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Estimation of Urban Suspended Particulate Air Pollution Concentration

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ABSTRACT: A critical eye on the destructive impact of air pollution in Tehran is needed as the basis for urban planning, protection policy and management. This paper is focused on modeling in the GIS (Geospatial Information System) to estimate the concentration of particulate matter (PM) in any point of a typical part of Tehran which extends over 18.2 km^2 and includes the so-called "Traffic Zone". Many important general hospitals are located in this region, some of which are within the zone. The model is built on the data obtained in 42 stations located within the region. The results strongly indicate that the concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ of any points inside the region, including the traffic zone, do not meet the required international standard values. The extracted estimate values for the 22 hospitals reveal that the concentration of PM_{10} for "Azadi Psychic", "Children" and "Mustafa Khomeini" hospitals are the worst, estimating from the model to be 119.42 μg/m^3, 107.09 μg/m^3 and 101.14 μg/m^3 respectively. The percent ratio of the mean concentrations of PM_{10} /$PM_{2.5}$ / $PM_{1.0}$ in this region is found to be approximately 7: 2: 1.

Key words: GIS, Dynamic modeling, Particulate matter, Air pollution, Traffic

INTRODUCTION

Pollution can be defined as an undesirable change in the physical, chemical or biological characteristics of the air, water or land that can affect health, survival or activities of humans or other organisms (Smith, 1996; WHO, 1997; Patel and Raiyani, 1995; Anu *et al.,* 2002; anthony *et al.,* 2007; Minsi *et al.,* 2007; Marilena & Elias, 2008). Among the major air pollutants released to the atmosphere, suspended particulate air pollution are considered as one of the major health impact and therefore a large number of related studies have been undertaken in developing countries in the last decade (Cautreels & Van, 1978; Zhu *et al.,* 2002; Douglas *et al.,* 2002; Alam *et al.,* 2003; Gramotnev & Ristovski, 2004; Silibello *et al.,* 2008).The most important environmental problem Iran currently faces is air pollution, especially in the capital city of Tehran. The problem is very serious for the city which considered one of the most polluted cities in the world. Cars are chiefly to blame for Tehran's heavy pollution, because most of the city's more than 2 million cars are at least 20 years old and do not have catalytic converters to reduce pollutants. Unfortunately the city's geographical position is not helping the reduction of pollutants. The city is hammed by the tall Alborz Mountains to the north and therefore traps the pollutants over the city (Halek *et al.,* 2004).

Particulate matter is considered one of the main sources of air pollution problems in Tehran. The role, size distribution of particulate matter in the city's air pollution and also the effect of motor vehicles and trend of air borne particulate, have been the subject of extensive studies (Nabi and Halek, 2007). In air pollution studies, the air quality models are used to predict and estimate concentration of one or more species in space

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and time as related to the dependent variables. Modeling provides the ability to asses the current and also future air quality in order to enable "informed" policy decisions to be made (Bruckman *et al.,* 1992; Hochadel *et al.,* 2006; Zhou *et al.,* 2006; Gavin *et al.,* 2007; Yuqiong *et al.,* 2008).

One of the systems which have appeared lately is Geospatial Information System (GIS). GIS is not only a system for creating, managing and analyzing graphic and attribute data, but also is a decision supporting system (DSS). In fact, GIS can support managers, planner and decisions maker. Therefore, these days we will face big problems in big cities if we don' t use such systems (Pirmoradi, 2008).The rise of GIS technology and its use in a wide range of disciplines provides transportation and air quality modelers with a powerful tool for developing new analysis capability (Goodchild *et al.,* 1996; Burrouigh and McDonald, 1998; Appleton and Lovett, 2003; Tolga, 2004; Duanping *et al.,* 2006; Younes *et al.,* 2008). The organization of data by location allows data from a variety of sources to be easily combined in a uniform framework (Wilfred and Gerald, 2005; Mauro and Lorenzo, 2006).

A Comparison and case study conducted to apply the satellite data and GIS for producing maps of amounts of CO, O_3, NO_2 and SO_2 in Tehran's atmosphere (Sohrabinia and Khorshiddoust, 2007). With the help of GIS, concentrations of each of these pollutants were estimated to be much higher than standard values and forecasted that to go still higher. The results of such a study and other air pollution case studies in different countries not only could help the local, but the global environmental pollution experts and decision makers to set environmental politics. So for the application of GIS to estimate the air pollution in Tehran has been limited to find the concentrations of gaseous pollutants and not suspended particles (Sohrabinia and Khorshiddoust, 2007). This paper reports result of a novel study to estimate the concentration and spatial distribution of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in an 18.2 km^2 region selected within the Great Tehran. For this purpose, the study is focused for the first time on modeling in the GIS which used data extracted from 42 stations located in different parts of the region. Special attention is made to estimate the concentrations of particulate matter near 22 hospitals in this region, some of which are located in the so-called "Tehran's Traffic Zone". With the help of this modeling, one could estimate the concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in such important areas in this region where setting a station is impossible for sampling.

MATERIALS & METHODS

A region of 18.2 km^2 was used as our study area because many important general hospitals, including "Tehran heart center", "Imam Khomeini", "Shariati", "Arya", "Sasan", "Sajad", "Pars", "Mustafa Khomeini", "Toos" and "Rasoul Akram" are located in this area. Also in this area, a so-called "Traffic Zone" has been set up since 2000, covering the city center during peak traffic hours. Entering and driving inside this zone is only allowed with the special permit. Fig. 1 shows this region in Tehran. 42 sampling sites were set to collect the air samples according to the standard sampling procedures. Daily sampling were done in summer 2007, starting 8.0 AM (the morning rush hour) to 4.0 PM (the afternoon rush hour). The names of the sampling sites and their related geographical coordinates in Tehran are listed in Table 1. The meteorological data were reported by the Iranian Meteorological Organization. The mean temperature in the selected district in Tehran during the study fluctuates between 29-35 °C.

A portable Grimm aerosol spectrometer, model 1.108, which equipped with 15 ports, has been used for sampling. This instrument was able to measure the size distribution of particulate matter in urban and also in the industrial areas. The air flow was set at 1.2 Lit/min. and the particles were collected on PTFE filters.In order to build a "Surface Model" for PM_{10}, $PM_{2.5}$ and $PM_{1.0}$, different algorithms should be applied to interpolate the data from those obtained for the known sites and extend the results to the "surface". For this purpose mean concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$, in each sampling site for June, July and August, were calculated and interpolated and extended to the surface by "Inverse Distance Weight" or "Spine" algorithms by using ArcGIS9.2. To examine the precision of the surface models, the "Root Mean Square" method was applied.After building the surface models for each month in the summer, the concentration of each particulate matter could be estimated in all the points in the district and

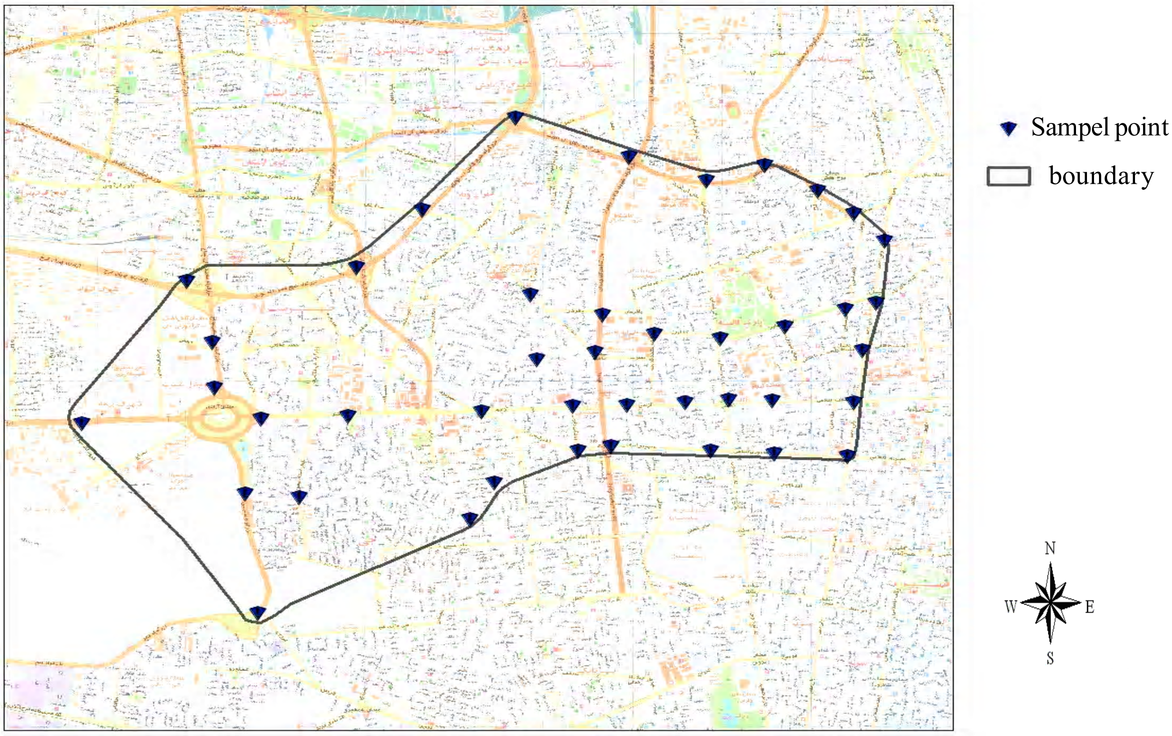

Fig. 1. The border of sampling points

consequently, the related distribution of the particles and their concentration could be evaluated and categorized. Also with the aid of "Mathematics Overlay", the models for these months could be overlaid and the final results for the particles could be evaluated for summer 2007.

RESULTS & DISCUSSION

The mean concentrations of particulate matter in 42 sampling stations in summer 2007 are shown in Fig. 2. The higher values belong to those crowded places like city squares and street intersections.

As it is shown in Fig. 2. the concentration of PM_{10} is much higher than the rest of particles in Tehran's air pollution. The percent ratios of different categories of particulate matter are found from Fig. 2 to be, 73 % (PM_{10}), 17 % ($PM_{2.5}$) and 10 % ($PM_{1.0}$). The suspended particulate matter concentration, as shown in Fig. 3. is higher for working days, especially on Saturdays which considered as the beginning of the week in Iran, the roads are usually congested with heavy traffic. The concentration of PM_{10} in the selected district along with the locations of the stations is shown in the related distribution map in Fig. 4. The darker the regions in this figure, the higher the concentration of particulate matter. The mean value of particulate concentration is calculated from the model to be 79.49 for the corresponding summer, having standard deviation of 13.63. It could be deduced from this figure that the highest concentration of the 123.19 $\mu g/m^3$ for PM_{10} belong to the intersection of "Sheik Fazlollah" and "Jenah" expressways, with and the least belongs to the intersection of "Saeedi" and "Hashemi" expressways, with 63.76 $\mu g/m^3$.

Similarly, the mean values of concentration of $PM_{2.5}$ and $PM_{1.0}$ are shown in Fig. 5 and Figure 6 respectively. As shown in Fig. 5. the mean value of concentration of $PM_{2.5}$ is recorded to be 19.20 $\mu g/m^3$, corresponding to the highest value of 45.30 $\mu g/m^3$ and the lowest of 14.00 $\mu g/m^3$. The standard deviation of the concentration of $PM_{2.5}$ is calculated to be 3.39. $PM_{1.0}$ concentration, as shown in Fig. 6. has the highest value of 34.80 $\mu g/m^3$ and the least value of 6.67 $\mu g/m^3$. The mean value for the concentration of this size of suspended particles is calculated to be 10.80 with the standard deviation of 2.44.As it is deduced from the mean concentration of particulate matter, Tehran, like many big cities, suffers from sever air pollution and therefore the city is often covered by smog making breathing difficult and causing widespread pulmonary illnesses. Unfortunately most of the hospitals in Tehran are located in the

Table 1. The names of the sampling sites and their related geographical coordinates

Site No.	Sampling Site Location:	X	Y
1	Karaj Road	529,208.36	3,950,734.79
2	Saeedi Highway - Dampezeshki intersection	530,759.07	3,949,955.15
3	Fath Square	530,881.52	3,948,624.39
4	Hashemi St.- Jeyhoon intersection	532,909.85	3,949,672.37
5	Dampezeshki St.- Karoon intersection	533,149.77	3,950,075.11
6	Dampezeshki St.- Moeen intersection	531,281.77	3,949,916.59
7	Azadi Square	530,913.31	3,950,790.60
8	Azadi St.- Sharif University	531,750.28	3,950,820.79
9	Azadi St.- Azarbaijan intersection	533,025.93	3,950,866.07
10	Azarbaijan St.- Roudaki intersection	533,948.99	3,950,433.25
11	Islamic Republic Square	534,259.18	3,950,482.14
12	Islamic Republic St.- Jamalzadeh intersection	535,217.38	3,950,436.52
13	Islamic Republic St.- Fakhre-Razi intersection	535,817.68	3,950,402.38
14	Islamic Republic St.- Valii Asr intersection	536,518.47	3,950,368.43
15	Valii Asr Junction	536,585.26	3,950,969.58
16	Enghelab St.- Tehran University	535,801.54	3,950,987.39
17	Enghelab Square	535,382.96	3,950,996.30
18	Azadi St.- Kaveh Parking	534,975.07	3,950,969.12
19	Azadi St.- Eskandari intersection	534,415.68	3,950,940.62
20	Azadi St.- Roudaki intersection	533,899.05	3,950,929.93
21	Khosh St.- Nosrat intersection	533,555.94	3,951,443.21
22	Sattar Khan St.- Behbudi intersection	533,486.26	3,952,164.38
23	Touhid Square	534,109.88	3,951,526.83
24	Chamran Highway - Bagher Khan intersection	534,175.64	3,951,945.33
25	Keshavarz Blv.- Imam Hospital	534,672.10	3,951,727.59
26	Keshavarz Blv.- Kargar intersection	535,307.38	3,951,675.23
27	Keshavarz Blv.- Hejab intersection	535,924.16	3,951,808.26
28	Keshavarz Blv.- Felestin intersection	536,504.66	3,952,005.79
29	Valii Asr St.- Taleghani intersection	536,657.85	3,951,550.26
30	Valii Asr Square	536,790.88	3,952,074.32
31	Valii Asr St.- Zartosht intersection	536,878.83	3,952,766.31
32	Fatemi Square	536,578.55	3,953,064.25
33	Golha Square	536,239.59	3,953,324.69
34	Gomnam Highway- Kurdistan intersection	535,731.10	3,953,601.66
35	Gomnam Highway- Kargar intersection	535,168.89	3,953,436.30
36	Gomnam Highway- Chamran intersection	534,436.39	3,953,698.72
37	Jalal Highway- Sheik Fazlollah intersection	533,348.68	3,954,133.80
38	Sheik Fazlollah Highway- Sattar khan Bridge	532,459.25	3,953,103.95
39	Sheik Fazlollah Highway- Yadegar Bridge	531,830.08	3,952,466.45
40	Sheik Fazlollah Highway- Jenah intersection	530,209.12	3,952,313.70
41	Jenah Highway- Fuel Pump Station	530,452.05	3,951,640.99
42	Azadi Square- Bus Terminal	530,468.40	3,951,129.45

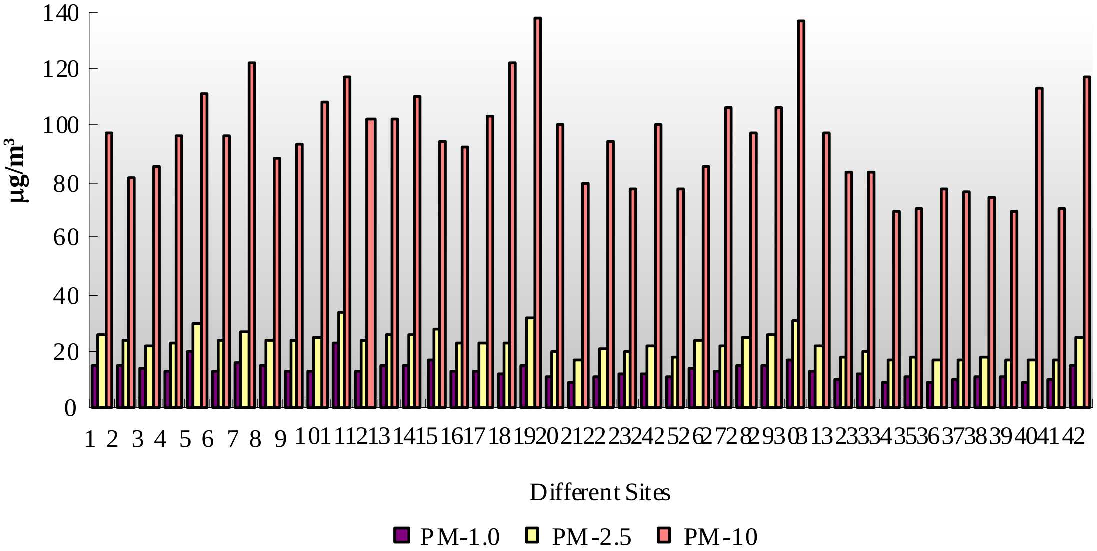

Fig. 2. Mean concentration of suspended particles in 42 site

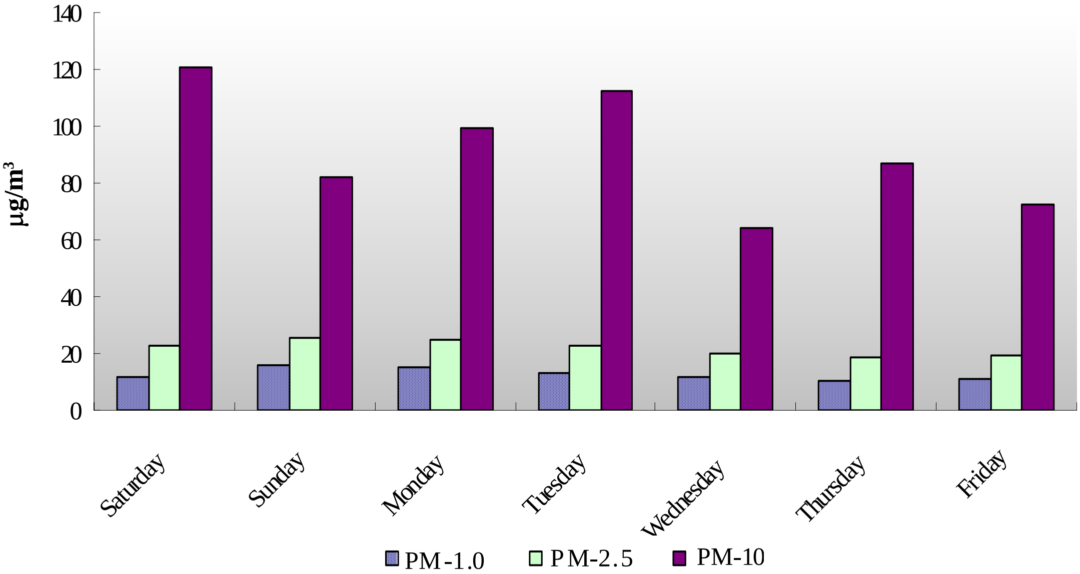

Fig. 3. Mean of Particulate Matter Concentration in week days

selected district, instead of being placed in the non-polluted areas. Fig. 1 shows the geographical position of the selected district in Tehran. From the aid of GIS database, the concentration of particulate matter in any selected points, especially those for hospitals located in this district could be estimated.The names and places of the 22 hospitals in the selected district with their mean concentrations of PM_{10} are listed in Table 2. As the mean concentrations of PM_{10} indicate, none of the hospitals meet the required international standard air pollution values. The extracted estimated values from GIS modeling revealed that the concentration of PM_{10} for "Azadi Psychic", "Children" and "Mustafa Khomeini" hospitals are the worst, estimated from the model to be 119.42 $\mu g/m^3$, 107.09 $\mu g/m^3$ and 101.14 $\mu g/m^3$ respectively.

CONCLUSION

Environmental modeling for an 18.2 km^2 selected district in Tehran is developed to asses the critical state of particulate matter concentration in an important part of Tehran, where the so-called "Traffic Zone" is located and also many hospitals, like "Azadi Psychic" and "Children" are continuing their daily activities. The annual average concentration of PM_{10} and $PM_{2.5}$ in each 42 site

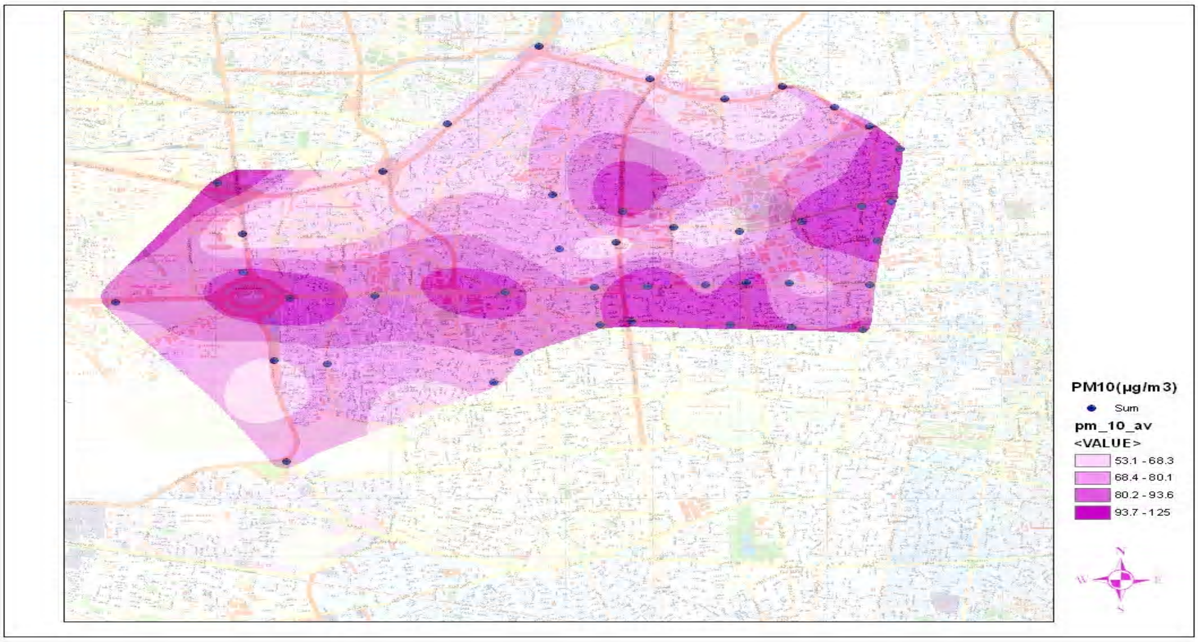

Fig. 4. The distribution of mean concentration of PM_{10} in the selected region

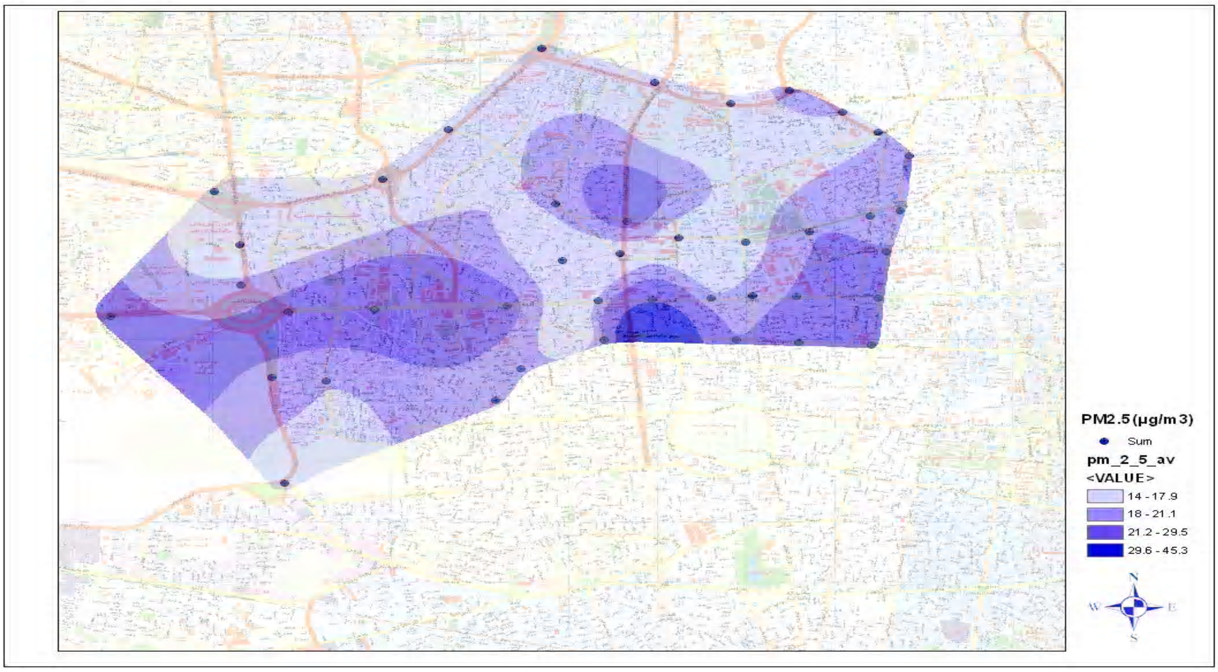

Fig. 5. The distribution of mean concentration of $PM_{2.5}$ in the selected region

and also in any point in the selected district exceed the National air Quality Standard (NAQS) of 50 µg/m^3 and 15 µg/m^3 respectively. The mean concentrations of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} are found to be 13.14 µg/m^3, 22.67 µg/m^3 and 95.72 µg/m^3 respectively. The highest concentration of PM_{10}, which is found to be 529.24 µg/m^3, belongs to "Valii Asr" square, which is also the worst square for $PM_{2.5}$ (105.88 µg/m^3). The highest concentration of $PM_{1.0}$, (89.87 µg/m^3) belongs to "Islamic Republic Square" in Tehran.

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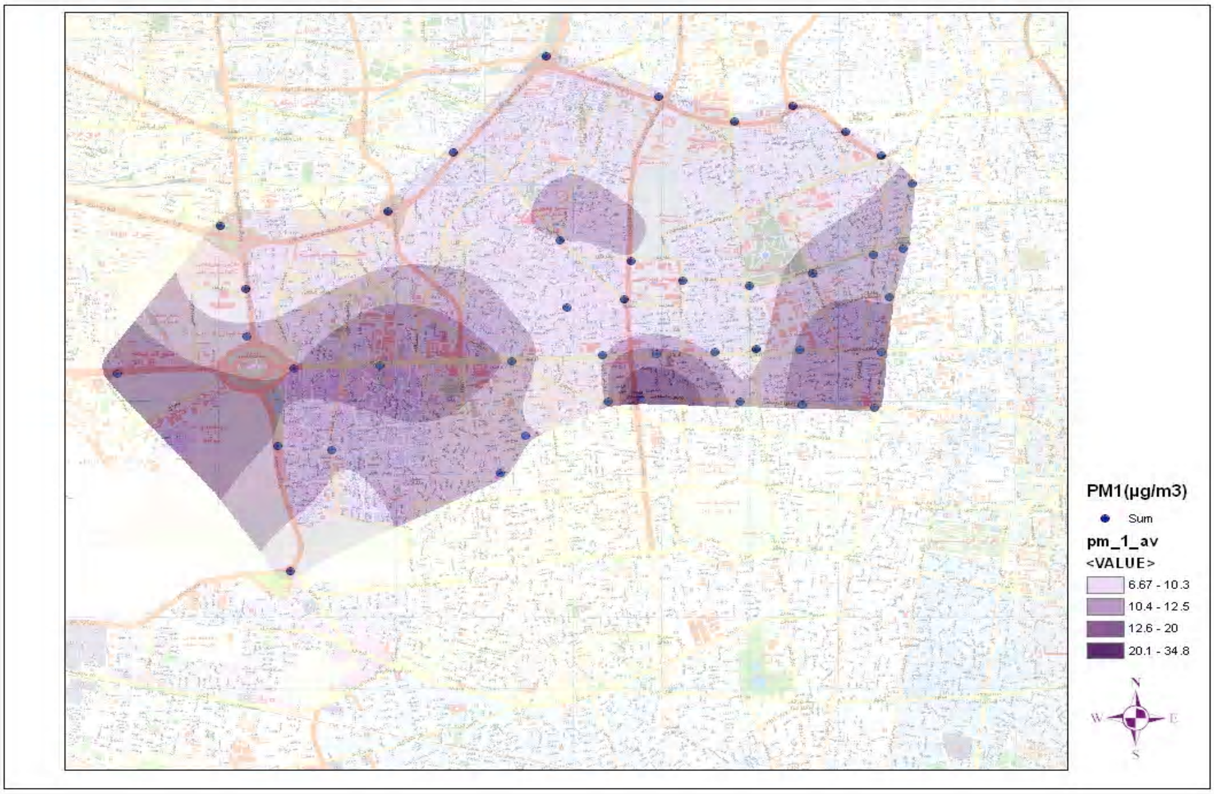

Fig. 6. The distribution of mean concentration of $PM_{1.0}$ in the selected region

Table 2. Names, locations and mean concentration of PM_{10} of the hospitals

	Hospital Name	Location	Mean Concentration of PM-10 (µg/m³)
1	Aria	Vesal St.	99.58
2	Artesh (501)	Fatemi St.	73.01
3	Artesh (503)	Ostad Moeen St.	83.68
4	Azadi	Azadi Sq.	95.76
5	Albourz	Vesal St.	82.31
6	Imam Khomeini	Keshavarz Blvd.	78.06
7	Cancer Institute	Keshavarz Blvd.	74.77
8	Pars	Keshavarz Blvd.	99.60
9	Rasoul Akram	Sattarkhan St.	70.31
10	Ravan Pezeshki	Jenah Highway	119.42
11	Sasun	Keshavarz Blvd.	96.76
12	Central 1	Bagherkhan St.	75.53
13	Sajjad	Fatemi Sq.	93.24
14	Shriati	Kargar St.	62.38
15	Firouzgar	Taleghani St.	97.26
16	Ghalb	Kargar St.	65.83
17	Kudakan	Taleghani St.	107.09
18	UT Health Center	Enghelab St.	90.69
19	Tebbi kudakan	Dr. Ghareeb St.	77.57
20	Mustafa Khomeini	Italia St.	101.14
21	Mehr	Zartosht St.	92.73
22	Meymanat	Azadi Sq.	98.22

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