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Evaluation of health effects of pollutant PM10 on air of Isfahan City, Iran

Sima Sabzalipour[1*], Somayeh Mansouri Moghadam[2], Mehdi Nourzadeh Haddad[3] and Elahe Zallaghi[4]

[1]*Assistant Professor, Department of Environment, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran*
[2]*Ph.D Student of Environment Pollution, Islamic Azad University, Ahvaz, Iran*
[3]*Assistant Professor, Department of Agriculture Payame Noor University*
[4]*Ph.D Student of Environment Pollution, Lecturer at Applied Science Training Center, Ahvaz Municipality, Ahvaz, Iran*

ABSTRACT

According to the results of researches, there is a close relationship between daily changes in concentrations of particulate matters in fresh air and death caused by cardiovascular diseases and early physiological reactions. The air pollution crisis in some cities of Iran such as Isfahan, the second megacity in Iran, has been a serious event during recent years. The specific geographical situation of Isfahan such as locating in a pit with aggregation of pollutant matters in air has changed this city to one of the most polluted cities in Iran in terms of air pollutants. Therefore, the health of Isfahan citizens is at risk. the purpose of this study is to estimate heart attacks and respiratory deaths attributed to pollutant PM10 in Isfahan, 2013. This paper comprises three stages. The concentration of pollutant PM10 was measured at the first stage using GRIMM devices in four research stations in 2013. Epidemiological indicators were estimated at second stage and Kolmogorov Smirnov Test was used to evaluate normal distribution of data though SPSS and EXCEL software (to illustrate charts) in third stage. the examination of monthly changes in concentration of particulate matters in air of Isfahan City, 2013 indicated that the most concentration was equal to 210/89 micrograms per cubic meter during December in Ahmad Abad station. On the other hand, the changes in quarterly mean of particulate matters of air in Isfahan, 2013 indicated that the most rate of concentration of matters has been in fall while it was more than standard level in Ahmad Abad station and the lowest concentration has been in winter. According to the other results, the number of heart attacks and respiratory deaths attributed to pollutant PM10 existed in air of Isfahan city under the central relative risk has been respectively equal to 598 and 115 members during 2013. The rate of attributing point for heart diseases has been equal to 7/5% in 2013 considering central relative risk. Considering the occurrence base equal to 497 members out per 1000 persons for cardiovascular mortality, the cumulative mortality rate of this event has been equal to 598 members. The more numbers of daily contacts with PM10 in concentration interval between 100 and 110 microgram/cubic meter and the largest number of cardiovascular mortalities (90 members) has been related to this concentration interval. Cumulative number of respiratory death caused by PM10 was estimated to 115 persons in 2013. 56% of this death was occurred in days with concentration lower than 120 microgram/cubic meter. With per 10 microgram/cubic meter increase in particulate maters, there will be 0/8% and 1/2% increase in heart (cardiac) death and respiratory deaths.

Keywords: Isfahan City, cardiac death, respiratory disease, epidemiology index

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INTRODUCTION

Particulate matters as a branch of pollutants have many diversities and complications so that their size and chemical composition such as their concentrations in air are important features of these matters. Two important parameters of size and chemical composition have determining role in health risk of these compounds (1). Usually, transferred

particles by air have a size within the range of 0/001-500 micrometer that a big part of it consists of particulates matters within the range of 0/1-10 micrometer (2). Almost, 40% of particles with size of 1-2 micron remain in bronchi and air sacs. Particles with 0/25-1 micron size less remain in respiratory system. Particles with less than 0/25 micron size more remain in respiratory system due to Brownian motion (3). On the other hand, every person would enter 6/6240 gram dust into lungs through average 10 hours activity and 17 times respiration per minute including average 0/0368 gram dust per cubic foot of respiratory air averagely at time of dust phenomenon (10houres) (4). Due to health importance of particulates, the average 24-hours concentration considered for particulates with diameter smaller than 10 microns is equal to 50 microgram per cubic meter that should not be more than this rate more than 35 times per year. According to standards of European Union until 2010, concentration of 50 microgram per cubic meter should not occur more than 7 times per year and concentration of these particulates should not be more than 20 microgram per cubic meter (5&6). In 2005, Annett Peters expressed the relationship between cardiovascular disease and particulate matters in air referring to epidemiological documents. According to the results of this study, there is a close relationship between daily changes in concentrations of fresh airs' particulate matters and mortality caused by cardiovascular diseases, hospital admissions, worsening of symptoms of cardiovascular diseases, and early physiological reactions (7). Swartz et al examined the air pollution in 10 cities of United Nations in several days and concluded that the relative risk of heart attack will be double among people older than 65 affected by air pollutants (that means about 2% per 10$\mu g/m^3$ increase in PM10) (8). Elena et al (2006) evaluated the effects of exposure to air pollutants especially PM_{10} and $PM_{2/5}$ on health in Ukraine that its results was estimated 46000 cases of death that 27000 cases was mortality caused by cardiorespiratory diseases and lung cancer (9). The air pollution crisis in some cities of Iran such as Isfahan has been a serious event during recent years; hence, the health of citizens of Isfahan is at risk. Aggravating factors of air pollution crisis in Isfahan include slight wind with lower 5 meter/second speed, deployment of high-pressure system with 1025-1031 HPa pressure, severe decline of temperature to 4° C below zero, existence of fog in morning hours. Temperature inversion in Isfahan was more than other industrial megacities of Iran in 2013 while Tehran has been the first pollutant city of Iran during December and January, but autumn rainfalls has been less in Iran during 2013. Pollution severity of Isfahan's air increases like Tehran in autumn and winter while this city had been less polluted in past years because of existence of Zayanderud River except low-water seasons of Zayanderud. It is about 2 or 3 years that Zayanderud is without water 8-9 months per year changing to a waterless desert. Such drought of Zayanderud is the end of natural freshness of City. Climate conditions of Isfahan and geographical location of industries of this city cause northwest winds directing all pollutants to central core of city. Therefore, Isfahan is the second polluted megacity after Tehran in Iran. Deployment of anticyclone patterns with central pressure more than 1020 HPa on Isfahan weather during cold period of year has more effect on increased pollution of air compared to other atmospheric systems. Atmospheric conditions sometimes lead to formation of a high-pressure local system so that the air pollution is more intensified reaching to a critical limit in such conditions. Isfahan is the biggest industrial Province of Iran because of having 10/000 industrial units that 90% of them are active. About 15% of value added in industry sector of Iran is gained in Isfahan because of existence of 68 industrial areas and towns in Isfahan employing more than 250/000 members in industry sector. On the other hand, 70% of produced steel of Iran, 25% of value added in textile industry, and the biggest petrochemical and power plan industries are related to Isfahan Province. Air pollution of this province is not bearable and even the growth rate of some diseases in Isfahan is higher than the average rate in country. The specific geographical situation of Isfahan such as locating in a pit with aggregation of pollutant matters in air has changed this city to one of the most polluted cities in Iran in terms of air pollutants. The weather of Isfahan consists of most pollutants during winter. The rate of these pollutants is at a high level in summer and fall, but the weather is healthier in spring. Study of synoptic situation of air indicates that a high-pressure center is on the top of earth surface during winter days in Isfahan that this high-pressure center is the result of deployment and reinforcement of high-pressure center of Siberia and expansion of its effects on Iran. On the other hand, there is a high-altitude center within the middle layer of the atmosphere. This position would lead to temperature inversions and air stability. When the high-pressure center of Siberia reaches into Iran especially central areas of Iran, the level of pollutants will be strongly increased seriously harming inhabitants. This study has been conducted to examine situation of particulate matters in four research stations during 2013 as well as estimation of cardiorespiratory deaths in Isfahan in order to obtain required information for Urban Management Healthcare Deputy to be able implement practical solutions to fight against destructive effects of air pollution before occurrence of this phenomenon (13). There are different solutions to control emission of gas pollutants in atmosphere coping with air pollution. Some of these solutions are as follows: establishment of meteorological stations and air pollution in the city, establishment monitoring equipment and controlling exited gases from chimney of industries in West and South West of City, replacement of Clean Fuels, improvement of combustion conditions in equipment, industries and cars, proper management of energy consumption, development of public transportation, improvement of car production technology, lack of development of industries in west of city, controlling the height of urban structures in south of city and hillside of Safeh, design of main streets of the city in western-eastern direction, development of urban green space in some areas of city.

MATERIALS AND METHODS

2-Research method

2-1-Introduction of research area (Isfahan City)

Isfahan city is located about 424 kilometres south of Tehran. Isfahan continues to Chaharmahal Province in west mountain areas and to Karkas and Gharood Mountains in east. Plain are is created by alluviums of mountain streams and Zayanderud River. Having mild climate, Isfahan has relative regular seasons. Isfahan City with longitude of 51 degree, 39 minutes and 40 eastern second and Latitude of 32 degree, 38 minutes and 30 northern second and population about 1602110 members is the second megacity after Tehran in Iran.

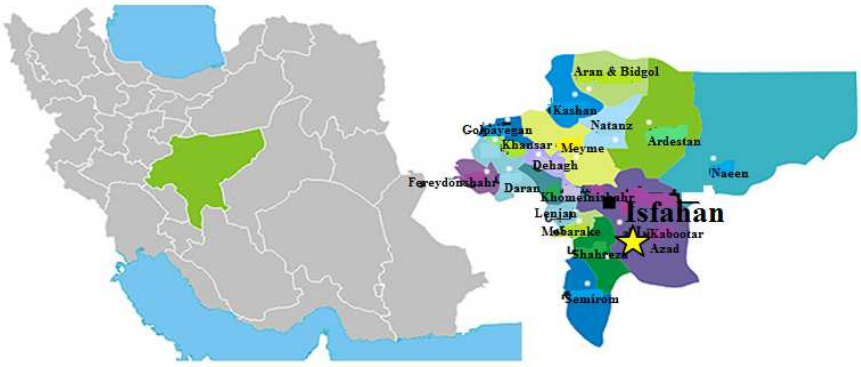

Diagram 1. A view of research area of Isfahan City

2-2-Determining the health effect rate based on the theory of risk ratio attributed to pollutant PM_{10} (estimation of epidemiological indicators)

This study has been conducted to estimate cardiorespiratory deaths attributed to pollutant PM_{10} in Isfahan based on use of epidemiological indicators. This paper includes three stages as follows:

First stage: sampling of pollutant PM_{10} in which, the concentration of PM_{10} was measured in four research stations including Valiasr, Ostandari, Azadi, and Ahmad Abad using GRIMM device for one year and parameters of temperature and pressure were red and recorded hourly through software of (WWW.MSN.COM).

Second stage: Estimation of epidemiological indicators: attribution point (AP) or attributed proportion is a part of health implication can be considered in relation with specific demographic exposing (with assumption of the possible relation between health implication and contact without the disturbing effect on this relationship) during a specific period. This point is calculable though following formula:

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

Where

RR(c): relative risk of health implication in group c or considered group

P(c): proportion of the population of group c or considered group

Relative risk of chosen health implication can be obtained using contact-response functions.

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

When the baseline incidence of health implication (I) in considered population is known, the attribution amount to contact of population (or numbers of cases per population unit) (IE) can be calculated as follows:

$$IE = I \times AP$$

This rate can be changed to number of estimated cases that are attributed to contact in a population with size of N:

$$N \times NE=IE$$

The user can use local statistics instead of determining baseline incidence of health implication. Therefore, incidence of health implication in population that is not exposure to contact (INE) can be estimated as follows:

$$INE=I-IE=1\times (1-AP)$$

In addition to all attributed cases, the distribution of attributed cases can be estimated based on intervals of pollutant concentration. If the relative risk at a specific level of pollutant concentration and incidence in non-exposed population are known, the extra incidence (I+ (c)) and number of extra cases (N+ (c)) in a contact group (c) will be calculable through following equation:

$$I+(c) = (RR(c-1))\ \ P(c) \times \ INE$$

All of the mentioned formulas are based on this assumption that the applied estimation in this analysis has been controlled in terms of all possible disturbers. Lower and upper bounds of estimation of attribution proportion and range of number of attributed options to expected exposure can be determined considering confidence intervals for estimation of relative risk in formula. Of course, non-certainty of effect (and range of estimated effects) is bigger in practice due to estimation errors of exposure and non-statistical non-certainties of concentration-response function.
Third stage: data analysis in which, Kolmogorov Smirnov Test was used to evaluate normal distribution of data though SPSS and EXCEL software (to illustrate charts).

3-Findings and Results

3-1-Pollution status of attributed weather to PM_{10} of Isfahan City in 2013

Study of changes in monthly mean of particulate matters in weather indicated that particulate matters in weather during 2013 was more than standard level compared to annual standard only in Ahmad Abad station. On the other hand, the most concentration of PM10 equal to 210/89 microgram per cubic meter was recorded in Ahmad Abad station. The lowest concentration of this pollutant was recorded in Ostandari station that was equal to 53/73 mg/m^3 during September.

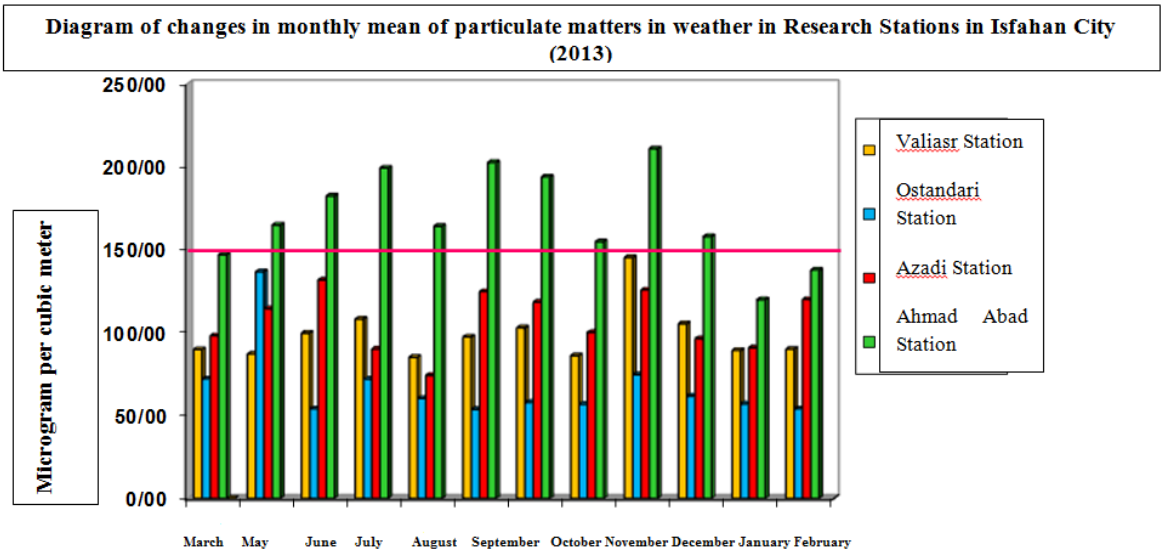

Diagram 1. Monthly changes in particulate matters in Isfahan City (2013)

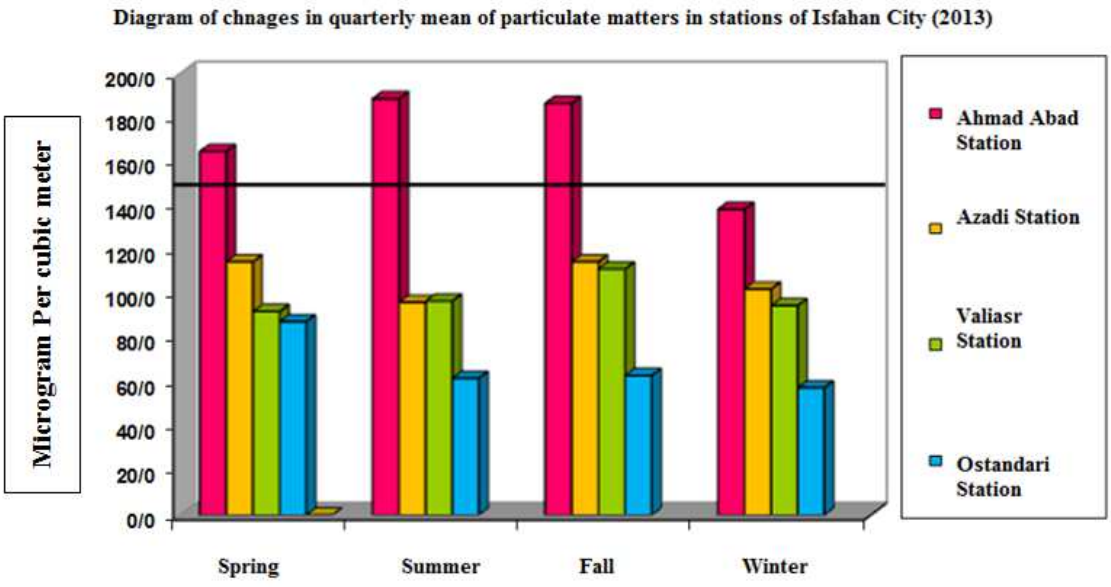

Diagram 2. Quarterly changes in particulate matters in Isfahan City (2013)

Examination of changes in quarterly mean of particulate matters in Isfahan during 2013 indicated that the most concentration of particles in fall was more than standard level in Ahmad Abad Station and the lowest concentration was in winter.

3-2-Tables of relevant data to epidemiological indicators of pollutant PM_{10} in Isfahan during 2013

Table 1. Estimation of indicators of relative risk, attribution proportion, and attributed cases to PM_{10} for cardiovascular death (BI=497) in Isfahan, 2013

Indicator / Estimation	relative risk (average)	Attribution proportion (%)	number of exposed persons (member)
low	1/005	4/8345	384/9
middle	1/008	7/5172	598/5
high	1/018	15/4609	1231

Table 1. Estimation of indicators of relative risk, attribution proportion, and attributed cases to PM_{10} for respiratory death (BI=66) in Isfahan, 2013

Indicator / Estimation	relative risk (average)	Attribution proportion (%)	number of exposed persons (member)
low	1/008	7/5172	79/5
middle	1/012	10/8673	114/9
high	1/037	27/32	288/9

The results indicated that all cases of cardiac and respiratory deaths attributed to pollutant PM_{10} in air of Isfahan City at the central relative risk during 2013 was respectively equal to 598 and 115 members.

3-3-Relevant diagrams to estimation of epidemiological indicators of pollutant PM_{10}

Diagrams have been illustrated based on cumulative number of cardiac and respiratory deaths within intervals of concentration of pollutant related to quantification discussion. There are three curves in each diagram that the middle curve is related to central relative risk, bottom curve is related to relative risk of 5% and the above curve is related to relative risk of 95%.

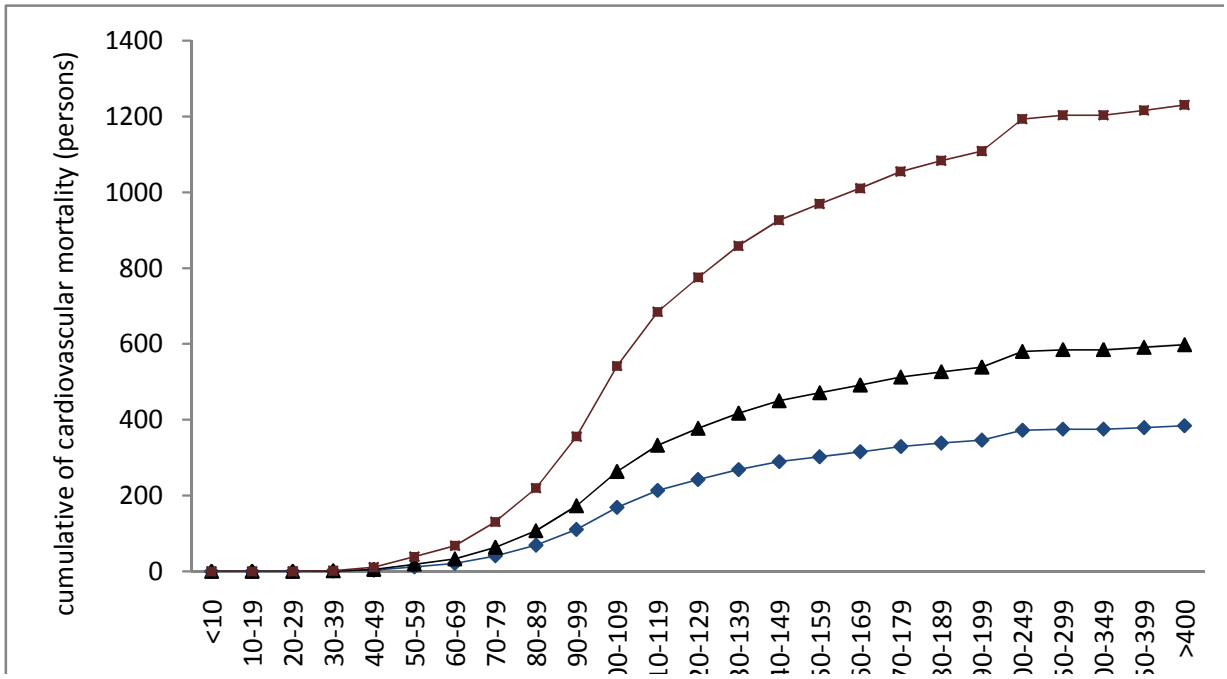

Diagram 3. Cases of cardiovascular death caused by PM_{10} within concentration intervals (Isfahan, 2013)

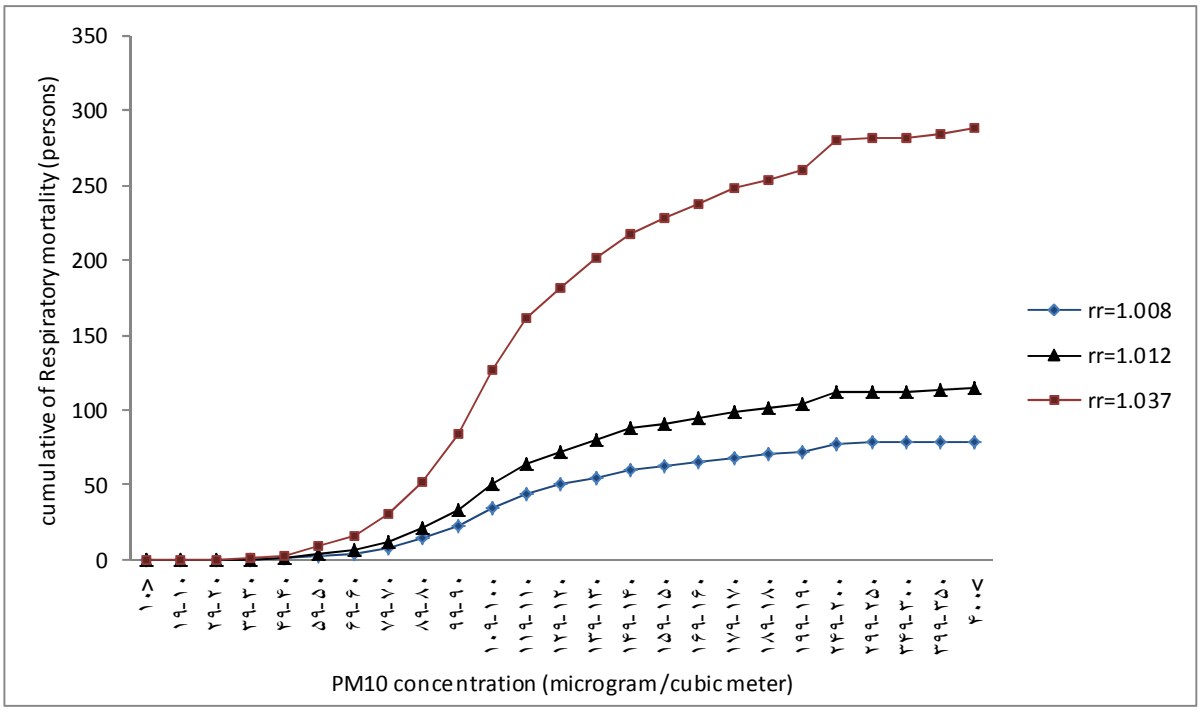

Diagram 4. Cases of respiratory death caused by PM_{10} within concentration intervals (Isfahan, 2013)

DISCUSSION AND CONCLUSION

Study of monthly changes in particulate matters in air of Isfahan in 2013 indicated that the most concentration of PM10 equal to 210/89 microgram per cubic meter was recorded in Ahmad Abad station in December. On the other hand, examination of changes in quarterly mean of particulate matters in Isfahan during 2013 indicated that the most concentration of particles in fall was more than standard level in Ahmad Abad Station and the lowest concentration was in winter.

4-1-Study of relative risk, attribution proportion, and baseline incidence attributed to PM_{10} in Isfahan during 2013

The obtained results of table 1 indicated that the amount of attribution proportion for cardiovascular deaths has been equal to 7/5% in 2013 considering central relative risk. The attribution proportion in situation of estimation with low relative risk and estimation with high relative risk was respectively equal to 4/8 and 15/4. Considering baseline incidence equal to 497 per 100 thousand members for cardiovascular death, cumulative number of death of this implication was equal to 598 members. The most number of contact days with PM_{10} has been within concentration interval between 100 and 110 microgram per cubic meter and the most number of cardiovascular mortalities (90 members) has been related to this concentration range. Diagram 3 indicates the fact that 56% of cardiovascular deaths were occurred in days with concentration less than 120 mg/m^3 and the danger of cardiac death was been increased equal to 0/8% with every 10 µg/m3 increase in concentration of particulate matters. The obtained results of table 2 indicated that the cumulative number of respiratory mortalities caused by PM_{10} was estimated to 115 members in 2013 in accordance with calculated relative risk and diagram 4. 56% of this death has occurred during days with less than 120 µg/m^3 concentration. The severe slope of relevant curve to rr =1/012 in diagram 4 indicates the most number of deaths (17 members) in this area (100-110 µg/m^3). It is obvious that slight decrease or lowest number of respiratory deaths is related to severe decrease in percent of member-day that this percent indicates low number of contact or exposure days with this concentration interval (10-30 µg/m^3). In other words, there was no day in Isfahan during 2013 with particles' concentration less than 30 microgram per cubic meter so that the risk of respiratory death increased equal to 1/2% with each 10 µg/m^3 increase in particulate maters. Comparison of results indicated that Tominz et al (2005) attributed 1/8% of total cardiovascular deaths and 2/5% of respiratory deaths to concentrations more than 20µg/m^3 of particulate matters (10). Goudarzi et al (2009) indicated that almost 4% of all cardiovascular and respiratory diseases were attributed to concentrations more than 20µg/m^3 (11). Mohammadi et al (2009) indicated that almost 13% of cardiovascular and respiratory diseases in Ahwaz are attributed to concentrations more than 20µg/m^3 (12). Zallaghi et al (2010) conducted a study in three research areas in Iran indicated that almost 12% of cardiovascular and 17% of respiratory diseases in Kermanshah are attributed to concentrations more than 30µg/m^3, 14% of cardiovascular and 19% of respiratory diseases in Booshehr are attributed to concentrations more than 20µg/m^3, and almost 19% of cardiovascular diseases and 25% of respiratory diseases in Ahwaz are attributed to concentrations more than 120µg/m^3 (13). Lower percent of attributed cardiovascular and respiratory deaths in Isfahan during 2013 compared to west and south west of Iran might be because of lower average of PM_{10} or even more days with less concentration of pollutants in Isfahan City, 2013.

Suggestions

Isfahan is the first industrial city of Iran in which, 10/000 industrial enterprises including refineries, power plants, steel, petrochemicals, Stone cutting, steel mill, plaster and brick kilns and oil factories are active. Each of these units has a considerable share in pollutants generating, of course these pollutants are separated from existence of old cars that are daily entering to motion cycle making the conditions of the city worse.

1-Plan of green space

1-1-planting seedlings in different areas of Isfahan Municipality, areas of barracks and military centers, around large factories such as refineries, cement, gypsum, steel and governmental centers.

1-2-the restricts under the control of Municipality of Isfahan that have desert tissue and structure should be more considered for plan of green space.

1-3-barracks that has large barren areas should be considered for dry farming species and species with low water consumption.

1-4-Some towns such as Barkhar, Shahin Shahr, Mobarake, Lenjan, and Isfahan are most polluted so they should be prior for implementation of green space plan.

1-5-planting some trees such as Haloxylon, Nitraria schoberi, Calligonum, Amyygdalus (Scoparia), Amygdalus (Amara) through dry farming and planting non-productive species such as Celtis australis, Robinia, Chinaberry, and Tamarix gallica for plan of urban green space.

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