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SENSITIVITY ANALYSIS OF $PM_{2.5}$ CONCENTRATIONS TO THE EMISSION SOURCES IN THE MEGACITY OF TEHRAN

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1. INTRODUCTION

Permissible emission limits are accounted for according to the ecological capacity to guarantee air quality guidelines and standards (Khajehpour et al. 2018). In order to manage and control the environmental emissions, it is critically important to identify the emission sources and to apportion the observed pollution among them (Khajehpour et al. 2017). Therefore, there have been numerous studies on the identification of the emission sources and their shares in causing environmental pollution (Belis et al. 2013; Naidja et al. 2018; Tunno et al. 2016; Viana et al. 2008; Zhang et al. 2017). There are different approaches which indicate the share of emission sources in air quality (not emission). Metrological conditions, source locations, and types, and land topography are among the most important factors to be considered in the quantification of the environmental effects of emission.

In recent years, the concentration of particulate matter in Tehran, the capital city of Iran, has become one of the main environmental challenges in this Megacity. In 2019, 75% of the polluted days in Tehran were due to a high concentration of $PM_{2.5}$ (TAQCC 2020).

Extensive studies have been conducted on the emission inventory of air pollution in Tehran. However, depending on the sectoral and geographic coverage and differences in emission factors and activity data, inconsistent emission inventories are reported for Tehran. The shares of mobile sources, residential, commercial, and industrial sectors are reported to be 83.2%, 2.4%, and 16.8% in $PM_{2.5}$ emissions in Tehran in 2012 (Bayat et al. 2012). In another official report in 2017 from Tehran Air Quality and Control Company (TAQCC), the share of mobile sources and stationary sources was 69.8% and 30.2% respectively (Shahbazi et al. 2016).

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On the other hand, numerous source apportionment studies were conducted to apportion the share of different emission sources in an observed PM concentration according to the chemical composition of the sample. These source apportionment studies have also reported different shares of emission sources in total PM samples in different locations of Tehran. For instance, in 2016, TAQCC published a report on source apportionment of particulate matters in Tehran. According to this report, 23% of particulate matter emissions in Tehran are caused by environmental dust. Among other compounds, 29% are from mobile sources and 7% are from other organic particles (Arhami et al. 2017).

Another approach for quantification of the contribution of the pollution to the emission sources is sensitivity analysis (Clappier et al. 2017). In this research, for the first time for Tehran, the sensitivity of the $PM_{2.5}$ concentrations to the emission sources is analyzed.

2. METHODOLOGY

2.1 The Procedure for the Sensitivity Analyses Approach

The methodology selected for this research is illustrated in Figure 1. In this procedure, the process for analyzing the sensitivity of the concentration to the emissions from a specific source starts from the identification of the geographical distribution and activity data (i.e., the extent of energy supply and temporal variations of energy demand). Then the emission factors are collected. Next, emission inventories are developed to simulate the spatial distribution of the emissions over the study area. The emission data, together with the meteorological and topographic data, then input to the pollutant dispersion modeling. By comparing the simulated concentrations with the actual concentrations recorded at the air quality monitoring station, the dispersion model can be validated. from all of the sources.

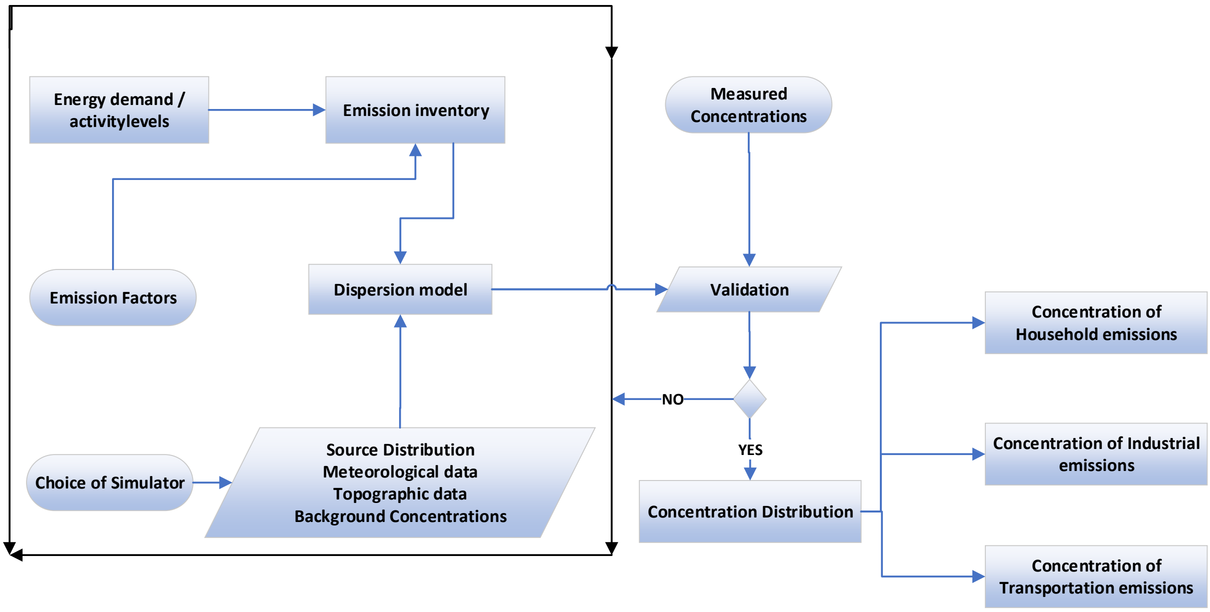

Figure 1 Procedure of analyzing the sensitivity of the concentration to the emission from a specific source

The final step in the sensitivity analysis approach is to calculate the contribution of each source of emission in the pollutant concentration in the absence of the other sources and to compare it with the concentration of the modeling when considering total emissions

2.2 Strengths and Limitations of the Sensitivity Analyses Approach

The sensitivity Analysis Approach has some advantages and disadvantages which should be considered. The main disadvantages of this method are:

- The approach is dependent on emission inventory input to the dispersion model,
- It is based on the uncertainties in the assumptions in concentration distribution modeling (boundary and background concentrations, emission sources, and mass fluxes, …) and the inaccuracies in the validation of the simulation results,
- It might be costly due to the necessity of access to compatible dispersion simulation models and gathering model inputs.

On the other hand, there are some advantages for this approach which are:

- Compatibility for consideration of secondary pollutant formation in the atmosphere,
- Possibility of long-term and short-term estimates,
- And finally, the Sensitivity Analysis Approach is the only tool for assessing the effects of different emission sources and to predict the effectiveness of the mitigation scenarios.

3. RESULTS and DISCUSSIONS

3.1 Tehran Emission Inventory

Emission factors of the fine particulate matters ($PM_{2.5}$) were estimated using the Greenhouse gases and Air Pollution Interactions and Synergies (GAINS) model which is developed at the International Institute for Applied Systems Analysis (IIASA) (IIASA 2020). The GAINS model used to evaluate the effects of air pollution controls and GHG emissions reduction policies on air pollutant emissions, public and environmental health, and abatement costs (Amann et al. 2008).

The sources of emissions in Tehran are divided into a general distribution of stationary and mobile resources. Mobile resources include different transportation modes, and stationary resources include domestic and public residential, commercial, waste management, industrial activities, Tehran oil refinery, and power plants.

Considering the number of activity levels, fuel consumption, and the technologies implemented in each of these sub-sectors (Taksibi et al. 2020), the emission factors reported in the GAINS model is used to calculate emission inventories for primary

$PM_{2.5}$ emissions for the base year 2010. The emission inventory results depicted in Figure 2 shows that the industry and energy conversion sectors had the highest share of primary $PM_{2.5}$ emissions among all sources, over the domain covering the Megacity of Tehran (50×50 km).

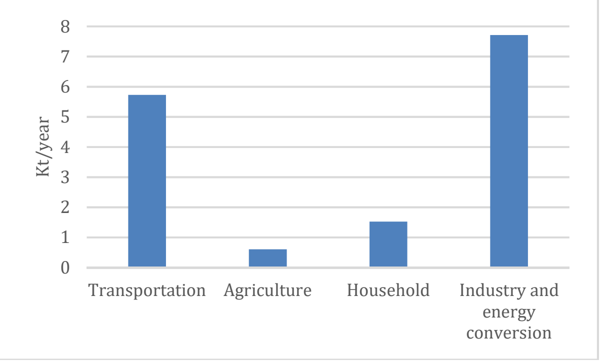

Figure 2 Tehran Emission Inventory in 2010

3.2 Pollutant Dispersion Model

The impact of a pollution source depends strongly on the meteorological condition, the site location, the stack height of the source (where appropriate), and the distribution of the affected population. Such variation is especially strong for primary pollutants.

ADMS-Urban is an advanced Gaussian dispersion model developed by the Cambridge Environmental Research Consultants (CERC). The model can simulate the dispersion of pollutants released from industrial, domestic, and road traffic sources into the atmosphere (Taksibi et al. 2020). Specific extensions of the model are especially suitable for urban areas (Ashrafi and Hoshyaripour 2010; De Nicola et al. 2013; Righi et al. 2009). The model predicts the boundary layer structure by using physical variables such as the Monin–Obukhov length and the boundary layer height. ADMS-Urban uses an advanced Gaussian approach with a normal distribution in stable and neutral conditions, whilst the vertical dispersion is approximated by two different distributions in a convective boundary layer (Khajehpour et al. 2018).

The input data for modeling pollutant dispersion can be categorized into 4 types: meteorological data, emission source data, background data, and geographical data.

Meteorological compulsory inputs, which are required for the implementation of the Disturbance model, are wind speed and direction, plus one of the reciprocal of Monin–Obukhov length, surface sensible heat flux, or cloud cover datasets parameters. In its operational configuration, the model provides daily runs, with a domain covering the Megacity of Tehran (50×50 km), at a resolution of 2.5 km.

3.3 Validation of the Model Results

Sharif monitoring station located in the west of the city is classified as an urban-traffic station by type of the area. It is closed to dominant emission sources from vehicles. To validate the model results in the base case, the predicted daily concentrations of $PM_{2.5}$ are compared with the measured values reported by TAQCC in 2010 (Figure 3).

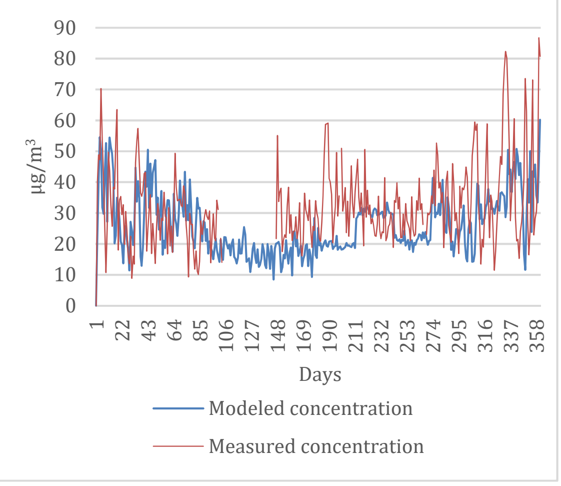

Figure 3 Validation result of the ADMS_Urban model with the actual $PM_{2.5}$ concentrations at Sharif air quality monitoring station

The result indicates that the patterns of fluctuations of the modeled concentration have overlap with the measured concentration at the receptor base. Therefore, the model can be assumed valid for the sensitivity analysis.

3.2 Sensitivity Analysis

In order to estimate the source contributions to the overall modeled $PM_{2.5}$ concentrations, individual modelings are done for each source of the emissions. The resulted concentrations of each of the emissions sources are then normalized to the total-source modeling results. The calculated concentrations are depicted in Figure 4.

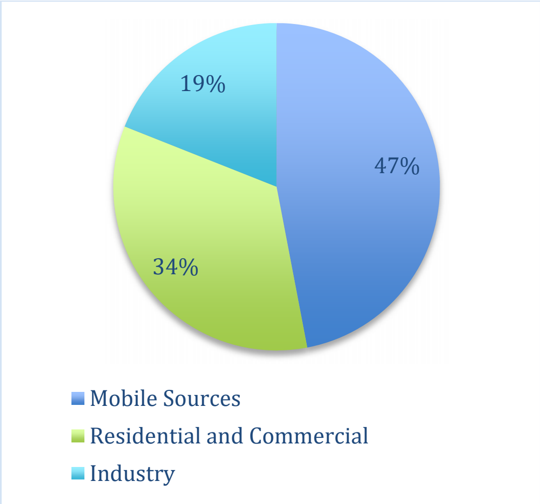

Figure 4 Sensitivity analysis of emission sources in a sample point in west of Tehran

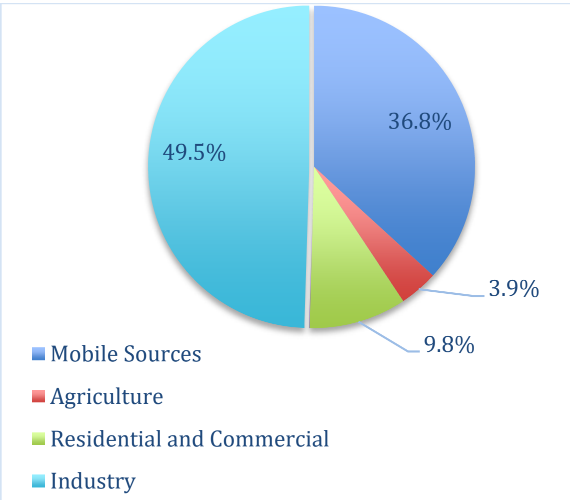

Figure 5 Share of emission sources in total emission inventory of Megacity of Tehran in 2010 (Taksibi et al. 2020)

According to this figure, near half of the $PM_{2.5}$ concentration in the Sharif air quality monitoring station in the west of Tehran is originated from mobile sources and 34 percent comes from the industrial sector.

A comparison of the derived results with the emission inventories which is shown in Figure 5 indicates the necessity of the sensitivity analysis for effective environmental management.

4. CONCLUSION

In environmental management, what matters is the proper control of the reason for the pollution. To this end, in addition to the emission inventory of the various sources, several other factors must also be considered in the environmental analysis, e.g., meteorological conditions, land topography, the secondary formation of the pollutants in the atmosphere, and closeness of the emissions sources to the residential point under study. These factors are taken into account in the sensitivity analysis. Therefore, the sensitivity analysis can reflect the share of emission sources in pollution and it is necessary for air pollution management in megacities, at least as a complement for emission inventory results. However, this needs the development of a validated pollutant dispersion model. Moreover, the pollution control policies must be evaluated by analyzing the sensitivity of the observed concentration to the mitigation measures under study.

This research work suffers from many shortcomings. Initially, more accurate and updated sensitivity analysis inputs are necessary for future studies. Also, the use of the use of pollution dispersion models which are capable of complete accounting of the secondary formation of the $PM_{2.5}$ in the atmosphere through photochemical reactions is necessary.

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