanshah in 2011

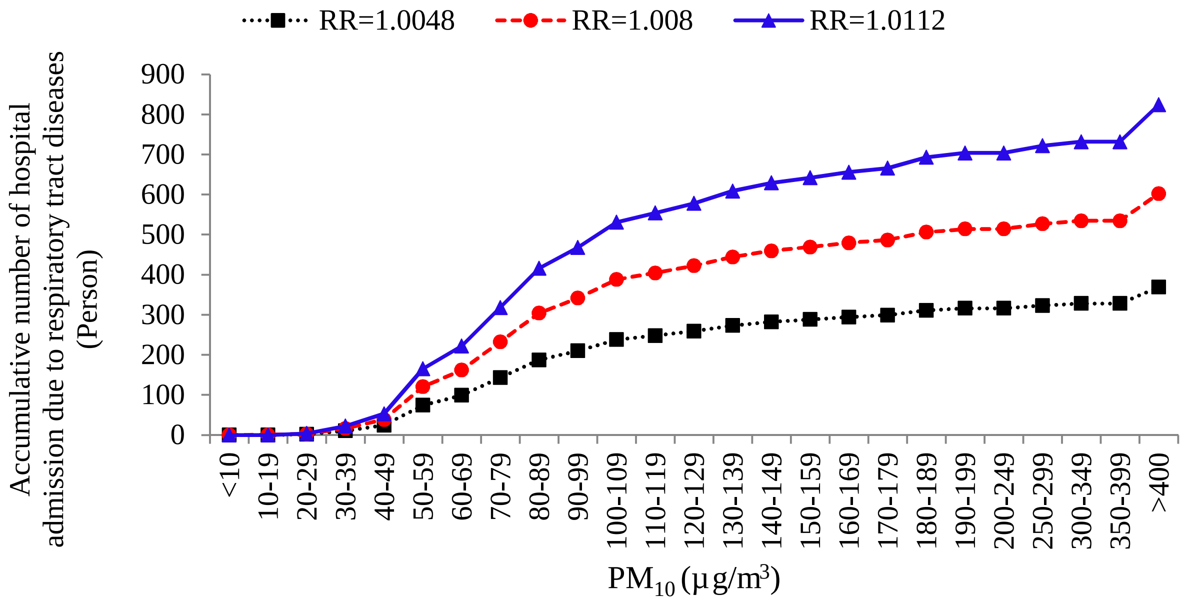

Figure 5. Accumulative number of hospital admission due to respiratory tract diseases attributed to PM10 based on PM10 concentration in Kermanshah in 2011

Conclusion

The average concentration of PM_{10} during the study period was 89.54 μgm-3, with the maximum concentration of 1809 μgm-3 in the summer. The maximum and minimum concentrations were observed for Ziba Park and Ostadnari stations, respectively. The low number of morbidity and mortality cases due to suspended particles in Kermanshah in 2011, in comparison with 2010, was due to the lower average concentration of PM_{10} or more days with lower concentration in the air. This means that individuals were exposed to a PM_{10} concentration of 200-250 μgm-3 for a longer time in terms of days, compared with 2010. Moreover, the concentration of PM_{10} did not reach lower than 30 μgm-3 on any day. However, the individuals were exposure to a PM_{10} concentration of 50-60 μgm-3 for a longer time, compared with 2010.

Conflict of Interests

Authors have no conflict of interests.

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