Journal of Air Pollution and Health (Spring 2019); 4(2): 81-86

Original Article

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Applying EPA's instruction to calculate air quality index (AQI) in Tehran

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ARTICLE INFORMATION

Article Chronology:
Received 7 April 2019
Revised 16 May 2019
Accepted 17 June 2019
Published 29 June 2019

Keywords:

Particulate matter; Particle; Ozone; Nitrogen dioxide; AQHI

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ABSTRACT:

Introduction: This study aimed to calculate and evaluate air quality index (AQI) in Tehran according to the EPA's instruction, and evaluate the obtained values.

Materials and methods: The study period included three years of 2013, 2015, and 2017 within the six-year period of 2013-2017. The concentrations of six studied pollutants were acquired from Department of Environment (DE) and Air Quality Control Company of Tehran (AQCC). EPA's method was applied to calculate AQI values during the study period, selecting the highest AQI value among all of the pollutants and monitors.

Results: The three-year average of AQI was about 147. During all the three years, the air quality had never been in a "good" condition (AQI<50). About 92%, 91%, 87% of AQIs indicated the conditions unhealthy for sensitive groups (100<AQI<150) or unhealthy for all groups (150<AQI<200). $PM_{2.5}$ accounted for most of the AQI values in Tehran, followed by NO_2 and O_3. Evaluating the histogram of AQI values indicated a strange form of distribution, showing a decline in the 100-150 range and a sudden increase just after AQIs higher than 150.

Conclusion: This study indicated that governmental organizations should follow EPA's instruction for AQI calculations to avoid underestimation of air pollution, and broadcast accurate and reliable AQIs to public. To determine the reason for the abnormal distribution of AQI, further studies with longer study periods are required.

Introduction

World Health Organization (WHO) has reported that 4.2 million deaths every year is the result of exposure to ambient air pollution. According to the first global conference on air pollution and health, air pollution causes 1 out of 9 deaths worldwide. Motor vehicles release huge quantities of carbon monoxide, hydrocarbons, nitrogen oxides, and such toxic substances, and fine particles. Depending on fuel formation, they can also produce significant masses of sulfur oxides and lead [1]. Short-term and long-term exposure to air pollution increase the risk of mortality and hospital admission [2-4]. There is an association between O_3 and SO_2 concentration and hospital admissions due to respiratory disease [5]. The associations between short-term exposure to air pollution and acute health effects such as problems in the cardiovascular and respiratory systems are proven [6, 7]. Long-term exposure to $PM_{2.5}$ and NO_2 is linked to elevated risk of diabetes [8-10]. Exposure to traffic-related air pollution during

Please cite this article as: Yousefi S, Shahsavani A, Hadei M. Applying EPA's instruction to calculate air quality index (AQI) in Tehran. Journal of Air Pollution and Health. 2019; 4(2): 81-86.

childhood has been associated with the risk of increasing risk of childhood asthma [11, 12]. Air pollution increases the risk of pre-term birth and low-birth weight [13]. In addition, an association between exposures to PM_{10} with childhood cancers has been observed [14].

Air quality index (AQI) is an index developed by the US Environmental Protection Agency (US EPA) for reporting daily air quality [15].This index focuses on health effect within a few hours or days after breathing unhealthy air. The raw measurements of criteria air pollutants are converted into a AQI value and category for each pollutant [15]. Each category of AQI suggests specific recommendations for public to follow and be at lower risk of air pollution. The proper calculation and reporting AQI can improve public health protection [16] Six criteria air pollutants are considered in AQI: ground-level ozone, particulate air pollution, carbon monoxide, sulfur dioxide, and nitrogen dioxide. AQI ranges from 0 to 500, and is divided into six levels of health concern or categories: good (between 0 and 50), moderate (between 51 and 100), unhealthy for sensitive groups (between 101 and 150), unhealthy (between 151 and 200), very unhealthy (between 201 and 300), and hazardous (over 300) [15].

Many countries such as Iran are using AQI to report air quality status. However, the procedure to calculate AQI has been changed in Iran. For instance, Iranian organizations average the AQI values across all the monitors in a city to calculate the AQI value of city; while, EPA recommends that the maximum AQI value of all pollutants in all monitors of a city should be selected and reported as the AQI value of that city. The Iran's procedure may lead to underestimation of AQI and air quality status that subsequently cause to false health recommendations to public. Therefore, there is a need for a study to calculate the real AQI values in Iran.

This study aimed to calculate and evaluate air quality index (AQI) in Tehran according to the EPA's instruction.

Materials and methods

This study was conducted on the concentrations of criteria air pollutants in Tehran, Iran. Tehran is the capital of Iran with about 9 million population, and reported high concentrations of air pollutants [17-20]. The study period included three years of 2013, 2015, and 2017 within the six-year period of 2013-2017. The criteria air pollutants were particulate matter with an aerodynamic diameter <10 µm (PM_{10}), particulate matter with an aerodynamic diameter <2.5 µm ($PM_{2.5}$), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and carbon monoxide (CO). The concentrations of six studied pollutants were acquired from Department of Environment (DE) and Air Quality Control Company of Tehran (AQCC). The datasets were checked whether there is invalid data.

EPA's method for air quality index (AQI) was applied to calculate AQI values during the study period. At first, the concentrations of each pollutant were averaged by rolling (moving) method based on the averaging durations specified by EPA, including 1) PM_{10}: 24-h, 2) $PM_{2.5}$: 24-h, 3) NO_2: 1-h, 4) O_3: 8-h, 5) SO_2: 1-h, and 6) CO: 8-h. Then, the highest average concentration of each pollutant among all of the monitors was detected. Second, the two breakpoints that covers the observed concentration (C_p) was found. Afterward, this equation was used to calculate I_p i.e. AQI:

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} \left(C_p - BP_{Lo}\right) + I_{Lo} \qquad (1)$$

Where BP_{Hi} and BP_{Lo} denote to the greater and lower concentrations of the air pollutant, and I_{Hi} and I_{Lo} are the AQI values corresponded to those breakpoints concentrations. Then, the highest AQI value of all air pollutants was selected as the AQI value of the city, and the critical (main) pollutant was determined. The critical pollutant is the one that the highest AQI value of the city has been calculated based on its concentration.

For each year, a final dataset including the highest AQI values in city and the name of critical pollutant was created. The percentage of AQI values in each AQI category was calculated. In addition, the percentage of contribution of critical pollutants was prepared. The statistical distribution of AQI values during the whole period was analyzed by Kolmogorov-Smirnov test. Data handling and statistical analysis were performed using Microsoft Excel and SPSS v.24, respectively.

Results and discussion

The air quality index (AQI) of all criteria air pollutants in three years of 2013, 2015, and 2017 was calculated according to the EPA's method. Table 1 presents the descriptive statistics of AQI values during the study period. The three-year average of AQI was about 147, which rely on the third category of AQI i.e. unhealthy for sensitive groups. The average, median, minimum, and quantiles 1 and 3 of AQI values in the third year were lower than those in the first year. However, the maximum value of AQI was higher than that in the first year. This trend indicates an overall improvement in air quality of Tehran, despite one or some air pollution episode contributing to the extremely high AQI values.

Many studies have been conducted to investigate the concentrations of various air pollutants in Tehran. These studies have indicated that the concentrations of criteria air pollutants especially particulate matter are several times higher than WHO guidelines. In a study to explore the association between AQI values and mortality, although no significant effect of air pollution was observed on CVD, for the under 60 year olds, two significant peaks occurred in AQI = 180 at lags 2 and 6 days [21]. Considering these results, our findings indicate a significant risk for the health of people in Tehran, where the average of AQI is 147.

The percentage of AQI values within each AQI categories were calculated, and the results are illustrated in Fig. 1. During all the three years, the air quality had never been in a "good" condition (AQI<50). This finding is highly interesting, because according to the yearly reports of AQCC for the years 2013, 2015, and 2017 there have been 3, 21, 14 days with AQI<50, respectively. This difference originates from the different calculation method of AQCC that instead of selecting the highest AQI value of the monitors for the whole city, calculates the average of AQI from monitors and assigns it to the whole city. However, the scientific and EPA-approved method is the one used in the present study.

Only 3.0%, 5.3%, and 10.8% of the times had an air quality of "moderate" (50<AQI<100). In addition, 91.7%, 91.2%, 87.4% of times were unhealthy for sensitive groups (100<AQI<150) or unhealthy for all groups (150<AQI<200). The percentage of AQI values in "very unhealthy" category in 2017 (1.6%) was lower than that in 2013 (4.9%). And finally, about the 0.5% of AQI values were higher than 300, indicating a "hazardous" air quality in Tehran. All of these values are higher than those reported by AQCC. This means that the formal reports underestimate the air pollution status in Tehran.

In AQI calculations, the "critical pollutant" is the pollutant that the highest AQI value in the city has been calculated from its concentration. As with each AQI value the critical pollutant should be reported, we investigated the critical pollutants of AQI values during the study period. Fig. 2 shows the percentage of AQI values according to their relevant critical pollutants. This table indicates that $PM_{2.5}$ accounts for most of the AQI values in Tehran, followed by NO_2 and O_3. $PM_{2.5}$ was the

Table 1. The descriptive statistics of AQI values during the study period

	Mean	SD	Median	Min	Q1	Q3	Max
2013	158.4	31.7	159	65	149	169	501
2015	141.0	36.3	141	59	115	159	501
2017	141.3	33.7	151	55	118	158	547
Three -year	146.9	34.9	153	55	123	163	547

critical pollutant in 87.1%, 76.6%, and 90.4% of times during 2013, 2015, and 2017, respectively. On average, NO_2, ozone, and PM_{10} contributed to 8.4% and 5.4%, and 1.1% of the highest AQI values, respectively. In contrast, SO_2 and CO had a negligible impact on the AQI values. These results are consistent with results of some previous studies investigating the concentrations of criteria air pollutants in Tehran, where the concentrations of particulate matter is the main health concern about ambient air pollution [22-25]. This is beside the concentrations of other air pollutants in indoor spaces that induce significant health hazard [26, 27].

The statistical distribution of AQI values in all the three years were investigated. The Kolmogorov-Smirnov test showed that the AQI values do not follow a normal distribution (K-S Dist. = 0.112). Fig. 3 illustrates the histogram of all AQI values during the study period. The two dash-lines in the figure is corresponding to the AQI=100 and AQI=150. This Figure indicates a strange form of distribution, showing a decline in the 100-150 range and a sudden increase just after AQIs higher than 150. The same pattern but in lower magnitude can be observed before and after AQI=100. These are possibly due to the manipulation of air pollutants' concentrations by responsible organizations. There is no logical explanation for this type of statistical distribution. Further studies are required to investigate the distribution of AQI values in a longer study period, and compare them to the distributions from other countries.

Conclusion

The AQI values in Tehran during 2013-2017 were calculated based on the EPA's method. The results showed that the air quality of Tehran is quiet poor. There was no AQI value below 50 that indicates "good" air quality. Most of the AQI values implied "unhealthy" for sensitive groups or all population. Some inconsistencies were found between our findings and the formal reports of AQI published by the governmental organizations that do not use the EPA-approved method for AQI calculations. This study indicated that governmental organizations should follow EPA's instruction for AQI calculations to avoid underestimation of air pollution and broadcast an accurate and reliable AQI to public. In addition, the distribution of AQI values were found to be strange, possibly due to the manipulation of air pollution concentrations. However, we cannot conclude this with high certainty. Therefore, further studies are required to investigate the distribution of AQI values in a longer study period, and compare them to the distributions from other countries.

Financial supports

No financial support has been provided for this study.

Competing interests

The authors declare that there are no competing interests.

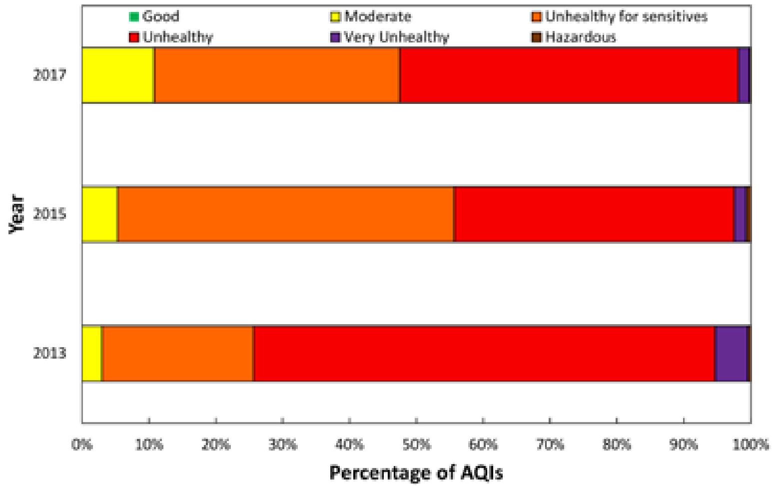

Fig. 1. The percentages of days within each AQI category

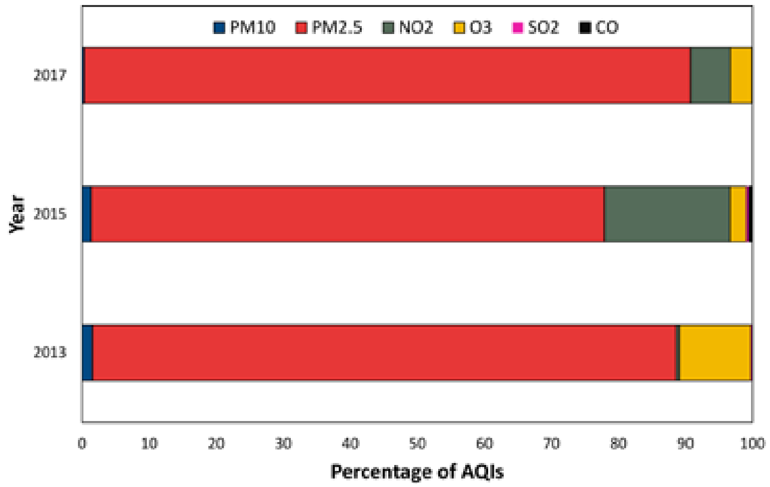

Fig. 2. The percentage of critical (main) pollutants responsible for the highest AQI value in the city

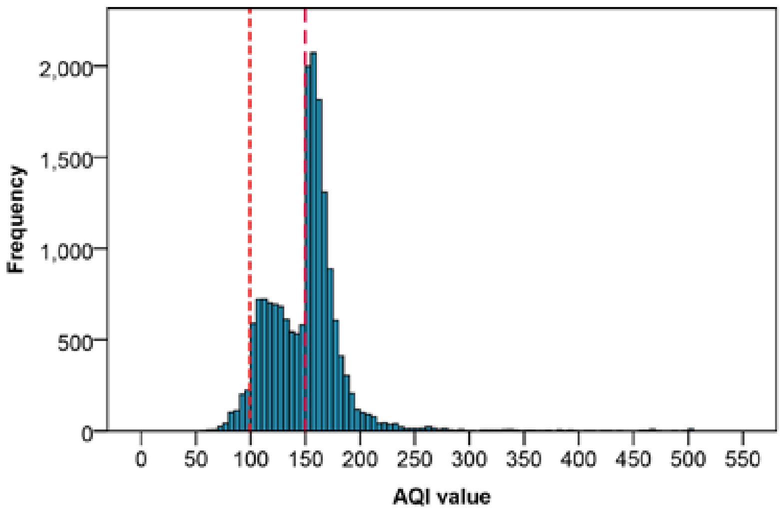

Fig. 3. The histogram of AQI values in all the three years of study period

Acknowledgements

The authors wish to thank Tehran University of Medical Sciences. We thank Tehran AQQC and DE for providing data.

Ethical considerations

"Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors."

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