GIS ASSESSMENT OF THE PM_{10}, $PM_{2.5}$ AND $PM_{1.0}$ CONCENTRATIONS IN URBAN AREA OF TEHRAN IN WARM AND COLD SEASONS

F. Halek [a, *], A. Kavousi-rahim[a]

[a] Materials and Energy Research Center (merc), P. O. Box 14155-4777, Tehran, Iran – f-halek@merc.ac.ir

KEY WORDS: GIS, Air pollution, Particulate matter, Seasonal pollution, Tehran air pollution

ABSTRACT:

In recent years, atmospheric models, such as GIS, are used for environmental analysis and the related management for supporting the environmental decision makers in different countries. In this study, concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ are found in urban areas of Tehran in warm and cold seasons and the data applied in the related modelling, using Arc-GIS. For this purpose, samples were collected from 42 sites in an 18 km^2 region located in the west and central parts of Tehran. The mean concentrations of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} are found to be 13.14 $\mu g/m^3$, 22.67 $\mu g/m^3$ and 95.72 $\mu g/m^3$ in the warm season; and 50.12 $\mu g/m^3$, 70.72 $\mu g/m^3$ and 193.86 $\mu g/m^3$ in the cold season respectively. In this paper, with the aid of GIS, concentrations of the suspended particles were measured in 22 major hospitals, the patients in which are in contact with these pollutants. It was found the concentrations of the suspended particles were much higher in the cold season.

1. 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., 2007).

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 trap 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 and time as related to the dependent variables. Modelling provides the ability to assess the current and also future air quality in order to enable "informed" policy decisions to be made (Bruckman et al., 1992; 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.

It should be pointed out that the wind speed and direction is an important factor affecting particulate pollution concentrations and its source apportionment. The yearly mean wind speeds in Tehran is reported to be between 4 and 5 m/s for eleven years (1995-2005) and the highest wind speeds were seen in March, April and May. The most probable wind direction in Tehran is on the west (Keyhani et al., 2010).

This paper reports results of a 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 on modeling in the GIS which

* Corresponding author.

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 sampling station is impossible.

2. EXPERIMENTAL

2.1 Study area and sampling in Tehran

A region of 18.2 km^2 was selected 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. Figure 1 shows this region in Tehran. 42 sampling sites were set to collect the air samples according to the standard sampling procedures. The names of the sampling sites and their related geographical coordinates in Tehran are listed in Table 1.
The mean temperature in the sampling sites was measured to be between 29-35 °C in the summer 2010 and 1-23 °C in the following winter.

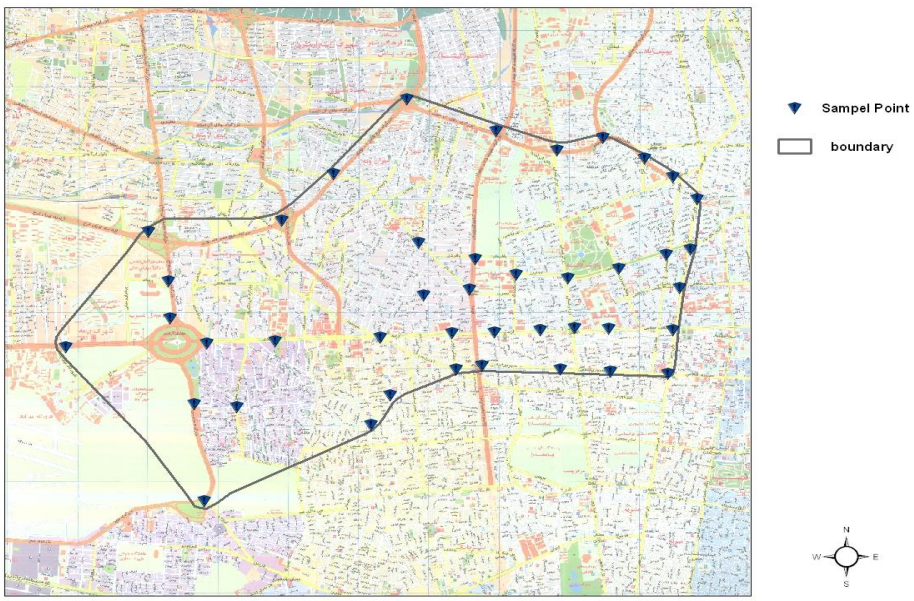

Figure 1. The borderline of the sampling points

2.2 Sampling Program

In this study, simultaneous measurements of mass concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$, in the sampling stations were done in the warm season (July, August and September 2010), followed by the cold season (January, February and March 2011). The samples were collected once a week, covering each day of the week to be sure that all the days of the week were included. Daily samplings were done in two consecutive seasons, starting 8.0 AM (the morning rush hour) to 4.0 PM (the afternoon rush hour). During every sampling day, samples from all of 42 sites were taken, assigning about 10 min for each sampling site. It should be pointed out that, to avoid the error arising from the fluctuation of particulate concentrations in different times of the day, daily samplings were done in different order of the sites. In other word, each daily sampling began at different site than previous sampling day and finished at different site consequently.

2.3 Instrumentation

A portable particle size analyzer-dust monitor Model Grimm-1.108 (made in Germany), was used for continuous measurement of the particles. This instrument was able to measure the size distribution of the particulate matter, including PM_{10}, $PM_{2.5}$ and $PM_{1.0}$. The instrument uses a light-scattering technology for single-particle detection, whereby a semiconductor-laser serves as the light source. A 47 μm PTFE filter is used for collecting the samples. The air flow was set at 1.2 lit/min. In order to measure the real exposure to the concentration of the particulate matter by human being as close as possible, all samples were collected at the height of 1.65 meter, which is defined as the average height of Iranian population (Haghdoost et al. 2008).
Instrument calibration was done according to procedure adopted by Grimm instrumental company, and therefore a correction factor of Cf = 1.05 is incorporated into all of the calculations.
A GPS (Global Positioning System) instrument (Model eTrex Vista) was used for geographical position (X and Y in table 1) determination of sampling schools.

2.4 Software and Modeling

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, interpolated and extended to the surface by "Inverse Distance Weight" or "Spline" 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 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 the months could be overlaid and the final results for the particles could be evaluated for each of the seasons.

Site No.	Sampling Site Location:	X	Y
1	Karaj Road – Airport Entrance	52° 92' 08"	39° 50' 73"
2	Saeedi Highway - Dampezeshki Intersection	53° 07' 59"	39° 49' 96"
3	Fath Square	53° 08' 81"	39° 48' 62"
4	Hashemi St.- Jeyhoon Intersection	53° 29' 09"	39° 49' 67"
5	Dampezeshki St.- Karoon Intersection	53° 31' 49"	39° 50' 08"
6	Dampezeshki St.- Moeen Intersection	53° 12' 81"	39° 49' 92"
7	Azadi Square	53° 09' 13"	39° 50' 79"
8	Azadi St.- Sharif University	53° 17' 50"	39° 50' 82"
9	Azadi St.- Azarbaijan Intersection	53° 30' 26"	39° 50' 87"
10	Azarbaijan St.- Roudaki Intersection	53° 39' 49"	39° 50' 43"
11	Jomhouri Square	53° 42' 59"	39° 50' 48"
12	Jomhouri St.- Jamalzadeh Intersection	53° 52' 17"	39° 50' 44"
13	Jomhouri St.- Fakhre-Razi Intersection	53° 58' 18"	39° 50' 40"
14	Jomhouri St.- Valii Asr Intersection	53° 65' 18"	39° 50' 37"
15	Valii Asr Junction	53° 65' 85"	39° 50' 97"
16	Enghelab St.- Tehran University	53° 58' 02"	39° 50' 99"
17	Enghelab Square	53° 53' 83"	39° 51' 00"
18	Azadi St.- Kaveh Parking	53° 49' 75"	39° 50' 97"
19	Azadi St.- Eskandari Intersection	53° 44' 16"	39° 50' 94"
20	Azadi St.- Roudaki Intersection	53° 38' 99"	39° 50' 93"
21	Khosh St.- Nosrat Intersection	53° 35' 56"	39° 51' 44"
22	Sattar Khan St.- Behbudi Intersection	53° 34' 86"	39° 52' 16"
23	Touhid Square	53° 42' 00"	39° 51' 53"
24	Chamran Highway - Bagher Khan Intersection	53° 41' 76"	39° 51' 95"
25	Keshavarz Blv.- Imam Hospital	53° 46' 72"	39° 51' 73"
26	Keshavarz Blv.- Kargar Intersection	53° 53' 07"	39° 51' 68"
27	Keshavarz Blv.- Hejab Intersection	53° 59' 24"	39° 51' 81"
28	Keshavarz Blv.- Felestin Intersection	53° 65' 05"	39° 52' 01"
29	Valii Asr St.- Taleghani Intersection	53° 66' 58"	39° 51' 55"
30	Valii Asr Square	53° 67' 91"	39° 52' 07"
31	Valii Asr St.- Zartosht Intersection	53° 68' 79"	39° 52' 77"
32	Fatemi Square	53° 65' 79"	39° 53' 06"
33	Golha Square	53° 62' 40"	39° 53' 32"
34	Gomnam Highway- Kurdistan Intersection	53° 57' 31"	39° 53' 60"
35	Gomnam Highway- Kargar Intersection	53° 51' 69"	39° 53' 44"
36	Gomnam Highway- Chamran Intersection	53° 44' 36"	39° 53' 70"
37	Jalal Highway- Sheik Fazlollah Intersection	53° 33' 49"	39° 54' 13"
38	Sheik Fazlollah Highway- Sattar Khan Bridge	53° 24' 59"	39° 53' 10"
39	Sheik Fazlollah Highway- Yadegar Bridge	53° 18' 30"	39° 52' 47"

40	Sheik Fazlollah Highway- Jenah Intersection	53° 02' 09"	39° 52' 31"
41	Jenah Highway- Fuel Pump Station	53° 04' 52"	39° 51' 64"
42	Azadi Square- Bus Terminal	53° 04' 68"	39° 51' 13"

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

3. RESULTS AND DISCUSSION

The mean concentrations of particulate matter in 42 sampling stations in summer 2010 are shown in figure 2. The higher values belong to those crowded places like city squares and street intersections.

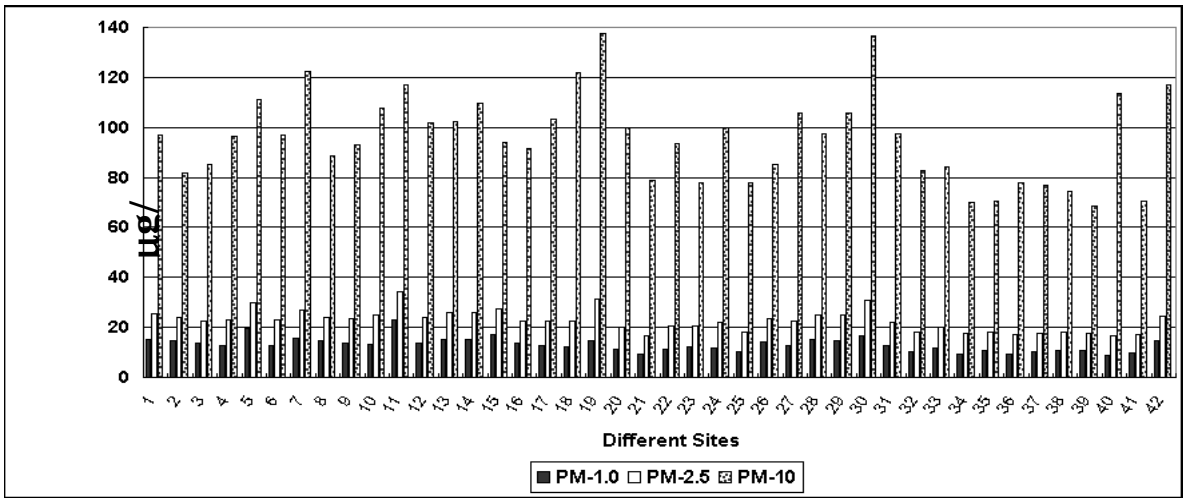

Figure 2. Mean concentrations of particulate matter in the warm season

As it is shown in figure 2, the concentration of PM_{10} is much higher than the other particles. During warm season, the percent ratios of different particulate matters are found from figure 2 to be, 73 % (PM_{10}), 17 % ($PM_{2.5}$) and 10 % ($PM_{1.0}$).

The concentrations of PM_{10} in the selected district, along with the locations of the stations in the warm season, are shown in the related distribution map in figure 4. The darker the regions in this figure, the higher the concentration of the particulate matter. The mean value of particulate concentration is calculated from the model to be 79.49 for the corresponding summer, with standard deviation of 13.63. It could be deduced from this figure that the highest concentration of PM_{10} (123.19 $\mu g/m^3$) belongs to the intersection of "Sheik Fazlollah" and "Jenah" expressways, and the least value (63.76 $\mu g/m^3$) belongs to the intersection of "Saeedi" and "Hashemi" expressways.

Similarly, the mean values of concentration of $PM_{2.5}$ and $PM_{1.0}$ are shown in figures. 5 and 6 respectively. As shown in figure 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 figure 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 PM_{10} is calculated to be 10.80 with the standard deviation of 2.44.

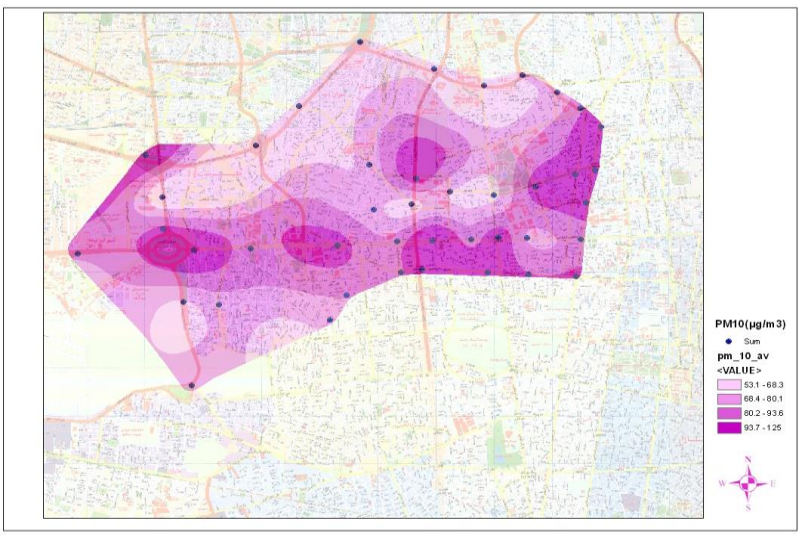

Figure 3. The distribution of mean concentration of PM_{10} in the selected region (warm season).

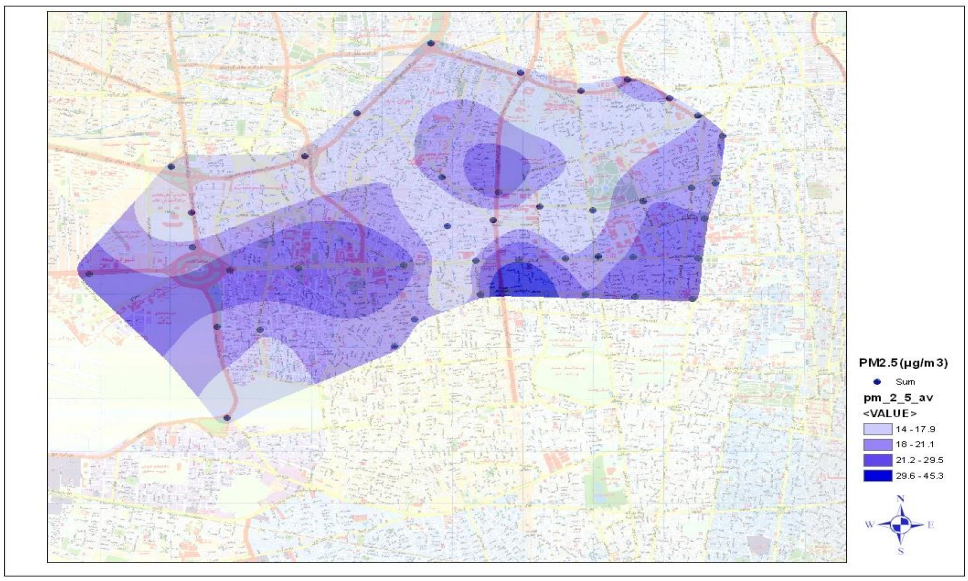

Figure 4. The distribution of mean concentration of $PM_{2.5}$ in the selected region (warm season).

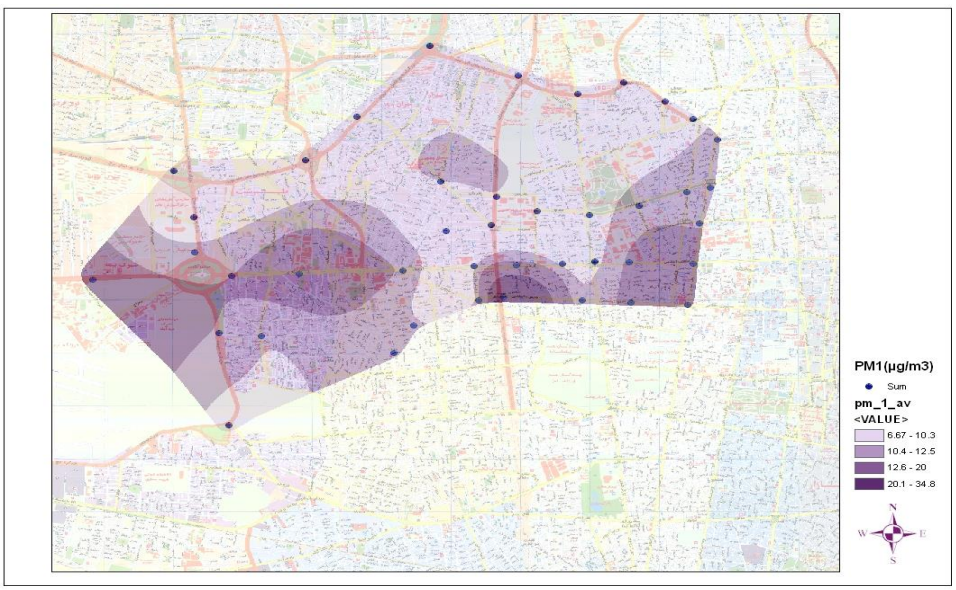

Figure 5. The distribution of mean concentration of $PM_{1.0}$ in the selected region (warm season).

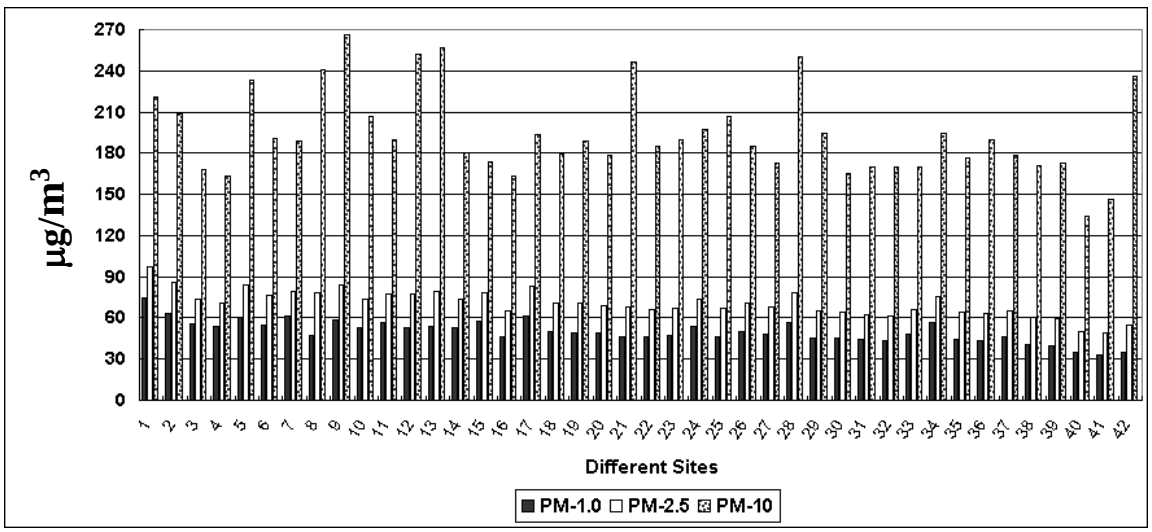

Figure 6. Mean concentrations of particulate matter in the cold season

As it is shown in figure 6, the concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in the cold season (Jan, Feb and March 2011) are much higher compared to the warm season. The average value of PM_{10} within 42 sites found to be 194 µg/m^3, while at the sites 9 (Azadi St. - Azarbaijan intersection) and 13 (Jomhouri St. - Fakhre-Razi intersection) the concentrations of PM_{10} were higher and estimated to be 266 µg/m^3 and 256 µg/m^3 respectively. Sites 40 (Sheik Fazlollah Highway - Jenah intersection) and 41 (Jenah Highway - Fuel Pump Station), have lower concentrations of PM_{10} during the cold season which estimated to be 134 µg/m^3 and 146 µg/m^3 respectively. Unfortunately the mean value of PM_{10} concentration in the winter season is higher than 24hr standard level of this pollutant (150 µg/m^3).

The average value of $PM_{2.5}$ within 42 sites in the cold season estimated to be 71 µg/m^3, while its daily standard level is 65 µg/m^3. However, sites 1 (Karaj Road) and 2 (Saeedi Highway - Dampezeshki intersection) have the higher concentrations of $PM_{2.5}$, which estimated to be 97 µg/m^3 and 85 µg/m^3 respectively.

Higher concentrations of $PM_{1.0}$, belong to the sites 1 (Karaj Road) and 2 (Saeedi Highway - Dampezeshki intersection) with the values of 74 µg/m^3 and 63 µg/m^3 respectively. Sites 41 (Jenah Highway - Fuel Pump Station) and 40 (Sheik Fazlollah Highway - Jenah intersection), have the lower concentrations of $PM_{1.0}$ during the sampling period with the values of 35 µg/m^3 and 33 µg/m^3 respectively.

In the cold season, the percent ratios of different sizes of particulate matter are found to be, 62 % (PM_{10}), 22 % ($PM_{2.5}$) and 16 % ($PM_{1.0}$). A comparison between the data for the two seasons (figures 2 and 6) indicates that the smaller particles ($PM_{1.0}$ and $PM_{2.5}$) have much higher concentrations than for the warm season.

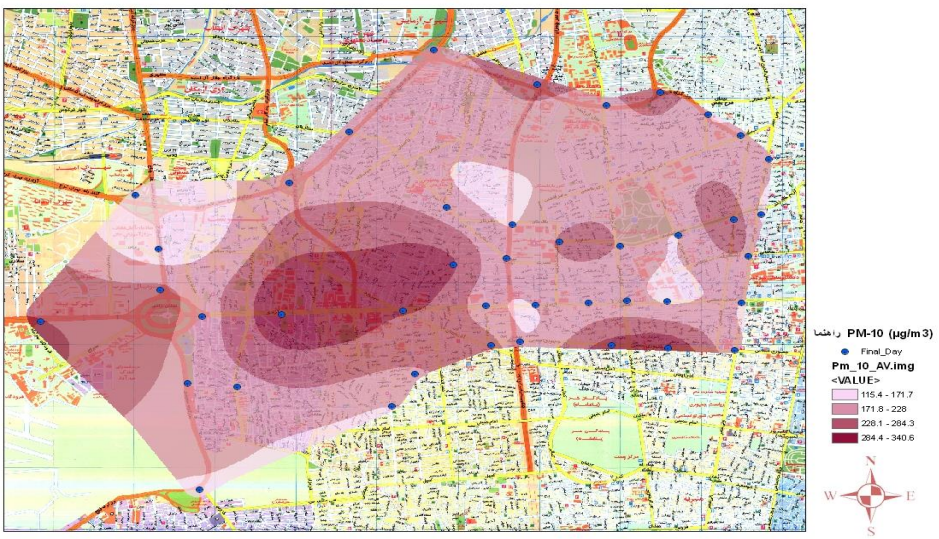

Figure 7. The distribution of mean concentration of PM_{10} in the selected region (cold season).

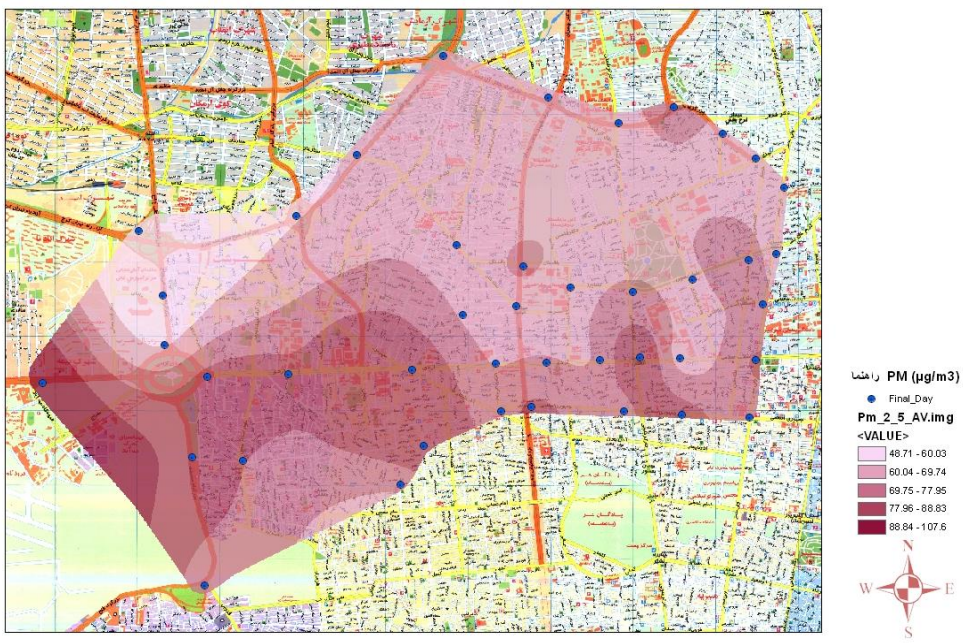

Figure 8. The distribution of mean concentration of $PM_{2.5}$ in the selected region (cold season).

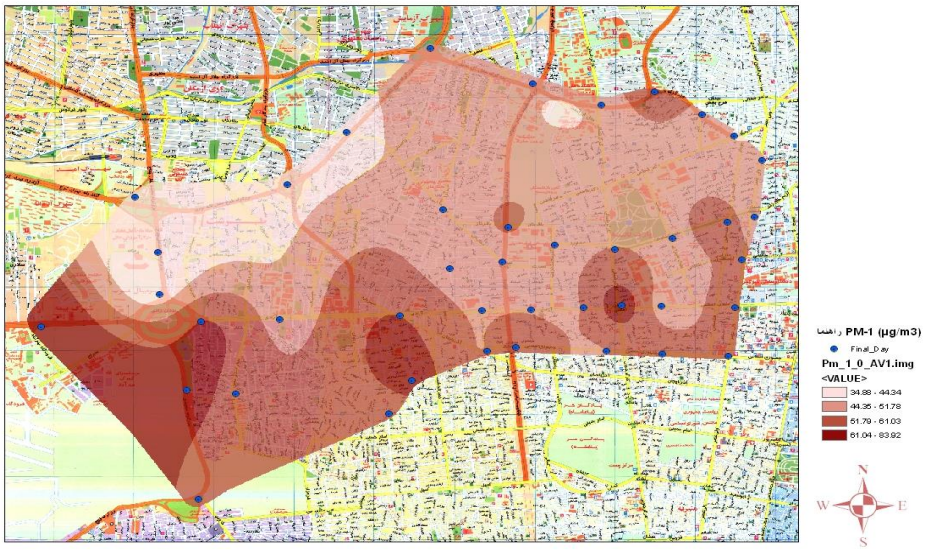

Figure 9. The distribution of mean concentration of $PM_{1.0}$ in the selected region (cold season).

As it is deduced from the mean concentration of PM, Tehran, like many big cities, suffers from severe 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 selected district, instead of being placed in the non-polluted areas.

Figure 1 shows the geographical position of the selected district in Tehran. From the aid of GIS database, the concentrations 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} in cold season indicate, none of the hospitals meet the required international standard PM_{10} annual level (150 µg/m^3) in the cold season. The extracted estimated values from GIS modelling in the cold season revealed that the concentration of PM_{10} for "Meymanat", "Azadi" and "Sasan" hospitals are the worst, estimated from the model to be 306.2 µg/m^3, 264.2 µg/m^3 and 252.7 µg/m^3 respectively. It is noted from the data listed in Table 2 that the highest concentration of PM_{10} (119.4 µg/m^3) in the warm season belongs to the "Ravan Pezeshki" hospital.

	Hospital Name	Location	PM concentrations (µg/m^3) Warm Season			PM concentrations (µg/m^3) Cold Season		
			PM_{10}	$PM_{2.5}$	$PM_{1.0}$	PM_{10}	$PM_{2.5}$	$PM_{1.0}$
1	Aria	Vesal St.	99.6	67.2	32.1	200.3	67.1	49.7
2	Artesh (501)	Fatemi St.	73.0	43.2	28.1	184.8	68.0	50.7
3	Artesh (503)	Ostad Moeen St.	83.7	68.2	48.2	245.8	81.6	59.2
4	Azadi	Azadi Sq.	95.8	78.2	53.8	264.2	81.7	57.5
5	Albourz	Vesal St.	82.3	62.3	44.2	170.8	68.1	49.2
6	Imam Khomeini	Keshavarz Blvd.	78.1	57.6	38.2	205.2	68.3	49.3
7	Cancer Institute	Keshavarz Blvd.	74.8	58.4	36.3	222.3	67.9	48.7
8	Pars	Keshavarz Blvd.	99.6	70.5	56.2	223.4	71.1	51.6
9	Rasoul Akram	Sattarkhan St.	70.3	48.2	38.3	212.1	64.2	46.5
10	Ravan Pezeshki	Jenah Highway	119.4	92.8	67.2	137.2	49.2	35.4
11	Sasan	Keshavarz Blvd.	96.8	70.2	51.3	252.7	74.3	54.1
12	Central 1	Bagherkhan St.	75.5	58.2	34.2	180.7	69.7	52.2
13	Sajjad	Fatemi Sq.	93.2	76.5	52.3	180.3	61.4	44.3
14	Shriati	Kargar St.	62.4	46.8	39.1	204.1	62.8	44.1
15	Firouzgar	Taleghani St.	97.3	79.2	53.4	212.9	70.4	48.8
16	Ghalb	Kargar St.	65.8	50.3	38.2	200.2	63.4	44.9
17	Kudakan	Taleghani St.	107.1	86.2	69.3	194.9	68.8	52.8
18	UT Health Center	Enghelab St.	90.7	73.2	54.6	170.7	75.9	58.5
19	Tebbi Kudakan	Dr. Ghareeb St.	77.6	53.6	41.3	222.3	67.5	48.3
20	Mustafa Khomeini	Italia St.	101.1	71.1	58.3	221.5	71.5	51.9
21	Mehr	Zartosht St.	92.7	65.8	33.8	197.5	62.7	48.6
22	Meymanat	Azadi Sq.	98.2	69.2	48.3	306.2	82.7	55.3

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

4. CONCLUSION

GIS modeling for an 18.2 km^2 selected district in Tehran has been developed to assess the critical state of particulate matter concentration in an important part of Tehran, where the so-called "Traffic Zone" is located and also many main Tehran`s hospitals, like "Imam Khomeini", "Ravan Pezeshki" and "Kudakan" are continuing their daily activities during warm and cold seasons.

The annual average concentration of PM_{10} and $PM_{2.5}$ in all the 42 sites and also in any point within the selected district exceed the National air Quality Standard (NAQS) values which set to be 50 $\mu g/m^3$ and 15 $\mu g/m^3$ respectively. Also in the cold season, daily average concentration of particles exceed the standard values of 150 $\mu g/m^3$ (24hr standard limit for PM_{10}) and 65 $\mu g/m^3$ (24hr standard limit for $PM_{2.5}$).

In comparison with the warm season, the concentrations of suspended particles in this district are much higher in the winter time. The mean concentrations of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} have been found to be 13.14 $\mu g/m^3$, 22.67 $\mu g/m^3$ and 95.72 $\mu g/m^3$ in the warm season. The concentrations of particulate matter increase in the winter time. For example mean concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ have been measured to be 50.12 $\mu g/m^3$, 70.72 $\mu g/m^3$ and 193.86 $\mu g/m^3$ in the cold season respectively.

In the warm season, highest concentration of PM10, which comes up to 529.24 $\mu g/m^3$, belongs to "Valii Asr" square, but it is the worst place with respect to $PM_{2.5}$ (105.88 $\mu g/m^3$). The highest concentration of $PM_{1.0}$, (89.87 $\mu g/m^3$) has been found for "Jomhouri Square" in Tehran. In the winter time, highest concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ have been measured to be 166.22 $\mu g/m^3$ (Karaj Road – Airport Entrance), 209.21 $\mu g/m^3$ (Karaj Road – Airport Entrance) and 617.41 $\mu g/m^3$ (Jomhouri St.- Fakhre-Razi Intersection) respectively.

REFERENCES

Alam, A., Shi, J.P. and Harrison, R.M., 2003. Observations of new particle formation in urban air. *Journal of Geophysical Research*, 108, pp. 4093 - 4107.

Anthony, L., Barry, S., Anthony, B. and Hugo, Z., 2007. Reducing the healthcare costs of urban air pollution: The South Africa experience. *Journal of Environmental Management*, 84, pp. 27-37.

Anu, K., Jaakko, K., Ari, K., Paivi, A. and Tarja, K., 2002. A model for evaluating the population exposure to ambient air pollution in an urban area. *Atmospheric Environment*, 36, pp. 2109-2119.

Appleton, K. and Lovett, A., 2003. GIS-based visualization of rural landscapes: defining sufficient realization for environmental decission-making. *Landscape & Urban Planning*, 65, pp. 117-131.

Bruckman, L., Dickson, R. J. and Wilkosen, J. G., 1992. Use of GIS software in the development of emissions inventories and emission modeling. *Proceedings of the Air & Waste Management Association*, Pittsberg, PA, USA.

Burrouigh, P. A. and McDonald, R. A., 1998. Principles of geographical information systems. *Oxford University Press*, pp 333, Oxford.

Cautreels, W. and Van Cauwenberghe, K., 1978. Experiments on the distribution of organic pollutants between airborne particulate matter and the corresponding gas phase. *Atmospheric Environment*, 12, pp. 1133-1141.

Douglas, W. D., Joel, S. and John, D. S., 2002. Air Pollution and Daily mortality: Associations with particulates and acid aerosols. *Environmental Research*, 69, pp. 362-373.

Duanping, L., Donna, P., Yinkang, D., Eric, W., Jianwei, D. Richard, S., Hung-mo, L., Jiu, C. and Gerardo, H., 2006. GIS approaches for the estimation of residential-level ambient PM concentrations. *Environmental Health Perspectives*, 114, pp. 1374-1380.

Gavin, C., Gareth, J., Malkolm, H. and Stephen, D., 2007. Predictive uncertainty in environmental modeling. *Neural Networks*, 20, pp. 537-549.

Goodchild, M. F. et al., 1996. GIS and environmental modeling. *Progress and research issues, Fort Collins, CO; GIS World Book*, pp 486.

Gramotnev, G. and Ristovski, Z., 2004. Experimental investigation of ultra fine particle size distribution near a busy road. *Atmospheric Environment*, 38, pp. 1767-1777.

Halek, F., Kavousi, A. and Montahaie, H., 2004. Role of motor-vehicles and trend of air borne particulate in the Great Tehran area, Iran. *International Journal of Environmental Health Research*, 14, pp. 301-307.

Haghdoost, A. A., Mirzazadeh, A., Alikhani, S., 2008. Secular Trend of Height Variations in Iranian Population Born between 1940 and 1984. *Iranian J. Public Health*, 37, pp. 1-7.

Keyhani, A., Ghasemi-Varnamkhasti, M., Khanali, M. and Abbaszadeh, R., 2010. An assessment of wind energy potential as a power generation source in the capital of Iran, Tehran. *Energy*, 35, pp. 188-201.

Marilena K. and Elias C., 2008. Human health effects of air pollution. *Environmental Pollution*, 151, pp. 362-367.

Mauro, D. D. and Lorenzo, B., 2006. MAP IT: The GIS software for field mapping with tablet pc. *Computers & Geosciences*, 32, pp. 673-680.

Minsi, Z., Yu, S. and Xuhui, C., 2007. A health-based assessment of particulate air pollution in urban areas of Beijing in 2000-2004. *Science of the Total Environment*, 376, pp. 100-108.

Nabi Bidhendi, G. R. and Halek, F., 2007. Aerosol Size Segregated of Tehran's atmosphere in Iran. *International Journal of Environmental Research*, 1, pp. 58-65.

Patel, T. S. and Raiyani, C. V., 1995. Indoor air quality: problems and perspectives. In: Energy Strategies and Green House Gas Mitigation. Ed. P. R. Shukla, New Delhi, p72.

Pirmoradi, A., 2008. Creating compatibility matrix of educational use and suitable site selection of new school for urban resource management and supporting decision. 4th GIS Conference along with ISPRS Workshop, 6-7 January 2008, Tehran-Iran.

Silibello, C., Calori, G., Brusasca, G., Giudici, A., Angelino, E., Fossati, G., Oeroni, E. and Buganza, E., 2007. Modeling of PM10 concentrations over Milano urban area using two aerosol modules. *Environmental Modeling & Software*, xx, pp. 1-11.

Smith, K. R., 1996. Indoor air pollution in developing countries: Growing evidence of its role in the global disease burden. In: Indoor Air 96, proceedings of 7th international conference on Indoor Air and Climate. Ed. K. Ikeda and I Iwata. Institute of Public Health, Tokyo, p 33.

Sohrabinia, M. and Khorshiddoust, A. M., 2007. Application of satellite data and GIS in studying air pollutants in Tehran. *Habitat International*, 31, pp. 268-275.

Tolga, E., 2004. A GIS based decision support system for estimation, visualization and analysis of air pollution for large Turkish cities, *Atmospheric Environment*, 38, pp. 4509-4517.

Wilfred, W. and Gerald, S., 2005. Environmental software systems for emission inventories. *Environmental Modeling & Software*, 20, pp. 1469-1477.

World Health Organization European, 1997. Regional office for Europe, Copenhagen. Air Quality Guidelines for Europe, Series no 23.

Younes, N., Ryuichi, I., Hikari, F. and Toshiaka, T., 2008. GIS integration model for geothermal exploration and well siting. *Geothermics*, 37, pp. 107-131.

Yuqiong, L., Hoshin, G., Everett, S. and Thorsten, W., 2008. Linking science with environmental decision making: Experiences from an integrated modeling approach to supporting sustainable water resources management. *Environmental Modeling & Software*, 23, pp. 846-858.

Zhou, P., Ang, B. W. and Poh, K. L., 2006. Decision analysis in energy and environmental modeling: An update. *Energy*, 31, pp. 2604-2622.

Zhu, Y., Hinds, W.C., Kim, S. and Sioutas, S., 2002. Concentration and size distribution of ultrafine particles near a major highway. *J. Air & Waste Manage. Assoc.*, 52, pp. 1032-1042.