A hybrid model of environmental impact assessment of PM2.5 concentration using multi-criteria decision-making (MCDM) and geographical information system (GIS)—a case study

Abstract

Air pollution as one of the consequences of industrial development has been increasing with population growth, urbanization, private transportation, and fuel consumption in metropolitan areas. Tehran as the largest city of Iran has many problems regarding its geographical conditions, population growth, weakness of planning, and lack of environmental management. Considering the importance of air pollution, particularly $PM_{2.5}$ pollutants, the present study assesses the environmental impacts of $PM_{2.5}$ in Tehran metropolis using four-year consecutive data. the Inverse Distance Weighting model for interpolation, Geographically Weighted Regression (GWR) model for measuring the relationship between key factors and $PM_{2.5}$ pollutant concentration, and ANP-FUZZY model for environmental impact assessment were utilized. The principal source of $PM_{2.5}$ emissions in the study area is related to the surrounding areas of Tehran such as sand and gravel mining, the closure of the chief part of the Tehran wind tunnel with high-raised buildings in the western region, dried wetlands, and open burning of solid wastes in the south of Tehran. Finally, four alternatives were introduced to assess $PM_{2.5}$ impacts. The assessment results of the proposed alternatives using the FANP model, demonstrate the strict management in the surrounding neighborhoods of Tehran with 38% sensitivity is the best alternative.

Keywords: EIA; $PM_{2.5}$ pollutants; IDW; GWR; ANP-FUZZY; Tehran

1- Introduction

Because of a massive transition toward urbanization, nowadays, the majority of the world population lives in urban areas such that the proportion of this population is still increasing (1, 2).

Metropolises and modern urban systems with their high density of population and economic activities, their nodal position in interwoven national and international networks, and their ambition to act as motors in the competitive process of open regions have faced increasing environmental problems. These issues range from air, soil, and water pollution to untouchable externalities such as noise annoyance, lack of safety, and destruction of "cityscape" (i.e., visual pollution). There are a wide variety of sources generating these urban environmental problems, including demographic factors, socioeconomic development, inefficient energy consumption, inappropriate technologies, spatial behavioral patterns, and most important of all, improper and/or weakly enforced urban environmental policy measures (2, 3).

In this regard, one of the most challenging environmental phenomena that humans face is the issue of air pollution. Air pollution refers to a chemical, physical, or biological change in the atmospheric air (4). This problem emerges whenever harmful gasses, smoke, or dust enter the atmosphere and, in turn, hinder the survival of humans, animals, and plants. Particulate matter (PM) is one of the major pollutants in the air. PM is a monopoly term used to combine aggressive and inhaled particles in the air. The term $PM_{2.5}$ refers to solid and liquid particles less than 2.5 μm in aerodynamic diameter (5, 6).

Epidemiological studies have shown that exposure to $PM_{2.5}$ causes adverse health effects such as deaths due to damage to the lungs and respiratory system. In this context, approximately 1.2 million deaths due to $PM_{2.5}$ have occurred in different parts of the world (7). Numerous studies have been conducted on the impacts of $PM_{2.5}$. For instance, Lichun Wu (2019), Masud Yunesian (2019), Fang Wang (2019), Lili Du (2019), Injeong Kim (2019), Motesaddi Zarandi (2019), Tin Thongthammachart (2019), Anoushiravan MohseniBandpi (2019), Zhang Yongyong (2019), and Peng Zhou (2014) indicated that carcinogenic risk of $PM_{2.5}$ is linked to metals part of $PM_{2.5}$ (8-17). Moreover, there are studies associated with ARDS risk, cytotoxicity, mortality, and lung damage connected to $PM_{2.5}$ (18-23). The health impacts of $PM_{2.5}$ are different because of the difference in the composition of $PM_{2.5}$ and some studies have been done in Tehran about the impacts of $PM_{2.5}$ (13, 15, and 21).

To date, no comprehensive study has been done on detecting the main sources of this pollutant and an appropriate strategy for its reduction and control. In recent years, suspended particulate pollutants, especially particles less than 2.5 microns in diameter, have been reported as significant pollutants. Moreover, almost all the air-polluted days have occurred due to increased concentrations of this pollutant in the Tehran metropolis (24).

Therefore, in the present study, we tried to identify the principal sources of this pollutant production and its contribution to the 22 districts of Tehran with a synoptic insight. For this purpose, the new spatial statistics methods of Geographically Weighted Regression (GWR) and interpolation methods were utilized. Next, considering the identification and the contribution of these factors, and based on the models' output and views of policymakers in this area, four possible scenarios are propose and assessed for controlling and reducing this pollutant. At this stage, the overall framework of the environmental impact assessment model is completed. Finally, using the ANP-Fuzzy method, an appropriate scenario is chosen to reduce this urban problem.

2- Data and Methodology

2.1- Introducing the area of the study

Tehran with an area of about 733 km^2 is located on the southern slopes of the central Alborz. The city lies between the coordinates of 51° 4′ to 51° and 33′ E and 35° 35′ to 35°, and 51′ N. Tehran extends from the south and southwest ends at the plains of Varamin and Shahriar and is surrounded on the east and north by the mountains. Fig. 1 shows the geographic location of the Tehran metropolis.

Fig. 1. Location map of the study area

2.2- Data Required for the Research Process

The data needed to conduct this research are presented in Table 1. These data, which include the information source and type, are as follows:

Access to valid and up-to-date data is one of the important factors influencing the criteria selection, which is one of the major challenges in developing countries.

In this study, desktop and field studies were conducted to gather information and awareness of environmental realities. After collecting the data, they were sorted out to be used to achieve the research objectives. For data analysis, related tools such as Super Decision, ArcGIS, Matlab, and Excel were used.

Table 1. Primary data layers used in the study

2.3- Methodology

According to Fig. 2, the first phase of the study process consists of three main steps: In the first stage, $PM_{2.5}$ emissions over the years were studied. To this end, urban utilization, traffic and demographic characteristics, and the analysis of the distribution of fuel types and gas were used and studied for producing a database.

In the second step, to implement the proposed model, all available information, including the units that were located in the Tehran 22 districts, was added to the base map.

In the third stage, statistical models based on regression analysis were used to understand the relationship between $PM_{2.5}$ emission distribution and factors such as urban utilization, traffic, and demographic characteristics. Next, the distribution of fuel types and gas was analyzed. The global statistical models used in many scientific studies, such as the Ordinary Least Squares regression (OLS), did not have the sufficient efficiency, the conformance of the model with the data, and the accuracy required for the analysis of spatial data, such as those of the present study. Accordingly, the GWR model was used to provide more realistic and more accurate results with the maximum compliance of the model with the data.

Finally, in the study process, the Hot Spot model was implemented on the data in order to understand the hot and cold spots of the pollutant and the main factors (i.e., Gas, Gas oil, Kerosene, Fuel oil, and Gasoline) on its creation and presenting more realistic results.

Fig. 2. First phase diagram of the research process

Based on Fig. 3, to implement the second phase of the study, the following steps were taken: 1) identifying the optimal criteria and alternatives based on the views of experts and executives in the field of pollution, 2) determining the one-way, two-way, and feedback communication between criteria and alternatives, 3) creating a matrix of paired comparisons between criteria and strategies based on experts' opinions, 4) examining the degree of incosistancy of paired comparisons, the formation, and calculation of primary super-matrix (non-weighted), weighted super-matrix and limit super-matrix, 5) determining the final weight of criteria and alternatives, and ultimately 6) performing model's sensitivity analysis by choosing the superior strategy.

Fig. 3. Second phase diagram of the research process

In this step of the study, the Super Decisions software and MATLAB software were used to program and implement the ANP Fuzzy method.

2.3.1- Theoretical GWR model

The GWR can be easily used to detect patterns in a set of data (25, 26). This statistical technique, which is linked to the GIS tools, can be used to obtain descriptive information such that to extract spatial weight functions with the nearest locations and most similarities. Some parameters were used to evaluate the performance of the GWR model. The AICc is a relative measure of performance that is used to compare models (26, 27). AICc is a method of bandwidth selection in the GWR model. In addition, Least AICc leads to the choice of the best bandwidth (26, 28). Here, the model with a lower AICc value shows a better fit with the observed data and has better model performance (26, 29, 30). The GWR model was implemented for each homogeneous unit in the original study map. Arc Toolbox software such as ArcGIS can be used to calculate all parameters related to the GWR model. In general, the GWR is calibrated using multiple local-area regressions for each sampling point (26, 31). By selecting the appropriate "bandwidth", it is possible to control the size of the local neighborhood in the GWR. Fixed-kernel local regression is calibrated with little data, while kernel bandwidth is compatible with bandwidth distance. The bandwidth is smaller where the data are dense and larger when the data are scattered (26, 28, 29). The adaptive model can provide a more desirable evaluation than the fixed kernel. Moreover, it can provide more accurate and rational results that are close to reality. The adaptive kernel bandwidth selected for this study uses the bisquare function (26, 28, 32).

2.3.2- ANP-FUZZY

The fuzzy logic is introduced in the pairwise comparison of ANP to compensate for this defect in the conventional ANP and is referred to as ANP-FUZZY.

In the first step, constructing components of matrix pairwise with fuzzy judgments and determining local priorities, a consistency index was extracted for each matrix using the fuzzy prioritization method (33).

Second, by reviewing the consistency index and the overall local priorities in the group, priorities are examined using the nonlinear programming approach as described in (33).

In the third step, the supermatrix was filled with the extracted group priorities to form an unweighted supermatrix. To create a weighted supermatrix, the unweighted supermatrix was multiplied with the corresponding cluster priorities. Finally, the resulting supermatrix was adjusted to column stochastic (33).

In the fourth step, the super-weighted matrix is limited by raising it to large enough strength to converge to a stable super-matrix (all columns being the same) and prioritize the scores of other options for matrix maximum weight. The above steps can be used to obtain the overall objective factors and ultimately the weight of each agent's list. Overall, using the ANP method to solve practical problems is a complex process (33).

ANP-FUZZY is widely used in decision making for different types of disciplines. Sadaf Feyzi et al. (2019), Lihong Chen et al. (2018), Xing Gao et al. (2018), Metin et al. (xx), Javad Seyedmohammadi et al. (2018), Farnaz Najafinasab et al. (2015), Yuxel and Dogwin (2008), Promentilla et al. (2008), Liu and Lee (2009), Razmi et al. (2009), and Darabi et al. (2019) applied FANP for siting municipal solid waste incineration power plant in the north of Iran. To determine the weights of relevant planning criteria for multi-attribute sustainability evaluation of alternative aviation fuels, they applied the ANP FUZZY method. These researchers investigated the performance of the urban environmental office in China to identify the risk of false behavior in the work system. The other relevant studies are as follows: FANP for land suitability assessment based on remote sensing (RS) and GIS for irrigated maize cultivation; the Fuzzy analytic network process (AHP) approach to evaluate land and sea criteria for land use planning in coastal areas, identify faulty behavior risk (FBR) in the operating system, and evaluate contaminated site multi-criteria interactions; FANP to support decision making for environmental impact assessment; FANP to design a decision support system for evaluating and selecting suppliers; and FANP for Urban Flood Risk Mapping using GARP and QUEST models (34-43).

Some other applications of the ANP-FUZZY are described in references (44-50). Moreover, numerous studies have used various decision-making approaches such as ANP, TOPSIS, FUZZY TOPSIS, AHP FUZZY, ANP, and DEMATEL (51-58).

3- Results

3.1- Base maps of the study

Investigating the relationship between $PM_{2.5}$ emission and essential factors (i.e., Types of fuel consumption, Gas consumption, Traffic, Population, and Urban land use) needs preparing some units for the anlaysis of the model. In this research, the map of the Tehran metropolitan areas was used to prepare the ground plan of studies. Fig. 4 shows the map of the base units of the studies with 108 homogeneous units.

Fig. 4. Baseline study map of Tehran

3.2- Analysis of $PM_{2.5}$ **dispersions over the years studied**

Descriptive statistics of $PM_{2.5}$ are presented annually in Table 2 for the years 2014-2017. The highest concentrations of $PM_{2.5}$ in Tehran are from 2014 and 2015 with a concentration of 56 μg/m3 and then with a decreasing trend in 2016 and 2017.

To better understand of $PM_{2.5}$ dispersions over the years studied, the 4-year average map of this contaminant was drawn (Fig. 5) according to information from the monitoring stations of air pollution in Tehran and using the Inverse Distance Weighting (IDW) interpolation method. The results of $PM_{2.5}$ zoning during the years 2014-2017 show that the southern and western regions and to some extent toward the center have the maximum concentration.

Table 2. Statistical description of $PM_{2.5}$ concentration (μg/m^3) in Tehran metropolitan air during 2014-2017

Fig. 5. Zoning concentration of $PM_{2.5}$ pollutant in Tehran (2014-2017)

3.3- Impacts of key factors on $PM_{2.5}$ **production and distribution**

3.3.1- Fuel consumption in Tehran

In the years 2014-2017, the highest consumption of gas was in the south and west districts. In addition, the highest Gasoil consumption was in the west and partly in the central districts, respectively.

The highest consumption of gasoline, fuel oil, and kerosene was in the central, western regions, and central, eastern and western districts, respectively. Meanwhile, the lowest gas consumption was in the central and southwest areas. Moreover, there is no significant difference in terms of consumption of gas oil, gasoline, kerosene, and residue oil in other areas. The use of fuel types in different regions over the studied years is shown in Fig. 6.

Fig. 6. The use of fuel types (Gas consumption (A), Gas oil consumption (B), Fuel oil consumption (C), Kerosene oil consumption (D), and Gasoline consumption (E)) in different regions shown over the studied years (2014-2017)

3.3.2- Land use

In this section, land use is classified into four categories of green area, administrative and commercial, industrial, and residential use in the districts of Tehran. The share and area of four categories are listed below in the form of a map and relative area.

As shown in Fig. 7, the central regions and to some extent, the eastern districts with a share of 50%, the western regions and, to a certain extent, the eastern and southern areas with an approximate share of 20%, the northern and western regions, the southern regions with a share of 20 to 45%, and central areas with the share of approximately 25% have respectively the highest portions of residential, industrial, green area, and administrative and commercial use. In comparison, the western and southern regions have the highest levels of green and industrial use with the lowest residential consumption. The central areas have a minimum area in terms of green space and industry.

Fig. 7. The ratio of the residential area to the area of other land uses (A) (2014-2017), The ratio of the industrial area to the area of other land uses (B) (2014-2017), The ratio of the green space area to the area of other land uses (C) (2014-2017), and The ratio of the commercial-administrative area to the area of other land uses (D) (2014-2017)

3.3.3- Population

In this section, population density and population distribution of the Tehran metropolitan area are discussed.

Central and, to some extent, the southern regions have the highest density, while the western and northern districts have the lowest population density and distribution. In comparison, the amount of available green-space is contradictory to population density in Tehran. In the western areas, the largest green spaces and the lowest population density are seen.

Fig. 8. Population distribution (A) and the ratio of the population to the area (B) (2014-2017)

3.3.4- Road Traffic

Based on the collected data, traffic exists in all streets of Tehran during the years 2014-2017. The northern regions and, to some extent, the eastern areas have the highest traffic congestion whereas the western districts have the least traffic. These results were extracted from separate maps of the passages over the years 2014-2017.

Fig. 9. Road traffic based on speed (2014-2017)

4- Discussion

As shown in Fig. 10A, the best fit of the model (R^2 = 0.31-0.42) to the data entered in the analysis appears in the central regions with a tendency toward the north for $PM_{2.5}$ concentration and gas consumption from 2014 to 2017. In comparison, the least conformance of the model with the gas consumption data is seen in the western, south-western, eastern districts, and, to some extent, the northern regions.

According to Fig. 10B, the local R^2 range of the amount of fuel consumption (i.e., gasoline, gas oil, kerosene, and fuel oil) and $PM_{2.5}$ emissions is between 0.01 and 0.35 (2014 to 2017). In addition, the best conformance of the model with the data entered in the analysis is seen in the eastern and southeastern parts of the study area. Finally, the least compatibility of the model with the data on fuel consumption is observed in the south and northwest areas.

Similarly, the range of R^2 to relations between traffic and $PM_{2.5}$, population distribution and $PM_{2.5}$, land usage, and $PM_{2.5}$ reached 30 to 69%, 14 to 23%, and 44 to 76%, respectively. It should be noted that this correlation values between traffic and $PM_{2.5}$ only is found in a small part of the east, and is not significant in other areas. From the relations between traffic and $PM_{2.5}$ pollutant, it can be inferred that traffic congestion is not the cause of high $PM_{2.5}$ concentrations in the Tehran metropolis. In the case of population distribution, there is only 14 to 23% correlation is just a small portion of the east and west. However, there is a difference in relation to land use factor compared to other factors such that in the majority of the western regions and north the correlation between the pollutant and the agent was reported to be up to 40%. But, $PM_{2.5}$ pollutant results show that the main polluted area of the Tehran metropolis is south-western regions, with no significant relationship between any of the main factors and $PM_{2.5}$. It seems that the cause of pollution in the southern districts is drying wetlands in the surrounding areas of Tehran, unconventional and non-standard waste incineration in these areas, and adjacency to the Kahrizak site of waste disposal. Nevertheless, regarding the western and southwest regions, it is possibly due to blockage of the wind tunnel entering Tehran by high-rise buildings as well as the location of sand and gravel factories in these areas.

Fig. 10. Local R^2 between of natural gas Consumption (A), Types of Fuel (Gasoline, Gas oil, Kerosene, Fuel oil) (B), Population (C), Roads Traffic (D), and Land use changes (E) with concentration of $PM_{2.5}$ Pollutant using the GWR Model (2014- 2017)

We used Std Residual, coefficient Intercept, and Hotspot statistics to validate the results of local R^2. The outputs of these statistics are presented below for the relationship between principal factors and $PM_{2.5}$.

- Std Residual
- Coefficient Intercept
- Hotspot

Std Residual

The results of the Std Residual show that the GWR model is generally a suitable model for all of the studied districts. Based on the obtained results, only one, two, or three out of 108 areas did not match with the GWR model. Likewise, most of these districts were within the Std range of the -2.5 to +2.5.

These areas show different results for various relations between essential factors and $PM_{2.5}$. As shown in Fig. 11, there are 1, 2, 4, 1, and 2 districts with a standard deviation outside of the range of -2.5 to +2.5 for Gas Consumption and concentration of $PM_{2.5}$, Types of Fuel (Gasoline, Gas oil, Kerosene, Fuel oil) and concentration of $PM_{2.5}$, Population and concentration of $PM_{2.5}$, Roads Traffic and concentration of $PM_{2.5}$, and Land use changes and concentration of $PM_{2.5}$, respectively.

Fig. 11. Std Residual between of natural gas Consumption (A), Types of Fuel (Gasoline, Gas oil, Kerosene, Fuel oil) (B), Population (C), Roads Traffic (D), and Land use changes (E) with concentration of $PM_{2.5}$ Pollutant using the GWR Model (2014- 2017)

Coefficient Intercept

This coefficient shows the effect of the other residuals in various districts with local R^2 between the essential factors and concentration of $PM_{2.5}$. As shown in Fig. 12, this coefficient for regions with maximum local R2 about Gas Consumption and $PM_{2.5}$, Types of Fuel (Gasoline, Gas oil, Kerosene, Fuel oil) and $PM_{2.5}$, Population and $PM_{2.5}$, Roads Traffic and $PM_{2.5}$, and Land use changes and $PM_{2.5}$ is 0.40, 0.34, 0.20 to 0.35, 0.35 to 0.40, and 0.26, respectively.

Fig. 12. Coefficient Intercept between of natural gas Consumption (A), Types of Fuel (Gasoline, Gas oil, Kerosene, Fuel oil) (B), Population (C), Roads Traffic (D), and Land use changes (E) with concentration of $PM_{2.5}$ Pollutant using the GWR Model (2014- 2017)

Hotspot

In the present study, Spatio-temporal analysis of $PM_{2.5}$ pollutants, Gas Consumption, Types of Fuel, was and Population performed by the hotspots zoning method in the Tehran metropolis. The Getis-Ord-Gi statistic was used to identify hot and cold spots. Since the intensity of the clustering was determined by the Z score, it was applied to identify hot and cold spots of $PM_{2.5}$ concentrations, Gas Consumption, Types of Fuel, and Population at different locations in the period of 2014 to 2017. The results of the Getis-Ord-Gi statistics showed that the south and south-western areas have higher densities of these pollutants and are in the lower rank of the western and central regions. Thus, it can be stated that the zoning results of the Z-Score show an increase in hot spots from north to south and east to west. The maximum consumption of Gas, Gasoline, Gas oil, Kerosene, and Fuel oil was in the south and south-east and western regions, western regions, central regions, central regions, central regions with northward orientation, respectively.

Likewise, the minimum consumption of Gas and Gasoline was in the central and rather southwestern and southeastern parts, respectively (above 90% confidence levels). This result also is true for Gas, kerosene, and Gasoil consumption but fuel oil did not differ much in other areas.

In terms of population, the highest population distribution with a 95 to 99% confidence level is seen in the eastern and partly northern regions, and the central areas have the lowest population, which could be due to the congestion of commercial and administrative uses.

Fig. 13. Hotspots of natural gas consumption (A), Types of Fuel (Gasoline (B), Gas oil (C), Kerosene (D), Fuel oil (E)), Population (F), and $PM_{2.5}$ concentration (G)-(2014-2017)

The ANP-Fuzzy model was implemented based on the above results, determined local explanation coefficient, and information obtained from interfering parameters.

In this study, to determine the appropriate strategy for reducing the $PM_{2.5}$ concentration, the following alternatives were proposed;

- Strict environmental management in the surrounding neighborhoods;
- Change the country's economic capital;
- Change in the urban management system to reduce the potential impacts of this pollutant (traffic management, car restrictions, road construction, and management; and
- NO Action and BAU (Business as usual).

As shown in Fig. 14, the initial model for the main objective and interventional parameters (variables of the research or criteria) was developed in the Super Decisions 2.8 software. The other parameters used for this purpose are the internal and external relations between the criteria, alternatives, and the goal drawn. The FUZZY-ANP method was used to determine the weight of effective measures for evaluating $PM_{2.5}$ consequences. Next, these weights were introduced into the Super Decisions software. Table 3 shows the final weights of the criteria derived from the Fuzzy ANP method. In implementing the ANP method, the goal, criteria, and alternatives were set in three branches, each containing some elements. Besides, these elements that are interconnected within the branch are also interdependent between the branches (Fig. 23). It is worth mentioning that the criteria and alternatives for assessing the environmental impacts of $PM_{2.5}$ pollutants were determined based on the views of experts in the field of environment and urban management.

Table 3. Fuzzy Numbers along with the final weights extracted from the MATLAB software

Fig. 14. The Lattice Structure of the Environmental Impact Assessment $PM_{2.5}$ pollutants extracted from the Super Decisions software

As shown in Fig. 15, for each alternative, three weights are obtained. The first alternative is the crude weight, second is the ideal weight, and the other is the normal weight, which is generated by dividing the raw weight on the total weight of the alternative.

Also, in Fig. 15, each of the criteria and options weight is presented in terms of its purpose and priority. In terms of criteria, the highest weight is for population density, $PM_{2.5}$ contamination concentration and respectively, fuel, weather, traffic, and land usage, in the order of their appearance.

Fig. 15. The results of the Environmental Impact Assessment of $PM_{2.5}$ pollutants extracted from the Super Decisions software

Fig. 16. The results of the Environmental Impact Assessment of $PM_{2.5}$ pollutants extracted from the Super Decisions software

4-1- Sensitive analysis of suggested alternative for each criterion

The sensitivity analysis was used to assess the sensitivity of the alternatives. According to this analysis, which is carried out according to the main criteria, one can decide which alternative is the proposed option of reducing and controlling the $PM_{2.5}$ pollutants based on a particular criterion. The sensitivity analysis results of the present study (Fig. 17) confirm that the strict management of the surrounding environment is the optimal strategy. In other words, if this strategy is implemented in the Tehran metropolis, the result will decrease in $PM_{2.5}$ concentration and its effects.

Fig. 17. Sensitivity analysis for criteria

5- Conclusion

The purpose of this study was to assess the environmental impacts of $PM_{2.5}$ pollutants in the Tehran metropolis by identifying the key factors. These factors include traffic, Population, Population density, Gas consumption, Land use, Climatic conditions, and Fuel consumption, as well as $PM_{2.5}$ concentrations regarding the production of this pollutant. According to the results, this study presents solutions and recommendations to reduce and control this pollutant.

Generally, it can be concluded that strict environmental management in surrounding neighborhoods by having the highest weight (38%) is the best option to reduce and control this pollutant. More specifically, it can be concluded that the concentration of $PM_{2.5}$ pollutants in the southern regions is more due to the drying of wetlands located in the south of Tehran. This is followed by the destruction of vegetation and soil erosion in this area as well as unconventional and non-standard waste incineration in the southern regions. In the western districts, such a high

$PM_{2.5}$ concentration is due to the presence of sand and gravel factories and the blockage of the entrance of the only wind tunnel to Tehran due to high-rise buildings in these areas.

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