Review of the PM2.5 source apportioning studies in the Megacity of Tehran

Hossein Khajehpour*
Assistant Professor, Department of Energy Engineering, Sharif University of Technology, Tehran, Iran

Farzaneh Taksibi
Master of Energy Systems Engineering, Department of Energy Engineering, Sharif University of Technology, Tehran, Iran

Mohammad Sadegh Hassanvand
Associate Professor, Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.
Center for Air Pollution Research (CAPR), Institute for Environmental Research (IER), Tehran University of Medical Sciences, Tehran, Iran.

ABSTRACT

Global trend of urbanization and limited environmental capacities have caused air pollution in Megacities, as one of the most prominent environmental concerns. In recent years, PM2.5 has been the major air pollutant in Megacity of Tehran and the leading environmental risk factor causing health effects. Identification of the sources of this pollution is necessary for effective environmental management program. Therefore, numerous studies have focused on source apportioning of PM2.5 in Tehran through emission inventory, source apportionment, and sensitivity analysis of the pollutants to the emission sources. Comparison of the methods and the derived results on relative shares of mobile and stationary sources in Tehran is studied in this short review. Our review shows that as the emission inventory approach is highly dependent to the geographic and sectoral coverage of the inventory, the results of this group of studies are not consistent. However, most of the source apportionment studies, although from different sampling locations and analytical methods, show similar shares of mobile and stationary sources in Tehran (in the range of 40% to 50%). This range is consistent with a published sensitivity analysis results which shows that 47% of the PM2.5 concentrations in Tehran is resulted from mobile sources. The paper is concluded with a discussion on the methodological limitations of the methods, and finally, some suggestions for further developments of the study are proposed.

Keywords: Air pollution, PM2.5, Source Apportioning, Megacity

1. INTRODUCTION

Air pollution and its health effects have been one of the main environmental issues since the industrial revolution. Exceeding the ecological capacity for handling environmental emissions has resulted in the accumulation of pollutants in the atmosphere. As a result, high concentrations of the local air pollutants has resulted in adverse human health effects. Especially in big cities and intense industrial zones emission rates are causing high pollutant concentrations. In big cities, which are very populated, pollution may adversely affect a high number of inhabitants and consequently causing high external health and economical costs. The concentration of the pollutant is highly dependent on the distribution of the emission sources, meteorological conditions, and topography of the city.

In order to manage and control the environmental emissions to guarantee permissible emission limits according to the ecological capacity and air quality standards, it is critically important to identify the emission sources and to apportion the observed pollution among them. Therefore, there have been numerous studies on the identification of the emission sources and their shares in causing environmental pollution.

The megacity of Tehran, with a population of ~10 million inhabitants, has been among the most polluted megacities in the MENA region [1]. According to the World Bank estimates, the environmental health costs form air pollution in Tehran has been as high as 2.6 B$ in 2016 [2]. In 2017, annual mean of particulate matter with a diameter less than 2.5 micrometers (PM2.5) concentration was nearly 3-time higher than the WHO air quality guideline level. Due to the geographic characteristics of Tehran, there have been differences among the 22 districts of the city regarding air pollutant concentrations.

PM2.5 has been the major air pollutant in Megacity of Tehran and the leading environmental risk factor causing health effects (Ref). This pollutant is either emitted from combustion and non-combustion emission sources or is produced from secondary photochemical reactions in the atmosphere. Therefore, most of the scientific literature about air pollution management in the city of Tehran has focused on the emission inventory and source apportionment of PM2.5.

2. SOURCE APPORTIONING METHODS

The subject of this research work is to review different techniques for estimation of the share of each emission sources in the PM2.5 concentrations in the Megacity of Tehran. There are three main methods for assessing the share of different emission sources on an observed concentration:

1- Through direct evaluation of the emission rates from each source in a complete emission inventory (EI) in which the emission rates are assessed based on the activity data or energy consumptions in a source of emission and the emission factor of the activity.

2- Through source apportionments (SA) from chemical analysis of a sample of pollutants in which the observed concentration is decomposed to the chemical components inside the sample. According to the previous study of the chemical characteristics of the emitted pollutant from a source, each chemical component is then attributed to one or more emission sources. As a result, shares of different emission source types in the total pollution are assessed proportionally to the share of the chemical substance attributed to that type of emission source.

3- Through sensitivity analysis (SNA) of the validated concentration distribution model from different emission sources, which assesses the sensitivity of the concentration to the emission from a specific source. A pre-requisite of this method is to develop a pollutant concentration distribution model, which is validated with the observed levels. Upon validation of the simulated concentrations, a comparison of the effects of changes in the emission rates from different emission sources on the concentration may be a proxy for apportioning the sources of pollution in observed pollution. The results of the sensitivity analysis help to understand the contribution of each source to the emission, and therefore, avail comparable results with the source apportionment studies.

3. RESULTS

For the review, the intention has been to cover all available literature, which have mainly or partly addressed the contribution of emission sources to the pollution. The literature is then categorized according to the date, the area and sector coverages, and the source apportioning

approach. Table 1 shows the reviewed literature in the present research work.

Table 1. The characteristics of included studies for PM2.5 source apportioning in Tehran

No.	Title	Assessment year	Approach	Study Area/Point	Ref.	Type
1	Tehran emission inventory by the Tehran Air Quality Control Company (TAQCC)	2013	EI	Metropolitan	[1-3]	Original
2	Evaluation of Tehran clean air action plan using emission inventory approach	2011	EI	Metropolitan	[4]	Complement to [1-3]
3	On the environmental effectiveness analysis of energy policies: A case study of air pollution in the megacity of Tehran	2015	EI	40x40 km2 area over Tehran	[5]	Original
4	Seasonal trends, chemical speciation and source apportionment of fine PM in Tehran	2017	SA	Central west	[6, 7]	Original
5	Source apportionment of ambient PM2.5 in two locations in central Tehran using the Positive Matrix Factorization (PMF) model	2018	SA	Two points in central and west	[8]	Original
6	Source apportionment of fine particulate matter in a Middle Eastern Metropolis, Tehran-Iran, using PMF with organic and inorganic markers	2020	SA	Two points in central and west	[9]	Original
7	Assessment of Emission Reduction Scenarios with a Focus on the Impact of Vehicle Fleets on Tehran Air Quality: Case Study	2013	SNA	Central west	[10]	Original according to EI in [1-3]
8	Sensitivity Analysis of PM2.5 Concentrations to the Emission Sources in the Megacity of Tehran	2015	SNA	Central west	[11]	Original according to EI in [4]

4. DISCUSSION (1 page)

Based on the engineering judgment on the accuracy of the results, the source apportionment results presented in the reviewed literature are compared with each other. Figure 1 shows the shares of mobile and stationary sources in the total anthropogenic PM2.5 concentrations/emissions, after excluding the shares of natural sources. In this figure, according to the methodological concepts of the reviewed research works, the EI studies show the contribution of the emission sources in total emissions over the city, while the SA and SNA approaches show the shares of emission sources in the observed concentrations at the sampling points. Also, it is worth mentioning that the SNA study of Shahbazi et al. (the 7th item in the Table 1) investigates the relative shares of different categories of the mobile sources in the observed concentration and does not study the shares of stationary sources [13]. Therefore, the results of this study are not relevant to the Figure 1.

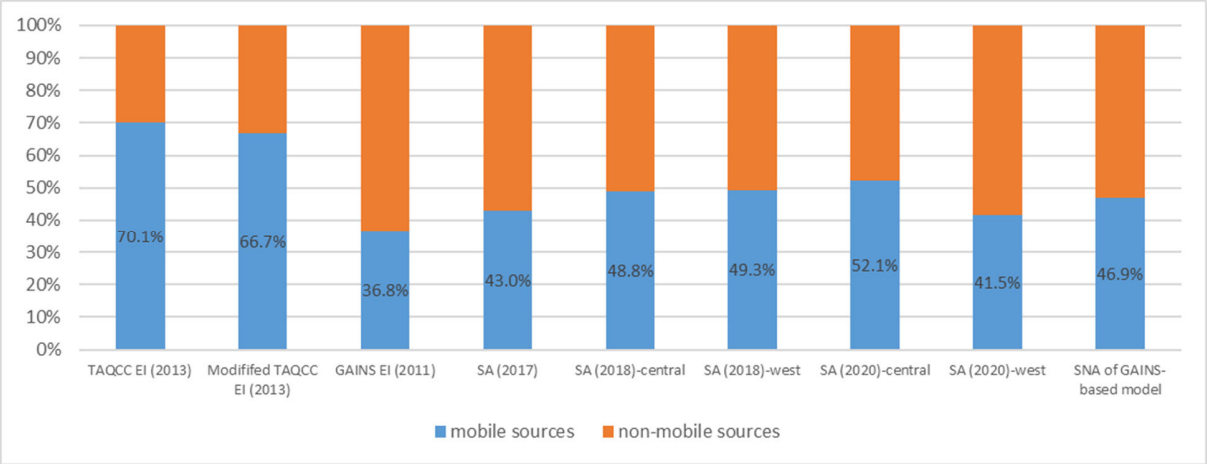

Fig. 1. Shares of mobile and stationary sources in the total anthropogenic PM2.5 concentrations/emissions in reviewed source apportioning studies in Table 1.

As it is shown in Figure 1, individual source apportioning studies show the lower share of mobile sources in total anthropogenic PM2.5 emissions than the value which is obtained in the official emission inventory report from the Tehran Air Quality Control Company for 2013 and its revision. One possible reason for the inconsistency between the results of different studies is the inherent methodological uncertainties among them. Uncertainties in activity data and emission factors, as well as differences in the coverage of the emissive sectors in the studied area, is the primary source of uncertainties in EI studies. The EI studies of the TAQCC consider only the emission sources inside the specific territory of the megacity of Tehran [4], while the EI study of Tehran by Taksibi et al, covers a wider 40x40 km2 area over the city which also includes the agricultural and more industrial emission sources in the South [8]. Also, the EI studies are not capable of taking into account the secondary formation of the particulate matter formation in the atmosphere due to photochemical reactions. However, on the other hand, the SA studies are specific to a sampling point in the city, and they are not averaged over the whole city. Considering the meteorological and topographic differences in Tehran, the sampling principle in SA studies may be a source of inconsistency among the results. And finally, the SNA studies, in addition to the inherent uncertainties in the EI studies, also suffer from the uncertainties of the pollutant dispersion modeling.

However, considering the international emission inventory results for different regions of the world it is also recommended that shares of stationary emission sources (buildings and industries) in total PM2.5 emissions are higher than the share of mobile source [1]. A European study based on a source allocation (SNA) of PM2.5 urban background concentrations (including. natural sources) found that the contribution of road transport (mobile source) in urban areas is about 14% [15]. However, the study shows a high range reaching from only 2% to 39% depending on the city. Especially in larger cities like Paris, Madrid, and London higher values are reported. At traffic stations the contribution is likely to be even higher, which needs to be considered when comparing source apportioning studies for different locations. In this paper, the sampling points of all the reviewed SA studies were in urban backgrounds of populated districts in Tehran.

The wide range of sectoral proportions nevertheless shows the necessity for targeted air quality plans for each city and even single city districts in the case of megacities. Source

apportioning methods can, in this regard, contribute to identifying key sectors for further policies.

5. CONCLUSION

Exceeding the ecological capacity for handling environmental emissions has resulted in the accumulation of pollutants in the atmosphere. Air pollution in the Megacities is one of the main environmental issues which imposes high damage costs. Identification of the shares of different sources of emissions is necessary for proper environmental management. PM2.5 has been the main pollutant in Tehran. In the present research work, recent air pollution studies in Tehran are reviewed to investigate the shares of mobile and stationary sources in PM2.5 concentrations in Tehran. Studies from different source apportioning approaches are reviewed. As a result, individual source apportioning studies show that the averaged contribution of mobile sources in the air pollution in Tehran is 48%, much lower than the value which is considered in the official reports claim.

This study is not to cover all the available literature on air pollution in Tehran. Conversely, it focuses on the available results from different PM2.5 source apportioning approaches in recent years. Also, it has only considered published results and SA studies which have assigned the chemical compositions of the samples to the emission sources. Additionally, indoor pollution sources are not taken into account. A more comprehensive study on further researches and interpretation of the results from different SA approaches is recommended to be investigated in future research works. Moreover, the transparency of methods used to estimate and apportion the emission sources is important to identify due to the uncertainty in various approaches causing differences in results.

6. ACKNOWLEDGEMENT (0.1 page)

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