Journal of Air Pollution and Health (Autumn 2017); 2(4): 199-204

Original Article

Available online at http://japh.tums.ac.ir

SPATIAL AND SEASONAL VARIATION OF $PM_{2.5}$ / PM_{10} RATIO IN TEHRAN, IRAN, DURING 2016 - 2017

*Masoud Masinaei[1], Mahmood Yousefi[2], Hamid Reza Shamsollahi[2]**

[1] Department of Epidemiology and Biostatistics, Tehran University of Medical Sciences, Tehran, Iran

[2] Department Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

ARTICLE INFORMATION

Article Chronology:

Received 14 October 2017
Revised 11 November 2017
Accepted 13 December 2017
Published 30 December 2017

Keywords:

$PM_{2.5}$ / PM_{10}; air pollution; prediction

CORRESPONDING AUTHOR:

hrshamsollahi@gmail.com
Tel: (+98 21) 88954914
Fax: (+98 21) 88950188

ABSTRACT:

Introduction: $PM_{2.5}$ is one of the most important air pollutants, affecting human health by penetrating in to the alveolar area. Thus prediction of $PM_{2.5}$ concentration and its behavior and also its seasonal and spatial variation are necessary for public health protection.

Materials and methods: For this purpose, $PM_{2.5}$/ PM_{10} was calculated in different seasons and different stations in Tehran city during 2016. Also the $PM_{2.5}$/PM_{10} ratio was compared in different area of the city. Then achieved results were analyzed by R.

Results: Seasonal variation of this ratio was significant. It shows that the maximum and minimum value of $PM_{2.5}$/ PM_{10} was in winter and summer, respectively. It seems it is due to the incomplete combustion of fuel in winter. Also we found that the $PM_{2.5}$/ PM_{10} ratio in the western area of city is significantly higher than the east. It can be due to the pollutants transmission from the town located in close proximity to the west of Tehran.

Conclusions: $PM_{2.5}$ / PM_{10} ratio can be different in various situations. It can be affected by the several factors such as pollutant sources, meteorological and seasonal factors and also traffic pattern. The $PM_{2.5}$/PM_{10} ratio can alert corresponding agencies for prediction the air quality that happens every year periodically.

INTRODUCTION

$PM_{2.5}$ is defined as the particulate matters with the aerodynamic diameters less than 2.5 μm (≤ 2.5) [1]. This range of size is important for human health because these particles can penetrate in to the alveolar area and decompose in this area [2]. $PM_{2.5}$ is formed by condensation and reaction between gaseous air pollutants. Besides, the size; chemical composition; and their concentrations are important for determination of their effects on human health and visual aspects [3]. The environmental and meteorological conditions can effect on these features. So the air pollution studies are focused on variation of $PM_{2.5}$ concentration and chemical composition.

Studies on $PM_{2.5}$ around the world are including the study on carbonaceous components in $PM_{2.5}$, inorganic ions, metals and heavy metals, shape and physical characteristics [4 - 5]. But one of the

Please cite this article as: Masinaei M, Yousefi M, Shamsollahi H.R. Spatial and seasonal variation of $PM_{2.5}$ / PM_{10} in Tehran, Iran, during 2016 - 2017. Journal of Air Pollution and Health. 2017;2(4): 199- 204.

basic aspects in this issue is $PM_{2.5}$ concentration in urban atmosphere. During recent years, several studies have been reported the associations between daily concentrations of fine particles and mortality with the strong correlation [6 - 7]. Almost all of such studies are based on a linear concentration – response relationship among fine particles and daily mortality. One of the robust studies in this issue has shown that an increase of 10 μg/m^3 $PM_{2.5}$ average concentration during 2-days can increase daily death, up to 1.5%. Hence, the correlation between PM_{10} and daily death was found less significant due to the aerodynamic diameter of particles between 2.5 to 10 μm [8]. As a result, measurement of $PM_{2.5}$ is important for air quality monitoring and the prediction of attributed health effects. Thus prediction or estimation of $PM_{2.5}$ concentration can help corresponding health agencies for necessary responses when the air quality is not suitable for sensitive or all people. Since $PM_{2.5}$ is a subset of PM_{10} , there is a robust correlation between them. Thus the behavior of PM_{10} can be the same as $PM_{2.5}$. The relationship between PM_{10} and $PM_{2.5}$ can be different in various cities. Several parameters such as meteorological variation, longitudinal and transverse extensions of city and traffic pattern can effect on this relation. Therefore the main aim of current study is survey and determination of spatial and seasonal variation of $PM_{2.5}$ / PM_{10} to find a linear model for predicting the $PM_{2.5}$ considering the PM_{10} concentration in different locations and different seasons in Tehran, Iran.

MATERIALS AND METHODS

To perform this study, the daily measurements of $PM_{2.5}$ and PM_{10} from 9 air pollution control stations in Tehran city (Iran) were used during March 2016 to September 2017. These stations are installed in the north, south, west, east and center of Tehran. Because of the large number of missing data, two stations were removed from the study, therefore 7 stations were considered. At first, we made sure that the result of study is not affected by those removed stations. Therefore the data collected from 7 stations was calculated monthly. To predict the concentration of $PM_{2.5}$ by PM_{10}, the linear regression analysis was implemented in each station and the scatter plots of $PM_{2.5}$ against PM_{10} in each station were drawn for this purpose. Also the ratio of $PM_{2.5}$ to PM_{10} was calculated for every day during this period of time. Furthermore, to have a better understanding of pattern of changes in $PM_{2.5}$ / PM_{10} ratios during the time, we constructed two time plots that display the ratios in every month for different stations and different areas (which the stations are), respectively. At the end, in order to test whether there is a significant difference in $PM_{2.5}$ / PM_{10} ratios between different areas, the Friedman test was performed. All the analyses were calculated by R (version 3.4.1) and the plots were created by ggplot2 package.

RESULTS AND DISCUSSION

As seen in Table 1, there is a strong relationship between $PM_{2.5}$ and PM_{10} concentration as expected ($P_{value} < 0.001$). The coefficients of regression lines for $PM_{2.5}$ (with PM_{10} as the covariate) in each station are reported in Table 1. Also in Fig. 1, the scatter plots of $PM_{2.5}$ against PM_{10} with the fitted regression lines in each station are plotted.

Table 1. Regression coefficients of all fitted models in all stations with $PM_{2.5}$ as the response variable and PM_{10} as the covariate.

Estimate	Station A (Center)	Station B (West)	Station C (East)	Station D (West)	Station E (East)	Station F (West)	Station G (West)
Intercept	6.25	12.98	6.69	3.7	11.36	7.65	6.02
PM_{10}	0.3	0.14	0.18	0.31	0.17	0.35	0.31

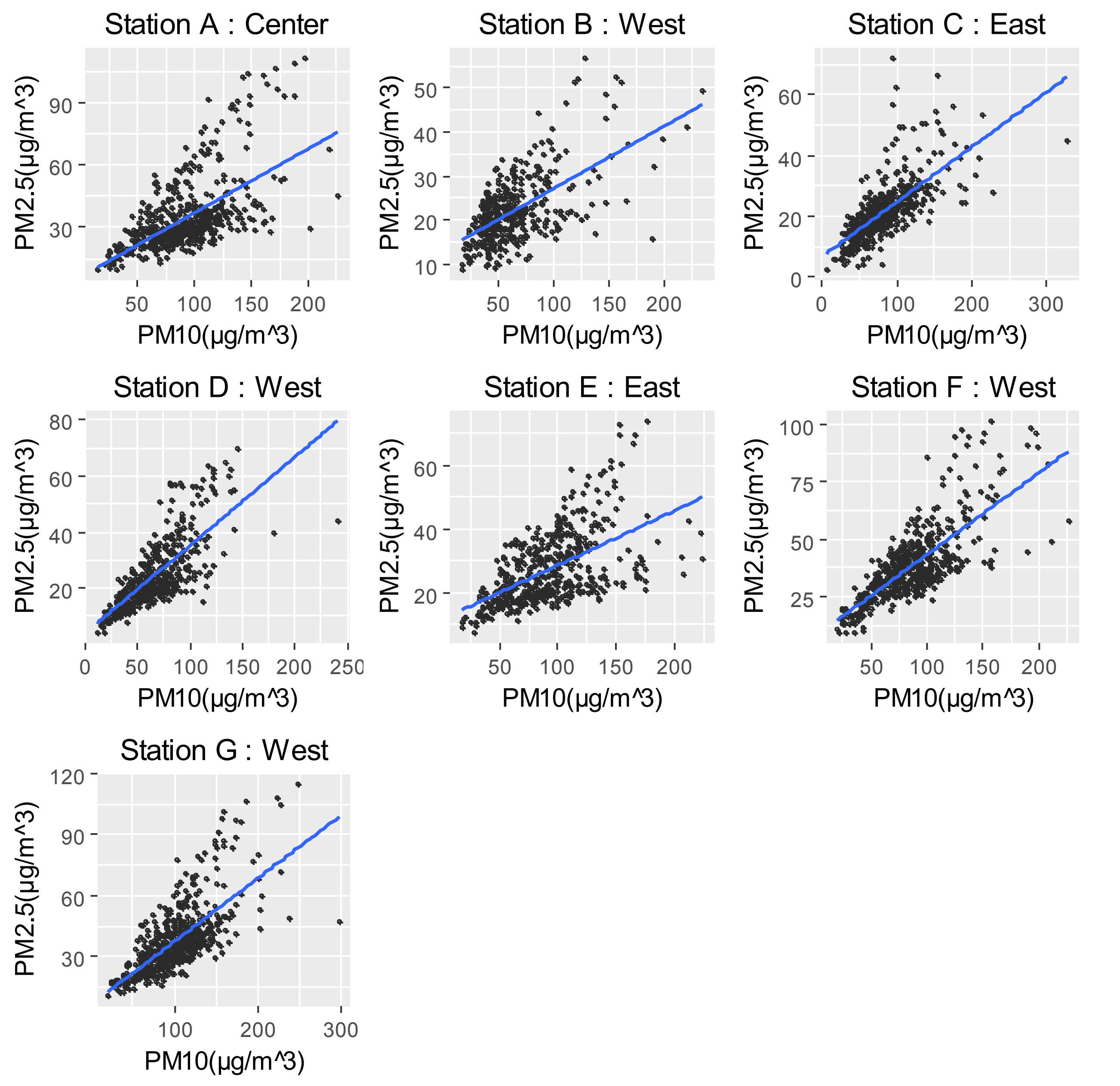

Fig. 1. The scatter plots of $PM_{2.5}$ against PM_{10} with fitted regression lines in all station

One of the most common indexes to describe the compliance of $PM_{2.5}$ from PM_{10} is $PM_{2.5}$ /PM_{10} ratio. Fig. 2 shows the trend of $PM_{2.5}$ /PM_{10} in different stations during the study period. In all stations, the maximum value of this ratio was observed in winter and the peak value between all stations was observed at station F in the west of Tehran, equal to 62.5 %. At this time, the minimum value was observed at station E in the east of Tehran, equal to 31.2 %. The same condition is observable about minimum values of $PM_{2.5}$/PM_{10} ratios. In each station, minimum value of this ratio was observed in summer time and the least value in all stations was observed at station E in the east of Tehran, equal to 16 %. At this time, the peak value was observed at station F in the west of Tehran, equal to 34.8 %.

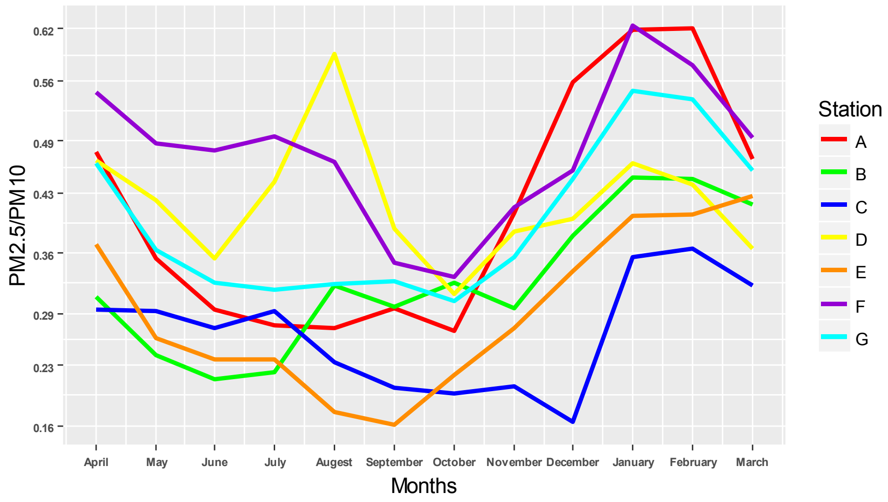

Fig. 2. Time plot of mean $PM_{2.5}$ /PM_{10} ratios in different stations

According to a study, it was mentioned that the max values of $PM_{2.5}$ concentration are observable in the winter for some reasons [9]. On the other hand dominant inversion in winter causes to keep the $PM_{2.5}$ in the air [10]. Another important parameter is $PM_{2.5}$ /PM_{10}. Several studies have reported the $PM_{2.5}$/PM_{10} ratio in different cities and seasons around the world [11-12]. This ratio is different from a city to another one. Based on a study, it was reported 45 % for $PM_{2.5}$/PM_{10} (SD = ± 10 %) [13]. Many of studies reported this ratio around this amount. But the important part of the current study is variation of this value from summer to winter. In the current study, the maximum and minimum value of $PM_{2.5}$/ PM_{10} was 62.5 % and 16 %, respectively. The range of variation in this ratio is extensive in comparison with the similar studies [14].

Meteorological factors can be one of the main effective factors in this variation. On the other hand, low efficiency of vehicles motors, traffic pattern, high carbonaceous material content and high level of NO_2 content have direct effect on secondary particles formation. To determine the spatial variation between $PM_{2.5}$/ PM_{10} ratio values in different areas of the city, Friedman test has been used. For this purpose we computed the mean of $PM_{2.5}$ /PM_{10} ratios in west and east areas, then the Friedman test was applied. The results of the test are shown in Table 2.

As mentioned in Table2, the differences in mean $PM_{2.5}$ /PM_{10} ratios between west and east areas are significant ($P_{value} < 0.001$). This difference is shown in Fig. 3.

As can be seen in this figure, the spatial variation of $PM_{2.5}$/ PM_{10} ratio in two groups is not negligible. Fig. 3 shows significant differences between $PM_{2.5}$/ PM_{10} values in east and west of Tehran.

Spatial and seasonal variation in $PM_{2.5}$ in urban areas is very important to predict the high concentration of $PM_{2.5}$ for awareness of sensitive group. In the current study, the $PM_{2.5}$/ PM_{10} in all stations had a same pattern. But, the differences between stations in various locations of the city are significant (Figs. 2 and 3).

Various studies have shown that $PM_{2.5}$/ PM_{10} ratio depends on air turbulence in the urban space.

Table 2. Friedman Test of mean $PM_{2.5}$/PM_{10} ratios (in different months) for west and east area

Friedman Test Statistic (Chi - Square)	**12**
Degree of freedom	1
P_{value}	< 0.001

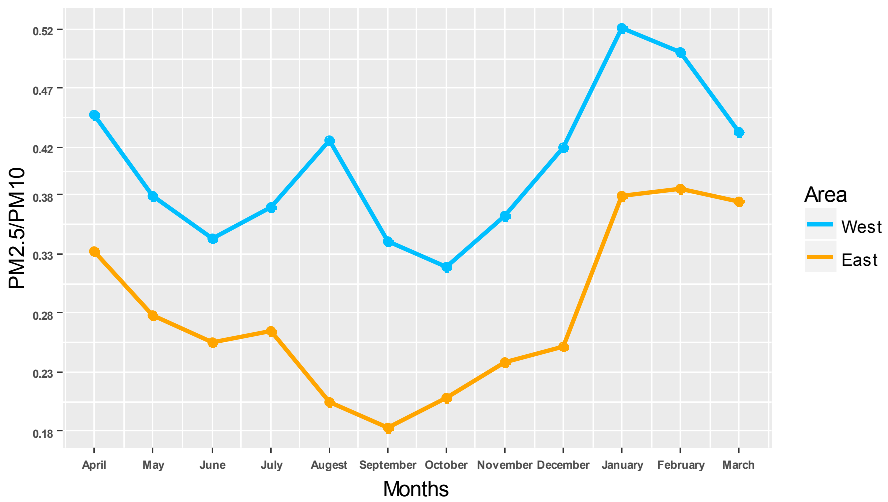

Fig. 3. Time plot of Mean PM $_{2.5}$ /PM $_{10}$ ratios in different areas

However, the high speed of vehicles results the resuspension of particles and decreasing the ratio of $PM_{2.5}$ / PM_{10} , in this study the mentioned ratio didn't decrease. The pattern of traffic in Tehran depends on some parameters. One of the most important traffic patterns is some towns with the significant population in the west border of Tehran with the close distance to Tehran (< 50 Km) which cause to increase the travel to Tehran. On the other hand, the direction of dominant winds in Tehran is from the west to the east. As the result, the west area of Tehran is affecting by the pollutant produced in these towns continuously. This reason could explain the higher $PM_{2.5}$ /PM_{10} ratio in the west of Tehran.

Several studies reported that main part of PM_{10} is consisted of $PM_{2.5}$. The concentration of $PM_{2.5}$ follows the concentration of PM_{10} [15]. In the current study, $PM_{2.5}$ consists of main part of PM_{10} weight at winter. Several parameters can effect on this matter. Based on a study, it was reported that BTEX concentration has peak value in the summer in Tehran urban air because of summer vaporization from the motors and fuel reservoirs. Also it was reported that BTEX concentration in $PM_{2.5}$ in summers is significantly higher than winter [16]. BTEX compounds have high molecular weight and low degree of reaction intensity. Therefor in the summer the main part of carbonaceous pollutants in the air is unburned molecules like BTEX. Hence there is different scenario in the winter [17]. In a study, it was reported that the main part of carbonaceous pollutant in the winter is incomplete combusted compounds [18]. They are more reactive and lighter than unburned compounds. Therefore, carbon content of fine particles is significantly higher in the winter than summer. It can increase the weight of $PM_{2.5}$, resulting the increase of weight ratio of $PM_{2.5}$/PM_{10}.

CONCLUSIONS

The concentration of $PM_{2.5}$ can be predicted by the concentration of PM_{10} in urban area. $PM_{2.5}$ / PM_{10} ratio has significant spatial variation in different area of the cities. Besides, there is significant seasonal variation in $PM_{2.5}$ / PM_{10} ratio. The maximum value of this ratio occurs in winter due to the incomplete combustion of fuels releasing $PM_{2.5}$. Moreover an increase in $PM_{2.5}$ concentration, can increase $PM_{2.5}$ weight portion in total weight of PM_{10}. It was observed that the maximum rate of $PM_{2.5}$ / PM_{10} in Tehran is significantly higher than similar studies around the world. May be it is for the incomplete combustion of fuels in winter.

FINANCIAL SUPPORTS

This study was supported by the authors.

COMPETING INTERESTS

The authors declare that they have no conflict of interest.

ACKNOWLEDGEMENTS

The authors are grateful to thank the air pollution laboratory, Environmental Health Engineering Department, Faculty of Health, Tehran University of Medical Sciences, Tehran, Iran.

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.

REFERENCES

[1] Bell ML, Dominici F, Ebisu K, Zeger SL, Samet JM. Spatial and temporal variation in PM2. 5 chemical composition in the United States for health effects studies. Environmental health perspectives. 2007;115(7):989.

[2] Nowak DJ, Hirabayashi S, Bodine A, Hoehn R. Modeled PM2. 5 removal by trees in ten US cities and associated health effects. Environmental Pollution. 2013;178:395-402.

[3] Pui DY, Chen S-C, Zuo Z. PM2. 5 in China: Measurements, sources, visibility and health effects, and mitigation. Particuology. 2014;13:1-26.

[4] Janssen N, Hoek G, Simic-Lawson M, Fischer P, Keuken M, Atkinson R, et al. Black carbon as an additional indicator of the adverse health effects of airborne particles compared with PM10 and PM2. 5. National Institute of Environmental Health Science; 2011.

[5] Monn C, Becker S. Cytotoxicity and induction of proinflammatory cytokines from human monocytes exposed to fine (PM2. 5) and coarse particles (PM10–2.5) in outdoor and indoor air. Toxicology and applied pharmacology. 1999;155(3):245-52.

[6] Franklin M, Koutrakis P, Schwartz J. The role of particle composition on the association between PM2. 5 and mortality. Epidemiology (Cambridge, Mass). 2008;19(5):680.

[7] Atkinson R, Kang S, Anderson H, Mills I, Walton H. Epidemiological time series studies of PM2. 5 and daily mortality and hospital admissions: a systematic review and meta-analysis. Thorax. 2014:thoraxjnl-2013-204492.

[8] Kloog I, Koutrakis P, Coull BA, Lee HJ, Schwartz J. Assessing temporally and spatially resolved PM2. 5 exposures for epidemiological studies using satellite aerosol optical depth measurements. Atmospheric environment. 2011;45(35):6267-75.

[9] Hueglin C, Gehrig R, Baltensperger U, Gysel M, Monn C, Vonmont H. Chemical characterisation of PM2. 5, PM10 and coarse particles at urban, near-city and rural sites in Switzerland. Atmospheric Environment. 2005;39(4):637-51.

[10] Querol X, Alastuey A, Ruiz C, Artiñano B, Hansson H, Harrison R, et al. Speciation and origin of PM10 and PM2. 5 in selected European cities. Atmospheric Environment. 2004;38(38):6547-55.

[11] Wang X, Bi X, Sheng G, Fu J. Chemical composition and sources of PM10 and PM2. 5 aerosols in Guangzhou, China. Environmental Monitoring and Assessment. 2006;119(1):425-39.

[12] Marcazzan G, Ceriani M, Valli G, Vecchi R. Source apportionment of PM10 and PM2. 5 in Milan (Italy) using receptor modelling. Science of the Total Environment. 2003;317(1):137-47.

[13] Xu G, Jiao L, Zhang B, Zhao S, Yuan M, Gu Y, et al. Spatial and temporal variability of the PM2. 5/PM10 ratio in Wuhan, Central China. Aerosol and Air Quality Research. 2017;17(3):741-51.

[14] Sun Y, Zhuang G, Tang A, Wang Y, An Z. Chemical characteristics of PM2. 5 and PM10 in haze− fog episodes in Beijing. Environmental science & technology. 2006;40(10):3148-55.

[15] Marcazzan G, Ceriani M, Valli G, Vecchi R. Source apportionment of PM10 and PM2. 5 in Milan (Italy) using receptor modelling. Science of the Total Environment. 2003;317(1-3):137-47.

[16] Amini H, Hosseini V, Schindler C, Hassankhany H, Yunesian M, Henderson SB, et al. Spatiotemporal description of BTEX volatile organic compounds in a Middle Eastern megacity: Tehran Study of Exposure Prediction for Environmental Health Research (Tehran SEPEHR). Environmental Pollution. 2017;226:219-29.

[17] Fazlzadeh Davil M, Rostami R, Zarei A, Feizizadeh M, Mahdavi M, Mohammadi A, et al. A survey of 24 hour variations of BTEX concentration in the ambient air of Tehran. Journal of Babol University of Medical Sciences. 2012:50-5.

[18] Yang H, Yu JZ, Ho SSH, Xu J, Wu W-S, Wan CH, et al. The chemical composition of inorganic and carbonaceous materials in PM2. 5 in Nanjing, China. Atmospheric Environment. 2005;39(20):3735-49.