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# Health impact assessment of particulate matter in Sanandaj, Kurdistan, Iran

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Original Article

## Abstract

Air pollution is a major environmental issue in all regions of the world. We aimed to assess the health impacts of particulate matter with an aerodynamic diameter < 10 µm ($PM_{10}$) in Sanandaj, Kurdistan, Iran. The air pollution data were obtained from Sanandaj Department of Environment Protection. The annual mortality and morbidity, including cardiovascular and respiratory diseases attributable to $PM_{10}$ exposure were estimated using AirQ model, which is the proposed method for health impact assessment of air pollution by World Health Organization. The annual, winter, and summer averages of $PM_{10}$ in 2013 were 81.5, 64.7, and 98.3 µg/m$^3$, respectively. The total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases, respectively, were estimated 228, 120, 23, 118, and 305 cases. Approximately 11.7% of total mortality was associated with concentrations more than 20 µg/m$^3$. This study was the first attempt to assess the health impacts of air pollution in Sanandaj, Kurdistan, Iran. In summary, we found increased mortality and morbidity attributable to $PM_{10}$ exposure.

**KEYWORDS:** Air Pollution, AirQ Model, Health Impact Assessment, Morbidity, Mortality, $PM_{10}$

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## Introduction

Air pollution is a major environmental issue in all regions of the world.[1,2] Foundational epidemiologic studies have found a variety of chronic and acute health effects attributable to ambient air pollution.[3,4] These include hospitalizations, respiratory, and cardiovascular diseases.[5-12] The World Health Organization (WHO) estimated that the annual global burden of these health outcomes is roughly 865,000 premature deaths.[3] Furthermore, almost 150,000 lost lives in 2003 were attributed to ambient air pollution exposure in South Asia.[9]

One of the air pollutants that can penetrate deep into the human lung is particulate matter with aerodynamic diameters < 10 µm ($PM_{10}$). The health impacts of $PM_{10}$, such as asthma, bronchitis, impaired lung function and cardiopulmonary diseases are well-recognized.[13-16]

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In addition, many studies reported that short- and long-term exposure to $PM_{10}$ can lead to elevated mortality and morbidity risks.[6,17-21]

Sanandaj is the capital city of Kurdistan province in North West of Iran. In recent years, the annual mean $PM_{10}$ concentrations increased dramatically and there are many public concerns regarding this issue. Therefore, in this study, the authors aimed to assess the health impacts attributable to $PM_{10}$ exposure in Sanandaj, Iran.

## Materials and Methods

Sanandaj is the capital city of Kurdistan Province in North West of Iran. Based on the latest census report, the population is about 450,000 persons.[22] Meanwhile, it is located in the longitude and latitude of 47°00′ E and 35°32′ N and the altitude is about 1450-1538 m above sea level. The city is developing and non-industrialized (Figure 1).

The complete mean daily $PM_{10}$ data from January 01, 2013 to January 01, 2014 were obtained from Sanandaj Department of Environment Protection. The data were for Azadi square monitoring station, which is a traffic station (Figure 1).

AirQ 2.2.3 software and its used approach has been proposed by WHO to estimate the impacts of short-term exposure to air pollutants on the health of the population. It has been developed to estimate the health impacts of exposure to specific air pollutants on a resident population in a certain area and period. In this software, health impact assessment of air pollutants is standing on the calculation of attributable proportion (AP) in which AP is the 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. The AP can be easily calculated with the following formula:[21,23,24]

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

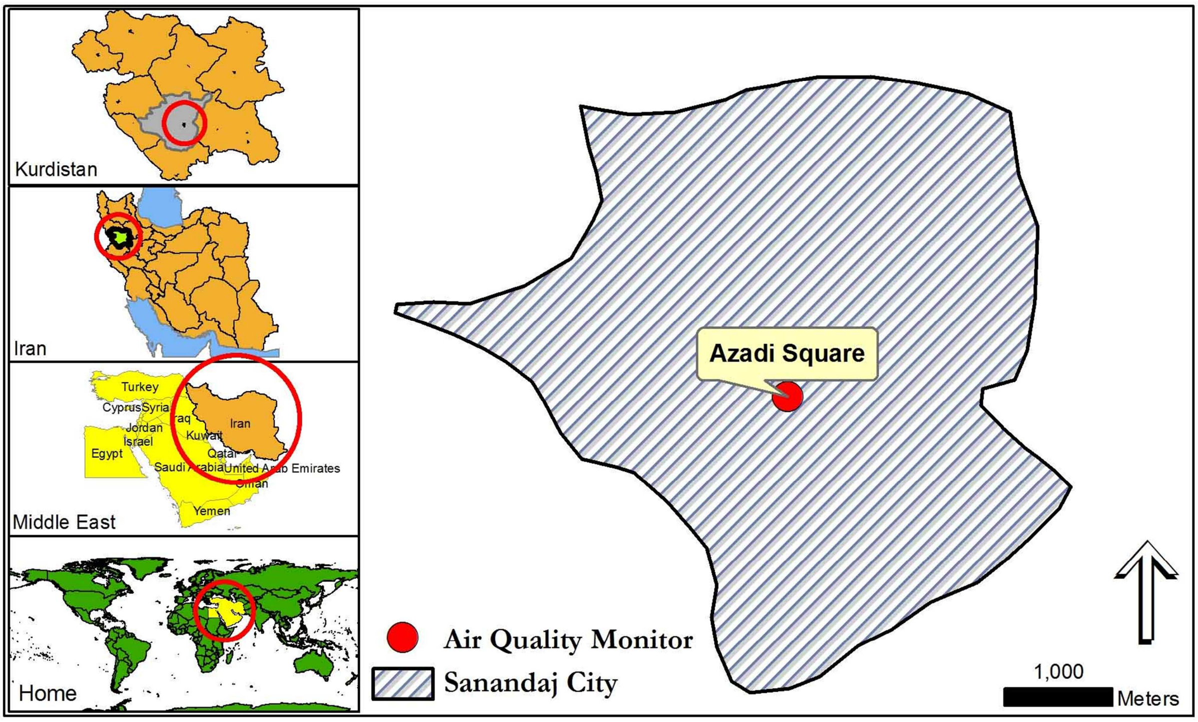


**Figure 1. This study area of Sanandaj, Iran, and location of the air quality monitoring station in 2013**

where RR denotes the relative risk for a given health endpoint, in category "c" of exposure, obtained from the concentration–response functions derived from wide literature (i.e., current existent epidemiological studies) and $P(c)$ denotes the proportion of the population in category "c" of exposure.

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:

$$\text{IE} = I \times \text{AP} \quad (2)$$

where IE denotes the rate of the health outcome attributable to the exposure, and $I$ denotes the baseline frequency of the health endpoint in the population.

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

$$\text{NE} = \text{IE} \times N \quad (3)$$

where NE denotes the number of cases attributed to the exposure and $N$ denotes the size of the population investigated.[21,23,24]

In this research, mean daily $PM_{10}$ data and exposed population were entered to the software for the period of January 2013 to January 2014. Afterwards, number of cases for total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases were calculated using relative risk and baseline incidence of WHO.[25]

## Results and Discussion

This paper is a case study, which assesses the effects of $PM_{10}$ on human health for people living in Sanandaj using a method developed by WHO. Figure 2 shows a summary of $PM_{10}$ concentrations measured in Azadi Square Station in 2013. The annual average $PM_{10}$ was 81.5 µg/m³, which is two-fold of the European Union standard and much higher than WHO air quality guideline (20 µg/m³). The highest $PM_{10}$ concentration with a maximum value of 666.9 µg/m³ was measured during summer.

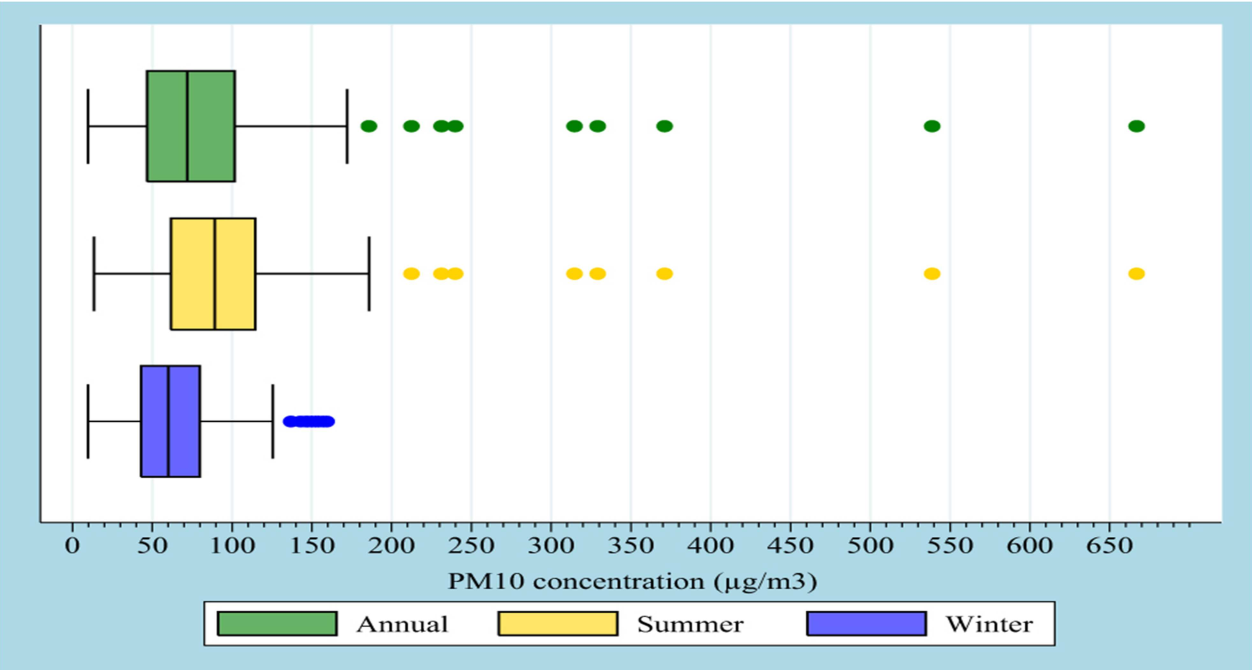


**Figure 2. Descriptive statistics of measured particulate matter with aerodynamic diameters <10 µm concentrations in Sanandaj, Iran, in 2013**

Figure 3 shows the percentage of time that people were exposed to $PM_{10}$ concentrations. These data are used to estimate the short-term health effects. The highest percentage of person-days was associated with 40-49 μg/m³ of $PM_{10}$, which shows that maximum exposure days to $PM_{10}$ were at these concentration ranges. In addition, this diagram demonstrates that with the increase in $PM_{10}$ concentration the number of exposure days reduces.

The excess cases and estimated AP to $PM_{10}$ for total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases are shown in table 1.

Figure 4 shows percentage of the cases related to aforementioned effects at different $PM_{10}$ concentrations. Although a higher percentage of person-days was associated with 40-49 μg/m³ of $PM_{10}$ (Figure 3), percentage of the cases related to health end points is relatively low; however, its maximum was occurred at 70-79 μg/m³ (Figure 4).

Fifty-one percent of short-term effects were happened at the time of concentrations not

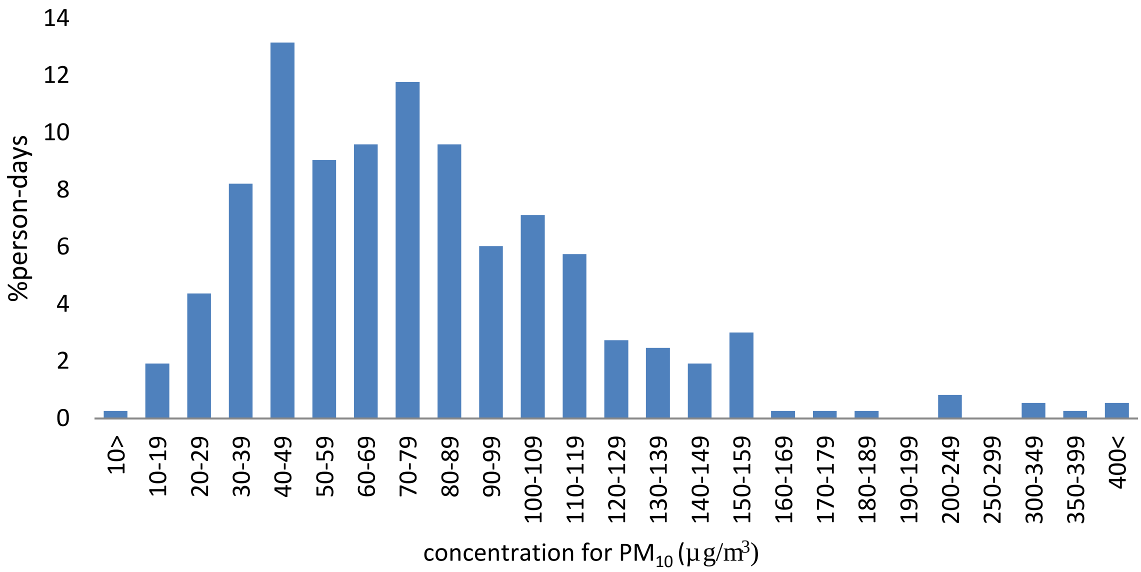


**Figure 3. Percentage of days on which people in Sanandaj are exposed to different concentrations of particulate matter with aerodynamic diameters <10 μm**

**Table 1. Baseline incidence, relative risk, estimated attributable proportion, and number of annual excess cases due to short-term exposure to particulate matter with aerodynamic diameters <10 μm above 10 μg/m³**

| Health endpoints | BI* | RR | Attributable proportion in percent (uncertainty range)** | Number of excess cases (uncertainty range)** |
|---|---|---|---|---|
| Total mortality | 1013 | 1.0074 (1.0062-1.0086) | 5.0 (4.2-5.8) | 228 (193-263) |
| Cardiovascular mortality | 497 | 1.0080 (1.0050-1.0180) | 5.4 (3.4-11.4) | 120 (77-254) |
| Respiratory mortality | 66 | 1.0120 (1.0080-1.0370) | 7.9 (5.4-20.9) | 23 (16-62) |
| Hospital admissions due to cardiovascular disease | 436 | 1.0090 (1.0060-1.0130) | 6.0 (4.1-8.5) | 118 (80-166) |
| Hospital admissions due to respiratory disease | 1260 | 1.0080 (1.0048-1.0112) | 5.4 (3.3-7.4) | 305 (187-419) |

* Crude rate per 100,000 inhabitants; ** Obtained using the lower and upper RR values; BI: Baseline incidence; RR: Relative risk

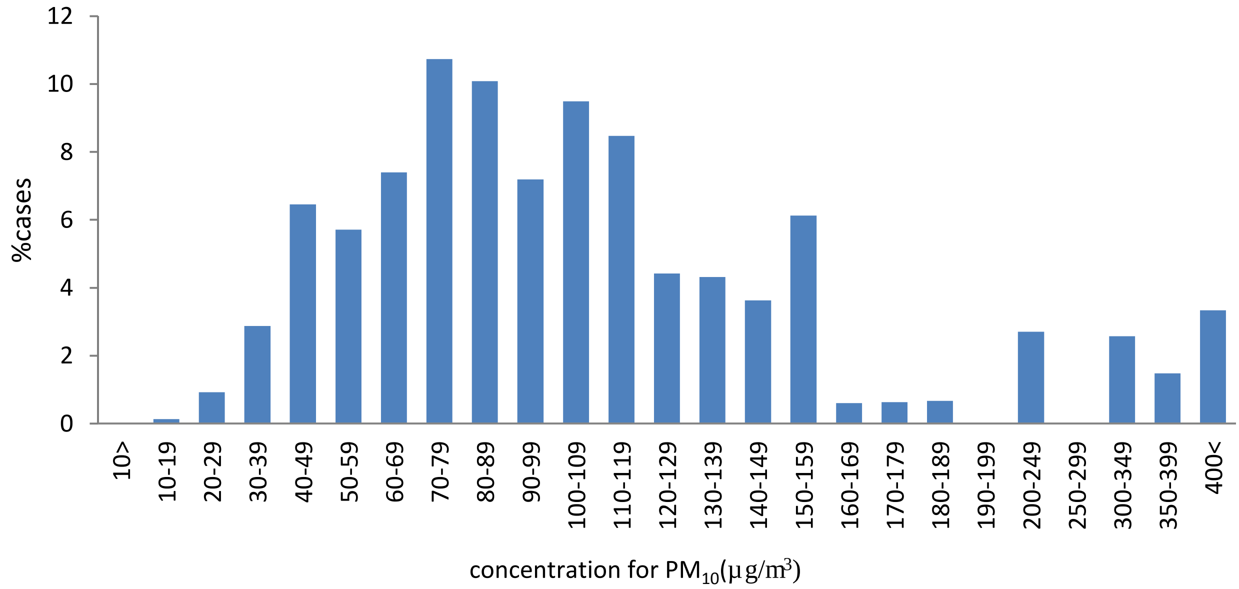


**Figure 4. Percentage of a number of cases that are exposed to different concentrations of particulate matter with aerodynamic diameters <10 μm**

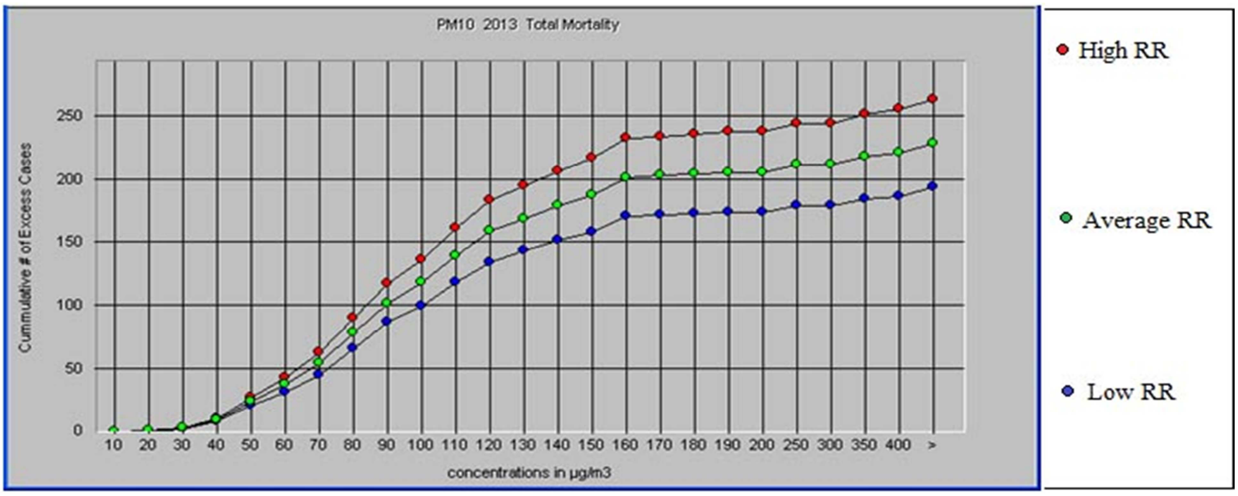


**Figure 5. Estimated cumulative number of total mortality cases attributable to particulate matter with aerodynamic diameters <10 μm comparing concentration intervals by means of the model (Sanandaj, Iran, 2013)**
RR: Relative risk

exceeding 99 μg/m³. In Sanandaj, with a population of 450,000, the total non-accidental mortalities were 1936 cases in 2013. Figure 5 also shows that the cumulative number of total mortalities were 228; therefore, based on this model 11.7% of them were related to concentrations over 20 μg/m³ of $PM_{10}$.

Another study conducted by Goudarzi et al. in 2008, showed that 4% of the total mortalities in Tehran were related to concentrations above 20 μg/m³.[26] In 2005, Tominz et al. utilized AirQ model, in order to measure health effects of $PM_{10}$ in Trieste, Spain. They concluded that 1.8% of cardiovascular and 2.5% of respiratory mortalities were related to concentrations above 20 μg/m³.[27] A comparison between the results of the present study and other studies conducted in Tehran and Trieste shows that higher rate of mortality in Sanandaj can be related to higher mean concentration of $PM_{10}$ or extent of days with high $PM_{10}$ concentration in Sanandaj. In another studies on 29 European cities, 20 American cities, and some Asian countries, it was revealed that adverse health effects of short-term exposure to $PM_{10}$ in cities of different developing and developed countries are identical and mortality rate increases by 0.5% after $PM_{10}$ daily increase of 10 µg/m$^3$.[28-31]

Cumulative cases of different health end points attributed to $PM_{10}$ concentrations are illustrated in figures 6-9. Figures showed three ranges of relative risk based on model's default, which were considered for assessing health effects of $PM_{10}$. The total number of cases for total mortality, cardiovascular mortality, respiratory mortality, hospital admissions due to cardiovascular diseases, and hospital admissions due to respiratory diseases in relative average risk were 120, 23, 118, and 305 persons, respectively. Seventy-three percent of them were related to the $PM_{10}$ concentrations lower than 129 µg/m$^3$.

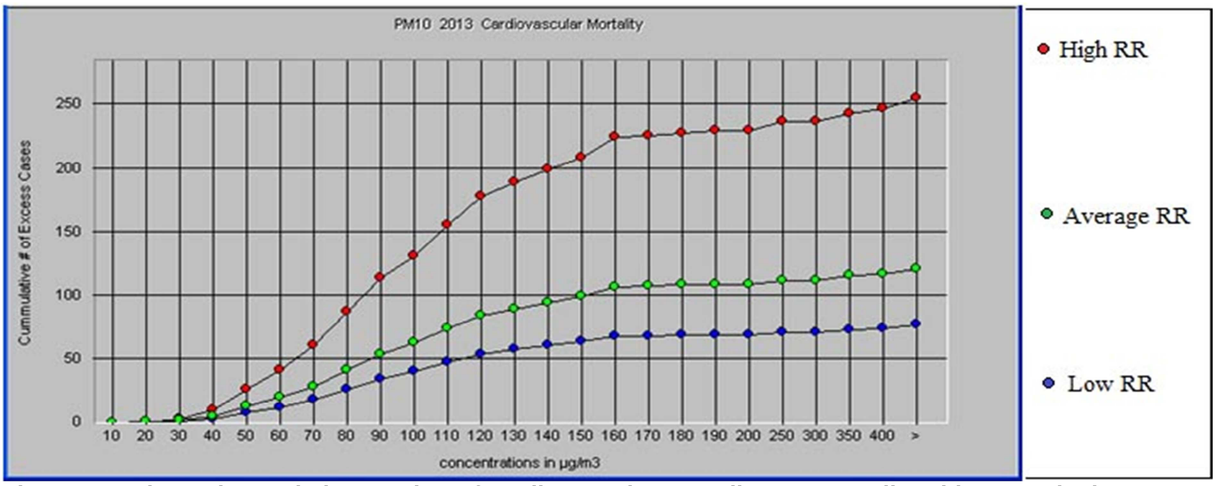


**Figure 6. Estimated cumulative number of cardiovascular mortality cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013)**
RR: Relative risk

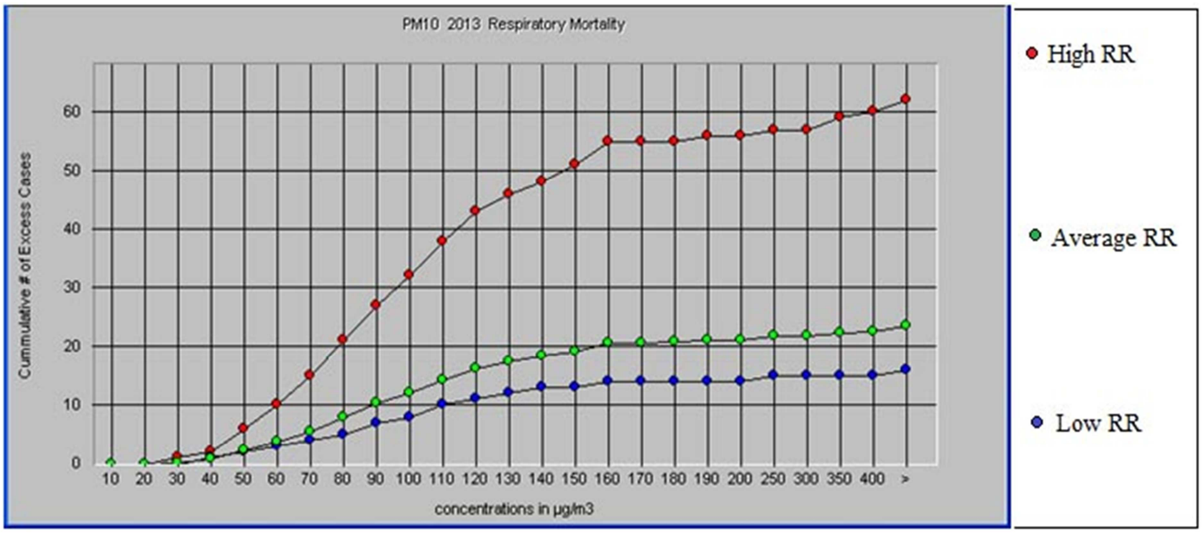


**Figure 7. Estimated cumulative number of respiratory mortality cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013)**
RR: Relative risk

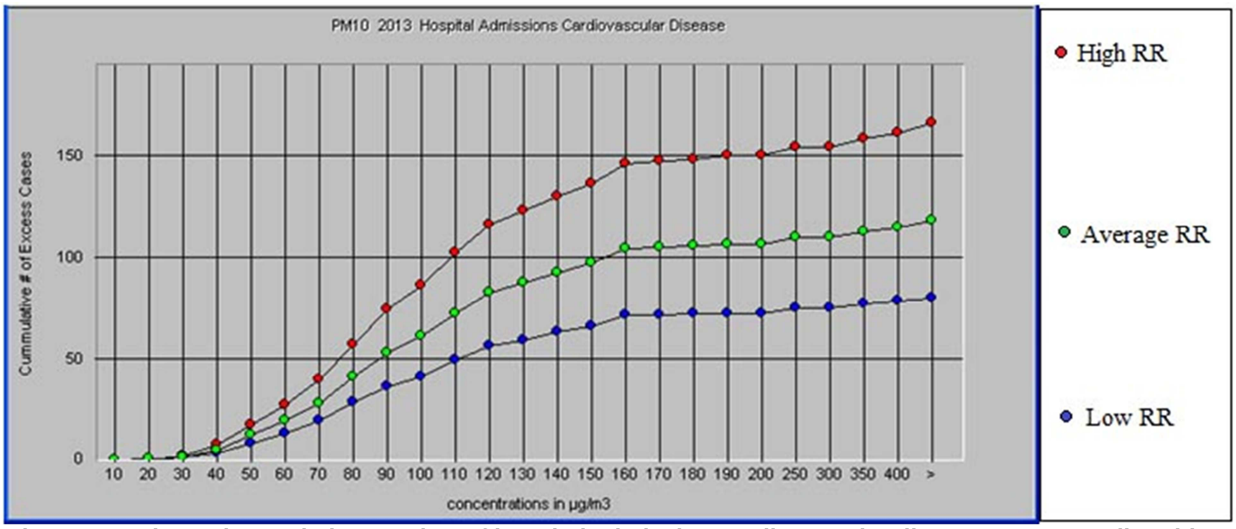


**Figure 8. Estimated cumulative number of hospital admission cardiovascular diseases cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013**)

RR: Relative risk

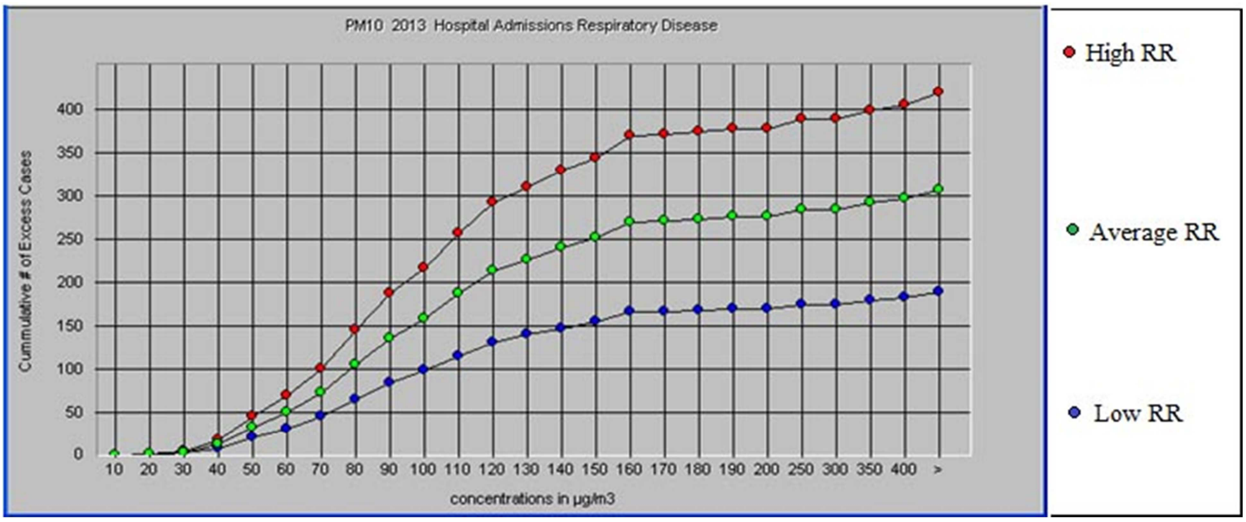


**Figure 9. Estimated cumulative number of hospital admission respiratory diseases cases attributable to particulate matter with aerodynamic diameters <10 µm comparing concentration intervals (Sanandaj, Iran, 2013)**

RR: Relative risk

## Conclusion

The objective of this study was to measure the adverse health effects of $PM_{10}$ on the Sanandaj people using AirQ software, which shows the effects of pollutants on residents of a certain area. The results of the present study are in line with other studies and reveal that 11.7% of mortality rates in Sanandaj are related to concentrations of $PM_{10}$ above 20 µg/m$^3$. A comparison between the results of the present study and other studies conducted in Tehran and Trieste shows that higher mortality rate in Sanandaj is due to higher average $PM_{10}$ or higher number of exposure days. Consequently, the health impact estimated for the city of Sanandaj underscores the need for urgent action to reduce the health burden of $PM_{10}$.

## Conflict of Interests

Authors have no conflict of interests.


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