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Original Article

Integrated Assessment of Air Pollution in Tehran, Over the Period from September 2008 to September 2009

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Abstract

Background: Air pollution is a major problem in urban\industrial areas, like Tehran, and has several impacts on human health. This study aimed at assessing concentrations of criteria air pollutants (CO, SO_2, NO_2, O_3, PM_{10}) in Tehran, extracting patterns of hourly, daily, weekly, and monthly variations of concentrations, and making comparisons to National Standards and WHO Guidelines.
Methods: Air quality data were taken from Air Quality Control Corporation and 5 sampling stations (out of 13) were selected for analysis according to data availability. Microsoft Excel 2003 was used for data analysis and plotting the charts.
Results: Patterns of temporal variation (hourly, daily, weekly, and monthly) of air pollutant concentrations were extracted. In some cases extracted patterns matched with the patterns proposed by other researchers. Pollutant concentrations were compared to National Standards and WHO Guidelines and it was observed that in most of the days, we exceeded the limit values.
Conclusion: Air pollution in Tehran is quite high and there are many days that we exceed the standards; therefore appropriate control strategies are needed. Although the number of sampling stations is high enough to be representative of whole city, it is proposed that an independent sampling station is setup to check the validity of the measurements.

Keywords: Air quality assessment, Pollutant concentrations, Temporal variations, Air pollution control

Introduction

In normal situation, the environment has the potential to neutralize impacts of natural and anthropogenic air pollutants. However with increasing pace of urbanization and industrialization, air pollution has overcome the environment and arisen as a major problem in such areas. In spite of covering only 0.04% of country's total surface area, Tehran, the capital of Iran, accounts for 13% (9 millions) of the total country's population; hence, it is known as a highly populated area. In Tehran, like other populated areas in the world, vehicular and industrial emissions are the major sources of air pollution (1-3).

Since people are continuously exposed to air, pollutants in the air can easily enter the body and cause adverse effects on human health both in short- and long-term. Therefore, many investigations have been conducted on the health impacts of air pollution (4-6) and it's been found that such effects mainly include hospital admissions (7,8), respiratory diseases (9,10), cardiovascular diseases and premature deaths (11,12), and neurobehavioral effects (13). Its been proved that a vast majority of people are concerned about such effects and are willing to pay for improving the air quality (14).

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Facing such a problem and proposing appropriate strategies for it require integrated air quality assessment, as EU requires its member states to assess the air quality by means of measurement or modeling (15). Hence, developed and some of the developing countries have been conducting extended investigations on the air quality assessment (16-25), emission inventory development (26, 27), assessment of temporal variations of air pollutants concentrations (28, 29), and development of air quality assessment models (30, 31), and some of them have resulted in proposing strategies for air quality improvement (2). International organizations have also published a variety of guidelines and standards as well (32, 33). In Iran, however, less attention has been paid and only a limited number of investigations have been done in this issue (34-37). National Standards (38) are also published regardless of the way we can comply with them. Another problem in air quality assessment is the large number of missing values (15, 39).

Tehran is located in the longitude of eastern 51° 8' to 51° 37' and the latitude of northern 35° 34' to 35° 50', covers a total surface area of 730 km^2, and has a population of 9 million. The increasing numbers of motor vehicles as well as large numbers of existing industries are known as the major sources of air pollutants in this area.

This study aimed at assessing concentrations of criteria air pollutants (CO, SO_2, NO_2, O_3, PM_{10}) in Tehran; extracting patterns of hourly, daily, weekly, and monthly variations of concentrations; and making comparisons with national standards and WHO guidelines.

Materials and Methods

Data collection methodology

Air quality assessment depends on a representative measurement network (1). In Tehran, Air Quality Control Corporation is in charge of measuring air pollutants concentrations. At the time of taking data from the abovementioned corporation, there were 13 active sampling stations throughout the city and in each one, pollutant concentrations were measured and the result were recorded as hourly means. Five sampling stations were selected according to data availability of more than 70% for all pollutants (Table 1): 1) Aghdasieh; 2) Geophysics; 3) Park roz; 4) Poonak; and 5) Shahre rey. The locations of selected sampling stations are shown in Fig. 1. Since air pollution data are produced continuously, the most recent available data at that time were used (i.e. 23 September 2008 to 23 September 2009). Criteria air pollutants, i.e. carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and PM_{10}, were selected to undergo analyses.

Dealing with air quality data

If concentrations are recorded as hourly means, then we have 8760 values for each pollutant a year. As it can be seen from Table 1, however, there are large numbers of missing values; for example, in sampling station 1 for SO_2, there were only 6317 values out of 8760 (i.e. 71.9%) present. This is not abnormal for an air quality data set, due mainly to the problems during data acquisition such as equipment calibration, insufficient sampling, errors in measurements, and power failure (15, 40, 41).

In order to minimize the effects of missing values, they should be rebuilt. A common method to rebuild the missing value is calculating the average of adjacent values. Another criterion was that in order to calculate an average over a period of time, at least 75% of the values should be present, otherwise the whole period should be neglected (15, 40, 41).

Pattern of hourly variations

Plotting air pollutant concentrations data as hourly means is a good way to recognize outlier values quickly. Time trends of concentrations can be also seen in this form.

Pattern of daily, weekly and monthly variations

In these forms of plotting data, the effects of short term variations of concentrations are reduced to some extent, and the time trends of concentrations become more apparent as well.

Pattern of diurnal variations

In this form of plotting data, pattern of air pollutant concentrations can be seen during the day and compared to the patterns proposed by other researchers (15). Microsoft Excel 2003 was used to plot these charts.

Results

Results of Aghdasieh (Sampling Station 1) are shown as a representative of whole sampling stations. Fig. 2 shows the time series of hourly means at sampling station 1. Fig. 3 shows corresponding time series of different pollutants over different periods of time. As it can be seen from Fig. 3, there are some points where the curves intercept the x axis. It should be noted that in these points, pollutant concentrations are not null, but are representative of the situations in which no reliable data (75%) were existed to calculate a meaningful average, and correspond to the parts of hourly charts that there is no dot. The last approach to pollutant concentrations is shown in Fig. 4. In this Figure, temporal variations of pollutants concentrations can be seen during June and December as representatives of two distinct meteorological conditions. Finally, air pollutants concentrations in all sampling stations were compared to National Standards (38) and WHO Guidelines (32, 33), the numbers of exceedances were calculated, and the results were extracted in Table 2 and Table 3, respectively.

Table 1: Data availability for different air pollutants in all sampling stations

Stations	CO	NO_2	O_3	PM_{10}	SO_2
Aghdasieh	93.2	93	92	95	71.9
Geophysics	85.2	97.9	97.3	91	91
Park Roz	92.1	86.7	89.9	75.1	91.3
Poonak	94.9	92.5	95.6	93.9	74.4
Shahre Rey	91.1	95.7	88.5	93.8	74.2

Table 2: Current status of air pollutants compared with National Standards. Number of Exceedances in different stations

Pollutants	National Standards	Station 1	Station 2	Station 3	Station 4	Station 5
CO	11.25 mg/m3 As 8-hr mean	16	56	3	4	30
NO_2	80 µg/m3 As annual mean	Exceeded	Exceeded	Exceeded	Exceeded	Exceeded
O_3	160 µg/m3 As 1-hr mean	336	354	329	350	321
PM_{10}	150 µg/m3 as 24-hr mean	19	14	14	14	10
SO_2	400 µg/m3 as 24-hr mean	3	3	7	9	2

Table 3: Current status of air pollutants of Tehran compared with WHO Guidelines. Number of Exceedances in different stations

Pollutants	WHO Guidelines	Station 1	Station 2	Station 3	Station 4	Station 5
CO	10 mg/m3 As 8-hr mean	25	96	8	10	53
NO_2	200 µg/m3 As 1-hr mean	47	54	7	58	38
O_3	100 µg/m3 As 8-hr mean	216	136	139	202	133
PM_{10}	50 µg/m3 as 24-hr mean	263	248	192	214	215
SO_2	20 µg/m3 As 24-hr mean	248	303	320	227	281

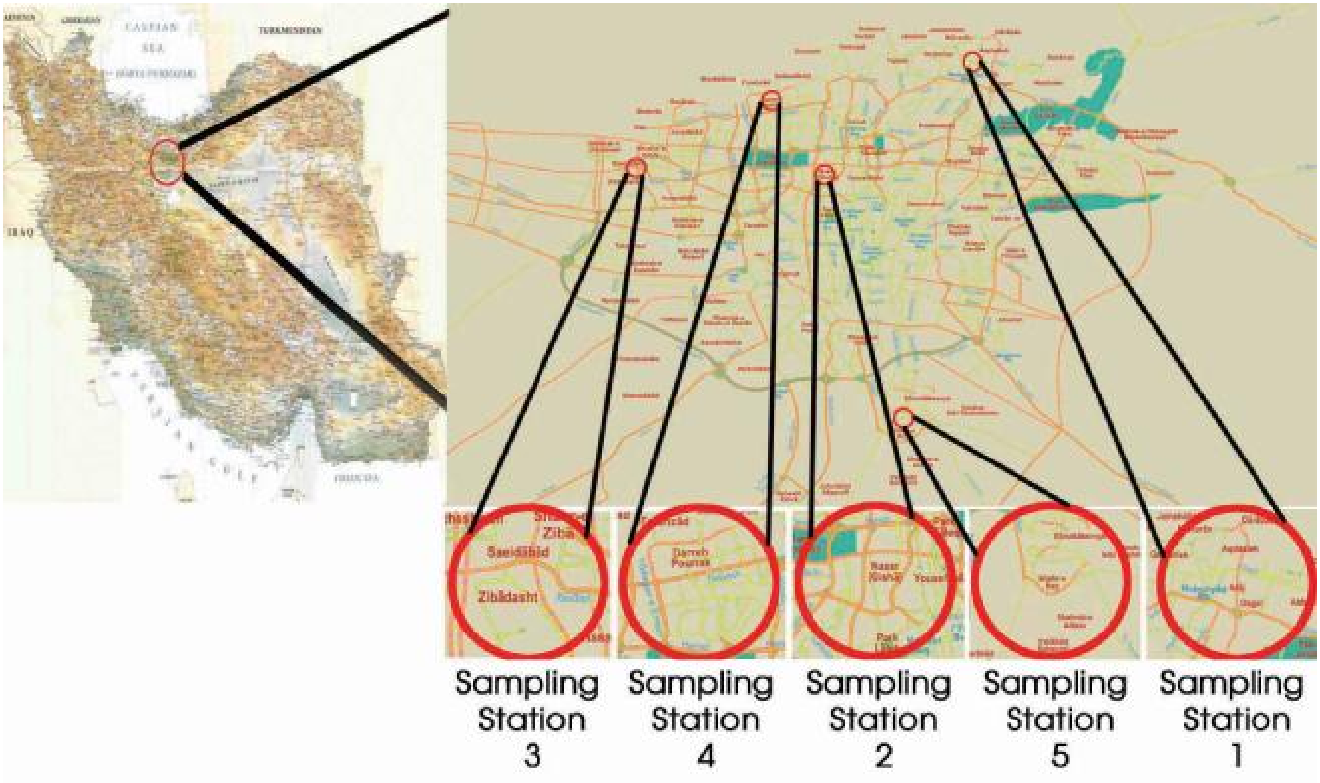

Fig. 1: Location of sampling stations

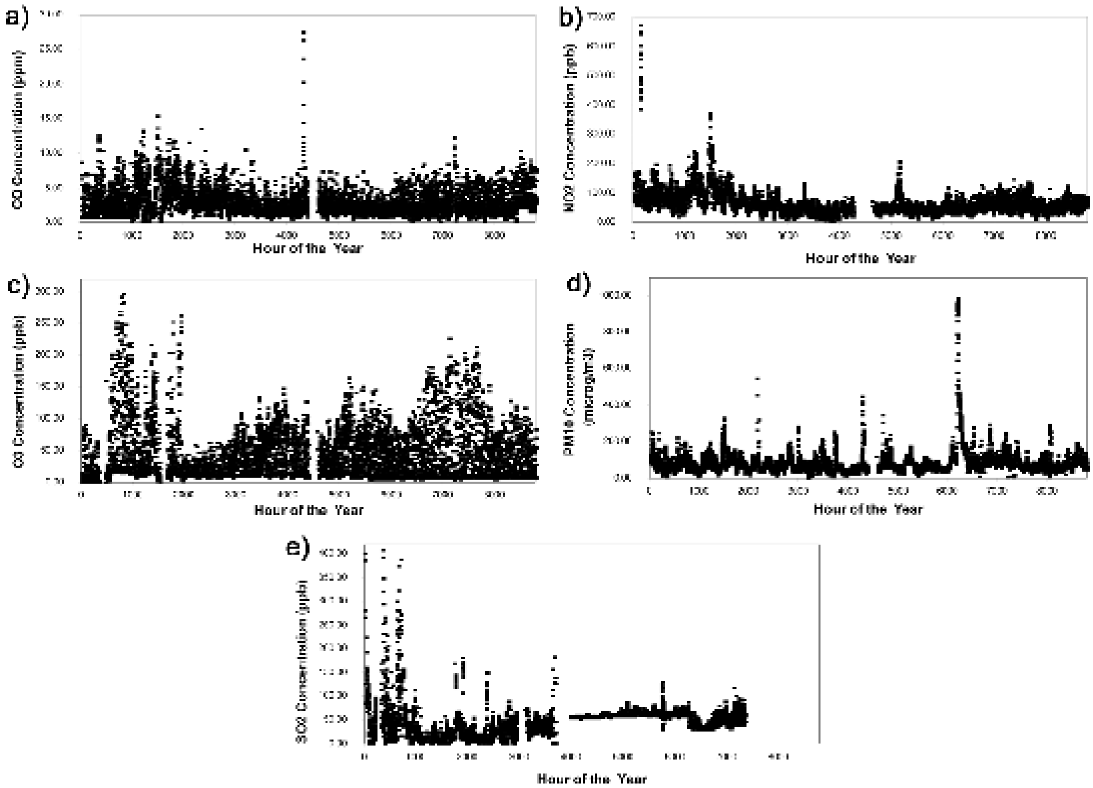

Fig. 2: Time series of hourly means at Sampling Station 1: a) CO, b) NO_2, c) O_3, d) PM_{10}, and e) SO_2

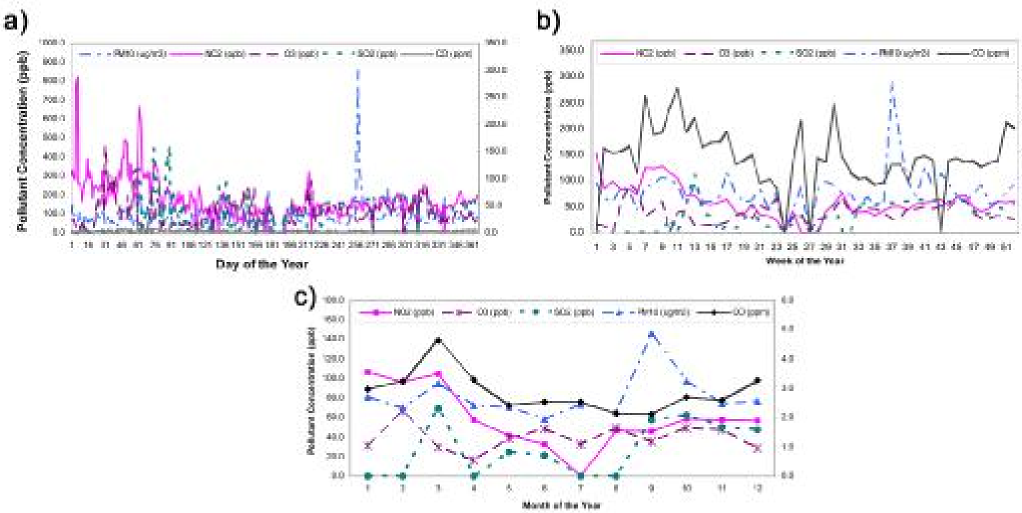

Fig. 3: Time series of: a) daily, b) weekly, and c) monthly means for different pollutants at Sampling Station 1

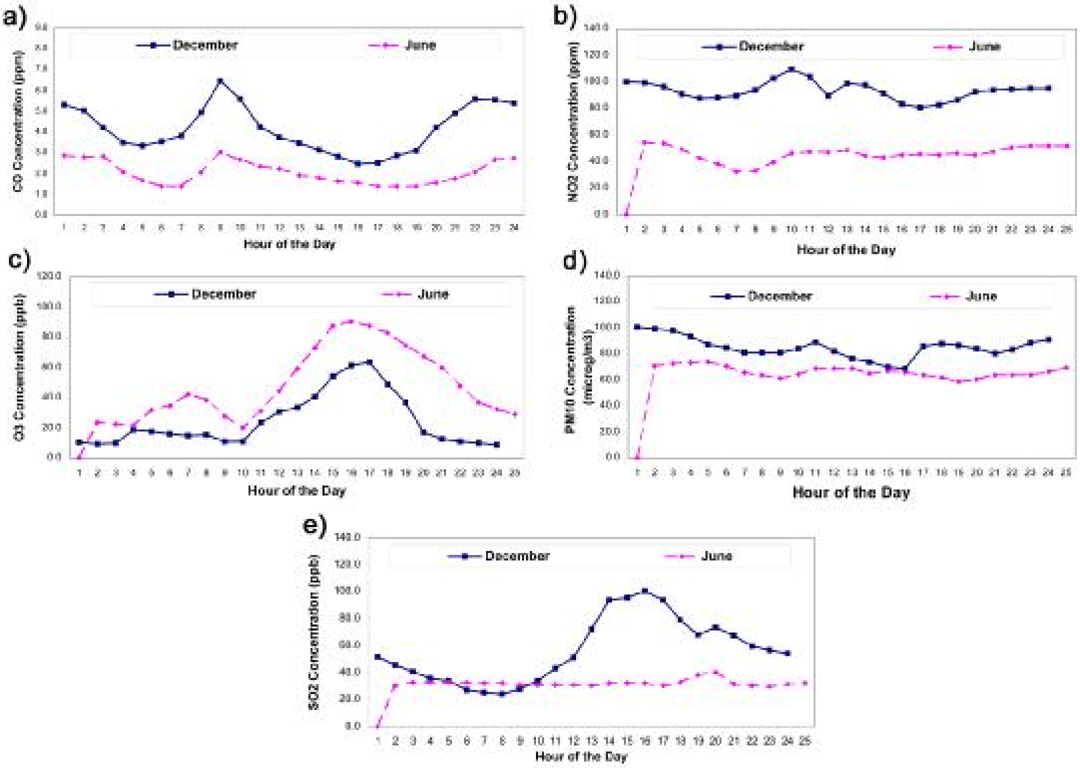

Fig. 4: Average diurnal variations in June and December at Sampling Station 1: a) CO, b) NO_2, c) O_3, d) PM_{10}, and SO_2)

Discussion

As it can be seen from Fig. 2 and 3, CO concentrations rose to a peak in December before declining through to February and remained low all the year. NO_2 concentrations peaked in autumn, reduced to half at the end of winter and remained low until the end of summer. O_3 concentrations highly fluctuated all the year and peaked in November. PM_{10} concentrations were almost consistent during all year but suddenly rose to double in June. SO_2 concentrations peaked in December, reduced to some extent in winter and again rose to its initial peak in spring. Fig. 4 shows temporal variations of pollutants concentrations in December and June. As it can be seen, CO concentrations (Fig. 4(a)) in December rose to a sharp peak in the early morning and had another peak at midnight, while in June the second peak displaced to 1-3 AM. Such variations are characteristic of a primary air pollutant. Similar patterns have been proposed by other researchers (42, 43). NO_2 concentrations (Fig. 4(b)) in December and June were almost consistent all the day. These patterns match with the patterns extracted earlier (42, 44). O_3 concentrations (Fig. 4 (c)) in December rose to a high peak in the afternoon (6 PM) and were almost low all the day; a similar pattern was seen in June except that the peak occurred earlier (4 PM). Same patterns were proposed earlier (42, 44, 45). PM_{10} concentrations (Fig. 4(d)) in December and June were consistent and high all the day. These patterns almost match with the patterns extracted by other studies (44). SO_2 concentrations (Fig. 4(e)) in December had a

two-hours peak in the afternoon and decreased thorough to early morning of the next day before increasing to its peak, while in June peak value was seen at 8 PM and concentrations were consistent during the day. These patterns only match with the patterns extracted by previous studies (42). As it can be seen from Fig. 4, concentrations of all pollutants in December, but ozone, were higher than that of June.
The differences in pollutant concentrations patterns in different seasons seem to be due to the different life patterns of the people in different seasons, and the changes happen to the time of journeys as well. Since in the late autumn, the hours of the day were shorter, the peak values occurred earlier than that of spring, and vice versa.

Comparing current status to National Standards and WHO guidelines

It can be seen from Table 2 that as concentrations compared to National Standards, pollutant concentrations exceeded the limit value in many days, especially for ozone (more than 300 days of exceedances). This can be due to either high ozone concentrations or strict legislation for it, or both. The least numbers of exceedances are seen for SO_2 and PM_{10}. Again, this can be due to either low SO_2 and PM10 concentrations or eath legislation for them, or both. Numbers of exceedances for CO were higher than SO_2 and PM10. In the case of NO_2, limit value was exceeded in all sampling stations.
As the concentrations were compared to WHO guidelines (Table 3), the number of days we exceeded the limit values raised dramatically. This time, SO_2 and PM_{10} were the worst pollutants in the case of number of exceedances. For ozone, however, numbers of exceedances decreased but are still high. This can reflect inappropriate legislation regardless of local situation. Another major problem in National Standards is that there is no strategy or framework to comply with them, but stricter standards are published annually.

In Tehran, like other populated areas in the world, vehicular and industrial emissions are the major causes of air pollution (1-3); hence, in the case of air pollution control and management, much attention should be paid on these causes. Simple strategies like reduced production of motor vehicles, use of alternative fuels, locating industries in remote areas, and extension of public transportation can have significant effects on air quality improvement, as it was experienced in Turkey (45).

Concluding Remarks

- Air quality in Tehran is quite low and in many days, standard levels were exceeded. Therefore, it is to policy makers to develop appropriate control strategies for air quality improvement.
- According to USEPA Standards, the number of sampling stations is high enough to be representative of whole city.
- It is recommended that an independent sampling station is setup to check the validity of the measurements.

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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