

original article

Assessment of daily variations of volatile organic compound in Tehran in 2010-2011

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INTRODUCTION

Volatile organic compounds (VOCs) are liquid or solid compounds which contain organic carbon and their rate of evaporation is significantly high. These compounds after particulate matters have the greatest abundance and diversity of emission and are typically caused by mobile and stationary sources such as industries, paints, surfactants, and cooking.^[1]

Depending upon compositions and concentrations, VOCs lead to various impacts on health and sanitation. The ranges

of impacts are included from odor nuisance to lung capacity malfunctioning and even cancer. VOC concentration levels were so high in some sites in the USA which cause cancer, birth defects, and other serious diseases.^[2] More than 50% of emitted VOCs are caused by vehicles which gasoline engines have the majority of proportion in comparison with gasoline engines.^[3]

VOCs play an important role to form ozone at lower levels of atmosphere and are the main cause of smog generation. The main concern of photochemical smog effects is human health.^[4] So the best way to prevent smog generation and ozone level increment is the prevention of VOCs emissions in ambient air. Photochemical assessment monitoring stations (PAMS) have been set up in accordance with the Air Clean Act (EPA 1990) in order to develop ozone monitoring in some countries such as South Korea, Chile, the USA, Canada, Britannia, and Australia from 1994. Meteorological parameters and VOCs, NO_x and ozone concentrations are recorded in these stations.^[5] Tehran, the capital of Iran, is one of the largest cities in the world, and most of its inhabitants

ABSTRACT

Aims: In accordance with the Air Clean Act developed for ozone monitoring, the measurement of volatile organic compounds (VOCs) based on photochemical assessment monitoring stations (PAMS) was carried out.

Materials and Methods: Thirteen species of VOCs were measured on Enghelab square in Tehran by PhoCheck PID Detector at morning, noon, and afternoon for 3 months. The data were reported as descriptive statistics.

Results: Most of the VOCs species showed diurnal variations with higher concentrations in the noon. The highest concentration of VOCs was aromatic group (AR: 0.549 ± 0.146 ppb). AR was the main contributor to photochemical smog.

Conclusion: The majority of the AR class and toluene may be followed by the impacts of heavy traffic and the peak values of VOCs concentrations occurred around mid-day which depends indirectly upon vehicles and emission of evaporations.

Key words: Air pollution, photochemical assessment monitoring stations, vehicles, volatile organic compounds

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experience poor air quality every day despite covering only 0.04% of the country's total surface area; it accounts for 13% (9 million) of the total country's population. Air pollution has reached alarming levels in Tehran, and the city dwellers are being continuously exposed to its harmful effects. From September 2008 to September 2009, in more than 150 days, 8-h mean ozone concentrations have exceeded $100 \mu\text{g}/\text{m}^3$.^[6] In particular, severe smog conditions have been reported in the winter months.^[7] Due to lack of investigations and also air pollution crisis and its impacts, this study was carried out to monitor and analyze VOCs concentrations on the Enghelab Square which is known as high-traffic area in Tehran, Iran.

MATERIALS AND METHODS

The location of Tehran is in the longitude of eastern $51^\circ 8' - 51^\circ 37'$ and the latitude of northern $35^\circ 34' - 35^\circ 50'$. The total population of the area in 2011 was 9 million, and it covers 730 km^2 . The sampling site was located on Enghelab square. The geographical location of the site is shown in Figure 1.

This is a cross-sectional descriptive study. Because the location of site sampling is near to highway and surrounded by small commercial and residential buildings, VOCs distributions represent the mixed effects of different types of human sources. Samplings were daily taken three times per day at 8 a.m., noon, and 4 p.m. from January to March 2011. Portable Phocheck as Photoionization detector with 10.6eV ultraviolet lamp was used to measure VOCs in this study. Detector is equipped with 0.5 microns filter and sucks the air by flow rate of about 200 ml/min. Then, volatile compounds are measured by ultraviolet light detectors. Before each sampling, the detector was calibrated by blue carbon filter which was made by its manufacturer. In this research, 13 species of VOCs were measured and simultaneously temperature and humidity were also recorded by portable PHB-318 detector. Finally, software, SPSS 16.0 and Excel 2010, were applied to analyze data and they were reported as descriptive statistics.

RESULTS

Table 1 shows the data of VOCs including chemical formula, four main classes consisting of alkene (AK), aromatic (AR), olefins (OF), and paraffin (PR). In addition, statistical summary of average concentrations of VOCs during the days in period of the study for each class is shown in Table 1. It should be noted that the average temperature and humidity in site sampling location were 17.2°C and 35.3%, respectively.

Reported results show that the lowest level of VOCs concentrations belonged to Aniline with 0.048 ± 0.051 ppb while the most level of average concentrations were allocated to Decane with 0.151 ± 0.108 ppb, Methyl bromide with 0.141 ± 0.156 ppb and toluene with 0.135 ± 0.108 ppb. As can be presented in Table 1, ARs have the most levels of concentrations.

DISCUSSION

As shown in Figures 2-4, the peak values of VOCs concentrations occurred at noon which depends indirectly upon vehicles and evaporation residues. In this regards, cooking can be one of the reasons for increase in VOCs

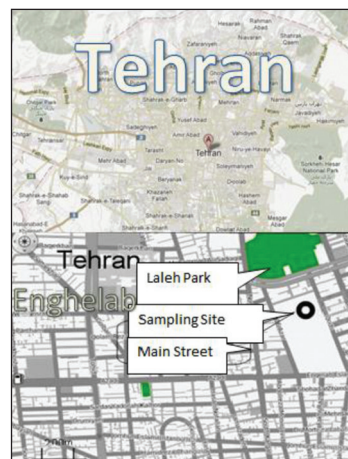


Figure 1: Geographical location of Tehran and the measurement site

Table 1: Data summary of volatile organic compounds from January to March 2011 (ppb)

| Compound | Class ^a | Formula | Ave ^b | S.D. | Median | Max |
|------------------|--------------------|---|------------------|-------|--------|-------|
| Anilin | AR | $\text{C}_6\text{H}_7\text{N}$ | 0.048 | 0.051 | 0.048 | 0.208 |
| Benzene | AR | C_6H_6 | 0.052 | 0.055 | 0.055 | 0.234 |
| Benzene aldehyd | AR | $\text{C}_6\text{H}_5\text{CHO}$ | 0.057 | 0.113 | 0.057 | 0.452 |
| Butoxy ethanol | AR | $\text{C}_6\text{H}_{14}\text{O}_2$ | 0.112 | 0.152 | 0.112 | 0.76 |
| Carbon disulfide | AK | CS_2 | 0.119 | 0.119 | 0.119 | 0.499 |
| Chlorobenzene | AR | $\text{C}_6\text{H}_5\text{Cl}$ | 0.078 | 0.083 | 0.078 | 0.374 |
| Cyclohexane | PR | C_6H_{12} | 0.106 | 0.101 | 0.106 | 0.421 |
| Decane | PR | $\text{CH}_3(\text{CH}_2)_8\text{CH}_3$ | 0.151 | 0.108 | 0.151 | 0.385 |
| Ethylbenzene | AR | $\text{C}_6\text{H}_5\text{C}_2\text{H}_5$ | 0.067 | 0.092 | 0.067 | 0.407 |
| 1-Hexene | OF | $\text{CH}_3(\text{CH}_2)_3\text{CH}=\text{CH}_2$ | 0.057 | 0.112 | 0.057 | 0.452 |
| Isobutane | PR | $\text{CH}(\text{CH}_3)_3$ | 0.118 | 0.149 | 0.118 | 0.624 |
| Methyl bromide | AK | CH_3Br | 0.141 | 0.156 | 0.141 | 0.586 |
| Toluene | AR | $\text{C}_6\text{H}_5\text{CH}_3$ | 0.135 | 0.108 | 0.135 | 0.508 |

^aAK: Alkene, AR: Aromatic, OF: Olefin, PR:Paraffin, ^bAve. ambient day concentration (ppb)

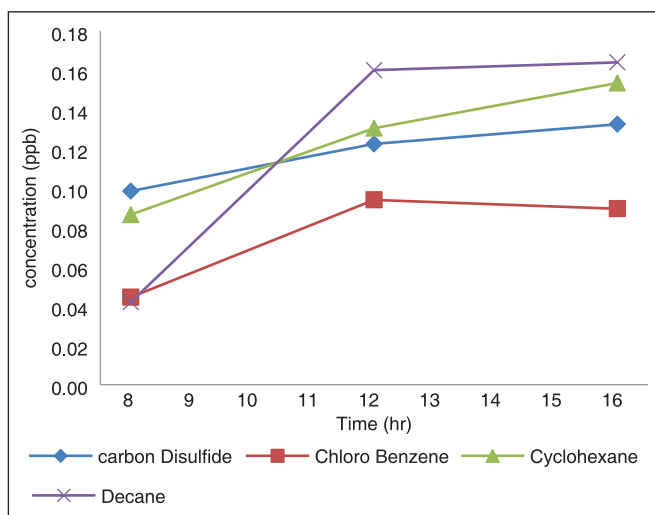


Figure 2: The hourly mean concentrations of decane, carbon disulfide, chlorobenzene, and cyclohexane in 2011

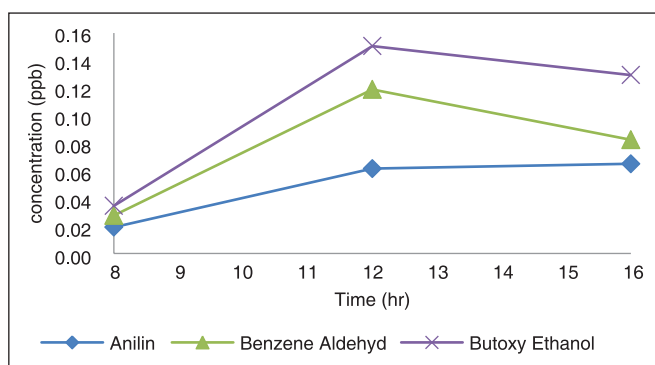


Figure 3: The hourly mean concentrations of aniline, benzene, benzaldehyde, and butoxyethanol in 2011

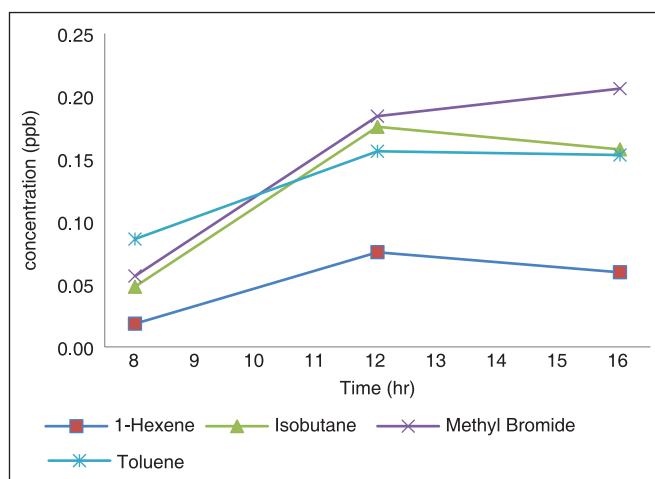


Figure 4: The hourly mean concentrations of toluene, isobutane, methyl bromide, ethylbenzene, and hexane in 2011

concentrations. Another reason is the gentle winds from West and South West to Enghelab square leading to dilution of pollutants in ambient air. The minimum wind speed was recorded at noon which was lower than 1 m/s. Also, it is expected that VOCs concentrations

decrease at afternoon because photochemical reactions reach the peak at noon. Another cause can be mentioned is plant activities. This source has low proportion of VOCs generation but biological reactions rise rapidly at sunrise leading to produce VOCs.^[8,9] The results of studies conducted in Seoul in 2004 revealed that the maximum levels of VOCs were observed at noon.^[2] In this study, ARs had the highest level of concentrations with 0.549 ppb. They are typically originated from vehicular combustion sources. In fact, 41-52% of combustion of fuels is composed of ARs which are more than other classes, 28-47% for paraffin, and 7-12% for OF. The high level of ARs along with toluene represents heavy traffic.^[2]

Comparison of measured data with data from other countries is presented in Table 2. According to this Table, the highest level of VOCs concentration is toluene (21.8 ppb) in Santiago, Chile,^[10] and is methyl bromide (19.2 ppm) in Karachi, Pakistan.^[11] However, the majority of VOCs concentration levels are generally lower than 20 ppb. As can be observed from Table 2, the lowest ratio for AR class belonged to Britannia with average 5.8 ppb among 12 cities.^[12] The most value of AR category was observed in Chile with 40.2 ppb. ARs are the main cause of ozone generation in Shanghai.^[7] About 79% of ozone produced in mentioned area was originated from AR compounds.^[13] AR concentrations are dominant in Santiago (Chile), Shanghai (China), and this study which are well known as five cities of the world for their smog. So, vehicles are the main factor of occurrences resulted from smog. However, the differences in compounds studied, VOCs measuring and analysis methods, and collected data avoid comparing data and concluding.

One of the restrictions of this research is the number of stations. Since it was not possible to take sample simultaneously from all stations by one detector, the selection of station in the middle of city was done in an area where whole VOCs sources, such as vehicles, restaurants, publishers, and green places are available.

It should be noted that more researches are essential to identify and monitor toxic and hazardous pollutants.

CONCLUSION

A total of 18 samples were measured from January to March 2011. To observe general characteristics and diurnal variations of VOC concentrations, concentrations were measured in the morning, noon, and afternoon. Total VOC concentrations showed diurnal variations with high concentrations in the noon. The majority of the AR class and toluene may be followed by the impacts of heavy traffic and the peak values of VOCs concentrations occurred around mid-day which depends indirectly upon vehicles and emission of evaporations.^[2] The presence of VOCs

Table 2: Comparison of volatile organic compounds concentrations in some countries

| Compound | This study | S. Korea | Britannia | Australia | U.S.A | China | Pakistan | Chile |
|------------------|------------|----------|-----------|-----------|-------|-------|----------|-------|
| Anilin | 0.05 | 0.78 | — | 3.3 | 3.2 | 5.4 | — | 5.7 |
| Benzene | 0.05 | 0.82 | 1.1 | 2.6 | 2.4 | 5.55 | 5.2 | 6 |
| Benzene aldehyd | 0.06 | 1.2 | 2.1 | 3.1 | 3.7 | 3.2 | 2.7 | 6.7 |
| Butoxy ethanol | 0.11 | — | — | — | 5.8 | 8.2 | — | — |
| Carbon disulfide | 0.12 | 7.8 | 5.6 | — | 4.8 | — | 2.8 | 6.3 |
| Chlorobenzene | 0.08 | — | — | 2.4 | — | 2.3 | 11.7 | — |
| Cyclohexane | 0.11 | 0.5 | 1.7 | — | 9.2 | — | 17.7 | 15.2 |
| Decane | 0.15 | 2.31 | 8.3 | 2.15 | 1.7 | 1.1 | 8.7 | 6.4 |
| Ethylbenzene | 0.07 | 0.7 | 0.46 | 0.54 | 0.66 | 1.4 | — | — |
| 1-Hexene | 0.06 | 0.05 | 0.34 | — | — | 2.8 | 17.2 | 14.3 |
| Isobutane | 0.12 | 0.31 | 2.1 | 3.4 | 2.9 | — | 16.7 | 18.3 |
| Methyl bromide | 0.14 | — | 9.1 | 6.2 | 8.2 | 4.7 | 19.2 | 12.2 |
| Toluene | 0.14 | 6.4 | 2.12 | 8.9 | 3.8 | 5.8 | 7.1 | 21.8 |

produces ozone and smog which cause acidification and climate change. Photochemical smog, ozone, and ARs lead to headache, eye irritation, respiration diseases, and even cancer in long term.^[14] European legislation^[15] regulates the standard levels of tropospheric ozone, and also recommends that a whole list of VOC ozone precursors be measured so that trends can be analyzed, the efficiency of emission reduction strategies can be checked, and sources of emission can be determined. There are different ways to reduce emission of VOCs from vehicles which include using of liquefied petroleum gas or compressed natural gas instead of using gasoline, using other transportation systems such as bus and bicycle which result in control and reduction of VOCs in ambient air.

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