رابطه بین توزیع فشار و تراکم آلاینده ها در تهران*

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چکیده

تهران یکی از شهرهای آلوده جهان است. علیرغم اقدامات جدی مسئولین شهر هنوز آثار مثبتی در روند کاهش آلودگی هوای شهر مشاهده نمی شود. برای اینکه به عامل اصلی یعنی توزیع فشار توجهی نمی شود. بدین جهت این تحقیق سعی کرده است که رابطه بین تغییرات تراکم آلاینده های تهران و توزیع فشار را بررسی کرده و الگوهای موثر را شناسایی کند. برای این منظور روزهای آلوده تهران براساس آلاینده های اصلی یعنی co NO_2 SO_2 و TSP در ایستگاه آلودگی سنجی مرکزی (ویلا) در دوره ۱۹۸٤-۲۰۰۱ از سازمان محیط زیست تهیه گردید. داده های فشار سطح زمین روز های آلوده در ساعات صفر گرینویچ دوره مطالعه از مرکز پژوهشهای اقلیمی دانشگاه آنگلیای شرقی انگلستان در محدوده ۲۰ تا ٤٧/٥ درجه شمالی و ۳۵ تا ٦٧/٨ درجه شرقی تهیه گردید.

با استفاده از روشهای آماری تحلیل مولفه های اصلی و خوشه بندی پراکندگی فشار روزهای آلوده به شش تیپ هوایی به شرح آنتی سیکلون شمالی، آنتی سیکلون سیبری، آنتی سیلکون غربی، کم فشار خراسان، و تیپ مداری طبقه بندی شد. بیشتر تیپ ها در پاییز فراوانتر بودند. توالی های آلوده طولانی مدت توسط تیپ مداری و توالی کوتاه مدت توسط الگوی کم فشار خراسان تولید شده اند.

نتایج بررسی هماهنگی بین تغییرات فشار روزانه فرودگاه مهرآباد و آلودگی هوای ایستگاه ویلا رابطه مثبتی را برای آلاینده های co NO_2 SO_2 و رابطه منفی برای آلاینده **TSP** با توزیع فشار روزانه نشان داد. رابطه های بدست آمده قابل توجه و معنی دار بودند به طوریکه براساس این روابط مدل های پیش بینی آلودگی هوای تهران از روی توزیع فشار روزهای قبل عملی شد.

واژگان کلیدی: تهران، تیپ های هوا، آلودگی هوا، رابطه بین الگوهای فشار و آلودگی هوای تهرانهٔ مدل های پیش بینی آلودگی هوای تهران.

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The relation between pressure distribution and air pollution concentration in Tehran

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ABSTRACT

Tehran is one of the polluted cities in the world. Despite the effective acts of the city authorities there is not yet sign of improvement. Because the main factor, that is, the pressure distribution is not considered. This research is undertaken to analyze the relation between the pressure changes and the pollution concentration of Tehran and identify the effective pressure patterns. For this purpose the polluted days of Tehran according to CO, NO2, SO2, and TSP were extracted from the daily pollution data of Villa station, located in the central part of Tehran, during 1984-2001 period. The NCEP 00 GMT daily pressure data of the pollution days at 2.5 degrees apart grid points within the 20°N to 47.5°N and 35°E to 67.5°E window were used.

Through the use of Principal Component Analysis and Clustering methods the pressure distribution of pollution days were classified into six groups and then the composite pressure pattern of each group was mapped. Each composite map was assigned as a weather type. These weather types are as: Northwestern Anticyclone, Caspian Low, Siberian Anticyclone, Western Anticyclone, Khorasan Low, and the Zonal type. Most of the types were frequent in fall. The Khorasan Low is the dominant type during the short period pollution runs whereas the Zonal type is dominant during longer pollution episodes.

The relation between the pressure changes and the pollution concentrations were studied through the use of the daily pressure of the Mehrabad station and pollution values of Villa station. The results showed positive relation between the Mehrabad grid point pressure and pollution concentration of CO, NO2, and SO2, but negative relation with the concentration of TSP.

Key words: *Tehran, weather types, air pollution, air pollution and pressure patterns .pressure models of Tehran pollution.*

Introduction

The relation between pressure patterns and the pollution concentration of the urban air was the main concern of the climatologists for long time (Comrie and Yarnal, 1992; Comrie,1994; Dorling and Dvies, 1995). Most of these works were focused on the relation between pressure and concentration of pollutants such as CO, SO_2, and NO_x.
Leavey and Sweeney (1990) have identified that the pollution of Dublin has transported from the Rhine valley through the orientation of pressure systems. According to Kassomenos and his colleagues (1998) seven main pressure patterns were responsible for the pollution of Athen. With the calm weather conditions southerly winds the pollution concentration intensifies whereas the unstable northery currents decreases it. The results of the research

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conducted by Cheng and Lam (2000) in Hong Kong was the same. Yarnal(1993) has reported elaborated literature in this regard.

Tehran, with an area of 780 square kilometers, is located on the southern foothills of Alborz mountains. It is very crowded city. Due to traffic jams and enormous vehicles many accidents occur every day (Ghayormanesh, 2003). The city in addition to its political role is an important city and most of the factories are located to its west. These conditions coupled with the prevalent westerly and northwesterly winds increase the pollution potential of the city. The elevation of the land increases from 1200 meters in the South to about 2000 in the North. Therefore the establishment of an inversion layer creates different pollution conditions over the city (Afshar, 2000; Rezaeepour, 1996). Accordingly, southern parts are more polluted than the North. Concentration of many factories in the west and the existence of many traffic jams have worsened the pollution conditions several times (Saidi, 1996). Although the pollutant resources exist and are active all over the year, but why some days, even work days, are very clear and some days even during weekend are very polluted? It is obvious that during a few days period nothing changes except the pressure patterns. During the stable days with low inversions, the pollution concentration increases (Deljoo, 1999). But low pressure patterns and windy atmosphere create very clear skys. Therefore it seems reasonable to study the pressure changes over the area and through time. This work has tried to develop a relation between temporal variations of pressure and pollution and identify the responsible pressure patterns.

Data and Methodology

In order to study the relation between pressure and urban air pollution, the daily pollution data of four main pollutants; SO2, CO, NO2, and PM were obtained from the Environmental Protection Agency of Iran for the central pollution station of Villa for 1984-2001 period. Due to many data missing periods, only 2840 days with pollution data were chosen. Among these days 1572 days were polluted with at least one pollutant. The polluted days were selected according the Table 1 thresholds. First, the frequency and intensity of the polluted days were studied according the pollution runs. Second, the relation between daily pollution concentrations and pressure values was studied from two different approaches:

To determine the pressure patterns responsible for the polluted days, the grid point pressure data were extracted from the NCEP reanalysis data of CRU, University of East Anglia, England, with 2.5 degrees resolution for the window between 35ºE-67.5ºE and 20ºN-50ºN during 2165 polluted days. Through the use of the Principal Component Analysis (PCA) and Clustering Analysis (Ward method), the daily pressure values of all grid points were classified into six major components. The composite map of the days of each component was drawn and named as a pattern. Within each weather type polluted days of each pollutant were extracted and their intensity was computed.

To measure the relationship between pollution concentration and the pressure values, the days which was polluted by all of the four pollutants, were selected (424 days). The daily sea level pressure of Mehrabad (Airport) station for these days were obtained from Iranian Meteorological Organization. The relation between air pollution concentration of each pollutant and daily pressure values of Mehrabad station was computed for 1 to 3 lag days.

Results

Statistical Analysis

All of the 1572 polluted days were analyzed into runs of polluted days. These runs were experienced from one day up to 75 days long at the most and are shown in Table 2. The runs were identified irrespective of the pollutant type. One-day long runs are frequent but the total days of six-day long runs are more than the others. The long period runs, especially runs longer than eight days, are very few. The higher frequency of short period runs indicates the effect of the synoptic systems which usually lasts 3 to 7 days(Alijani and Zahedi, 2002). According to Table 2, CO has polluted more than the others(about 37%) and particulate matters has the least effect among the pollutants. The higher share of CO is better shown among the short period runs. The intensity of the pollutants are shown in Table 3. According to this table the mean intensity of Co has increased by the length of the runs from 11^{ppm} *in one-day long runs to more than* 16^{ppm} *in the longer runs. The other pollutants do not show any preference.*

Weather types

The processing of the grid point pressure values of the polluted days through the PCA and Clustering methods resulted in six weather types. These weather types are plotted in Figure 1 and their frequency are listed in Table 4.

According to Table 4 the Zonal Type (ZT) has caused most of the pollution days and after that the Siberian Anticyclone (SA) was the second important type. The Khorasan Low has the lowest power in producing pollute d days. The ZT is important in producing CO, NO_2*, and PM pollution concentrations, but the SA type is important for* SO_2 *pollution. The description of the weather types are as follows:*

Western Anticyclone (WA)

During the dominance period of this type an anticyclone with the central pressure of more than 1028 hPa is located over Turkey. Its ridge is extended eastward to the south of Tehran which leads cold and stable air over the city. These northwesterly winds bring in the pollution of the factories located to the west of Tehran.

Caspian Low (CL)

This type has created a low over the Caspian Sea. This low in conjunction with the Siberian High ridge to the south of Tehran has developed a pressure gradient over the city. It also brings the northwesterly winds but due to its relative instability this type has the lowest impact on the pollution of the city.

Siberian Anticyclone (SA)

During these days the SA has expanded over Iran and developed a very stable air over Tehran. It is the second important weather type after the ZT. All of the pollutants except the CO have the highest pollution concentration during the days of this type.

Northwestern Anticyclone (NWA)

This type has developed an anticyclone to the north of the Black Sea. It has spread itself southward causing stable conditions and easterly winds over Tehran. It has the next lowest frequency after CL type. Because its easterly winds brings no remarkable pollution from the east of the city.

Khorasan Low (KHL)

The development of a low pressure over the Khorasan Province in the northeast of Iran brings unstable and cold northwesterly winds to Tehran. These currents sometimes amalgamate with mountain breezes of Alborz range and their temperature decreases remarkably. This type has the lowest frequency and intensity among all pollutants.

Zonal Type (ZT)

The ZT is the normal pressure pattern of Iran during the course of the year, especially in the cold period. During its occupation period a general high pressure pattern develops over the northern parts of Iran and the southern parts go under the relatively low pressure. The atmosphere of Tehran is stable and weak easterlies dominate. It has caused the highest concentrations in CO and PM but the lowest in NO2 and SO2.

The relationship Models

In order to compute this relationship the days with measurements of all pollutants were identified. These days were 424 days during the study period. The correlations between the pollution and pressure values of these days are shown in Table 5.
All of the correlation values were significant at $\alpha = 0.05$ level. According to Table 5 CO has the highest correlation and SO_2 shows the lowest value. All of the volatile pollutants show positive relation with the pressure but the solid particulate matters indicate negative relation. This is reasonable because the gaseous pollutants spread in the air. As the pressure gets higher and weather becomes calm, their concentration increases. Among these, Carbon Mono Oxide is produced more than the others in Tehran. It is produced by incomplete combustion of motor vehicles and car services and even by humans. During high pressure days it develops a very dense fog over the city. Second to CO is the emission of NO_2 which is produced by electrical plants and vehicles and some factories. The pollution concentrations of the future days was predicted according to the pressure values of the previous days. The regression models of these forecasts are written in Table 6. In this table D = today, Y = yesterday, DD = two days ago, and DDD = three days ago. The predicted values of the pollution values according to the yesterday pressure values are drawn in Figure 2. According to this figure the accuracy of the predicting models are very high for NO_2 and CO values stand for the second, especially in recent years. The model is very weak for SO2 pollution.

Conclusion

In order to understand the relationship between pressure patterns and the urban air pollution of Tehran area, the daily pollution concentrations of the central pollution measuring station(

Villa) were analyzed according to the area and station pressure changes. Six main pressure patterns (weather Types) were responsible to the air pollution of Tehran. These are WA, CL, SA, NWA, KHL, and ZT. The first frequent type is ZT followed by WA. The KHL was the less frequent and important.The relation between daily air pollution concentrations and point pressure values of Mehrabad station showed was negative for PM but positive for other pollutants.this means that during the low pressure days Tehran experiences higher PM concentrations. Because during these days the wind spreads the particulate material to the air. During the high pressure days the relatively heavy particulates cannot move to the air but the other gaseous pollutions are concentrated at the low levels. The regression models showed that the point sea level pressure of previous day is more reliable and correct to predict the pollution concentrations of Tehran. This study was based on the scattered and limited pollution data which caused sum bias and uncertainty on the results. But is regarded as a starting point for future researches. It is hoped that future works will be able to use continuous and long term data.

Table 1. The pollutants thresholds*.*

Pollutant	***Computing interval***	***Threshold***
CO	*8 hours*	*9^{ppm}. 10 µg /m^3*
SO2	*one day*	*$.14^{ppm}$. 365 µg /m^3*
NO2	*one day*	*$.05^{ppm}$. 94 µg /m^3*
PM	*one day*	*150 µg /m^3*

Table 2. Frequency of the polluted runs in each pollutant

	CO	PM	NO2	SO2
Mean	13.9	191.5	0.24	0.12
Runs: 1	11	176.7	0.16	0.11
2	12.1	175.2	0.12	0.12
3	13.1	185.8	0.14	0.11
4	13.9	190	0.13	0.11
5	15	209.8	0.12	0.12
6	13.7	188.1	0.15	0.12
7	13.3	217.9	0.13	
8			0.16	0.13
9	14.1	186	0.17	
10	16	230		
11		270	0.23	
12	13.2		0.16	0.14
13	13.9	235.5	0.19	
14	16.5			
15		220.7		0.15
16				0.11
17				0.12
18	23	204.7		
19	16.2		0.32	0.12
20	16.6	179		
21			0.18	
22	16.2			
23	14.4		0.2	
24				
25				
26	16.92			
27			0.19	0.12
28				0.14
29				0.13

Table 3. Mean pollution concentration of the runs

Runs	No. of Runs	No. of Days	SO2	%	PM	%	NO2	%	CO	%
1	102	102	9	8.8	24	23.5	9	8.8	60	58.8
2	43	86	10	11.6	15	17.4	10	11.6	51	59.3
3	38	114	17	14.9	23	20.2	20	17.5	54	47.4
4	22	88	9	10.2	31	35.2	10	11.4	38	43.2
5	18	90	9	10.0	16	17.8	8	8.9	57	63.3
6	21	126	18	14.3	20	15.9	12	9.5	76	60.3
7	4	28	1	3.6	1	3.6	7	25.0	19	67.9
8	6	48	7	14.6	6	12.5	27	56.3	8	16.7
9	3	27	17	63.0					10	37.0
10	2	20	4	20.0	6	30.0			10	50.0
11	4	44	11	25.0	6	13.6	11	25.0	16	36.4
12	2	24					12	50.0	12	50.0
13	4	52	5	9.6	10	19.2	27	51.9	10	19.2
14	1	14							14	100.0
15	1	15	15	100.0						
16	2	32	16	50.0	2	6.3			14	43.8
17	1	17			1	5.9	5	29.4	11	64.7
18	2	36	18	50.0					18	50.0
19	1	19					4	21.1	15	78.9
20	2	40			20	50.0		0.0	20	50.0
21	2	42					42	100.0		
22	1	22			2	9.1	20	90.9		
23	4	92	5	5.4	2	2.2	47	51.1	38	41.3
27	1	27	1	3.7			26	96.3		
28	1	28	28	100.0						
33	1	33	29	87.9	4	12.1				
36	1	36					36	100.0		
39	1	39					37	94.9	2	5.1
42	1	42					42	100.0		
54	1	54			1	1.9	53	98.1		
60	1	60	27	45.0			33	55.0		
75	1	75			1	1.3	49	65.3	25	33.3
Total		1572	256	16.3	191	12.2	547	34.8	578	36.8

Table 4. Frequency and intensity of the pollutants in the weather types.

Pollutants		WA	CL	SA	NWA	KHL	ZT	Total
CO	Frequency	113	131	120	67	26	274	731
	Intensity	12.41	14	14	13.6	13.7	14.6	14
NO_2	Frequency	122	104	67	34	40	214	581
	Intensity	0.29	0.27	0.28	0.27	0.23	0.2	0.25
SO_2	Frequency	83	36	71	16	10	40	256
	Intensity	0.13	0.12	0.13	0.13	0.12	0.12	0.13
PM	Frequency	115	86	102	48	25	221	597
	Intensity	188	191	104	184	175	195	191
Total		443	357	360	165	101	749	2165

Table 5. ***Correlations between daily pollution and pressure values***

Pollutant	***Pressure value of***			
	Present Day	*Yesterday*	*Two Days ago*	*Three Days ago*
CO	*0.51*	*0.36*	*0.37*	*0.4*
SO2	*0.19*	*0.17*	*0.19*	*0.24*
NO2	*0.49*	*0.33*	*0.24*	*0.24*
PM	*-0.31*	*-0.37*	*-0.43*	*-0.39*

Table 6. Regression models

$CO = .101*D_{PRESSURE}-97.016$
$CO = .222*Y_{PRESSURE}-219.84$
$CO = .234*DD_{PRESSURE}-231.728$
$CO = .259*DDD_{PRESSURE}-257.689$
$SO_2 = .000252*D_{PRESSURE}-.21$
$SO_2 = .001322*Y_{PRESSURE}-1.287$
$SO_2 = .001408*DD_{PRESSURE}-1.375$
$SO_2 = .001788*DDD_{PRESSURE}-1.762$
$NO_2 = .001401*D_{PRESSURE}-1.352$
$NO_2 = .003335*Y_{PRESSURE}-3.312$
$NO_2 = .002489*DD_{PRESSURE}-2.451$
$NO_2 = .0022*DDD_{PRESSURE}-2.163$
$PM = 1308.063-1.183*D_{PRESSURE}$
$PM = 5184.148-4.985*Y_{PRESSURE}$
$PM = 5771.84-5.563*DD_{DBBPRESSURE}$
$PM = 5464.97-5.261*DDD_{PRESSURE}$

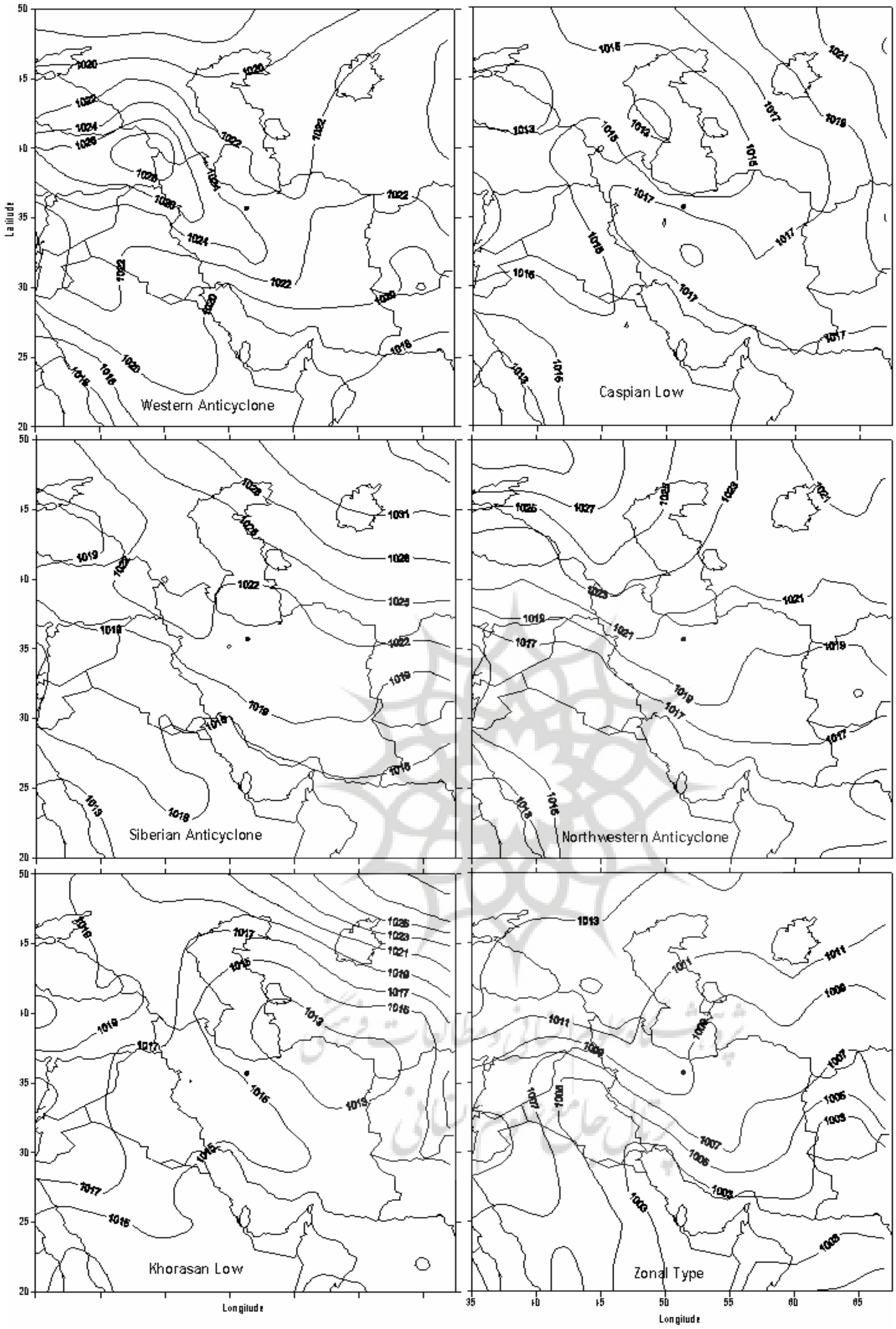

Figure 1. The weather types responsible for Tehran air pollution.

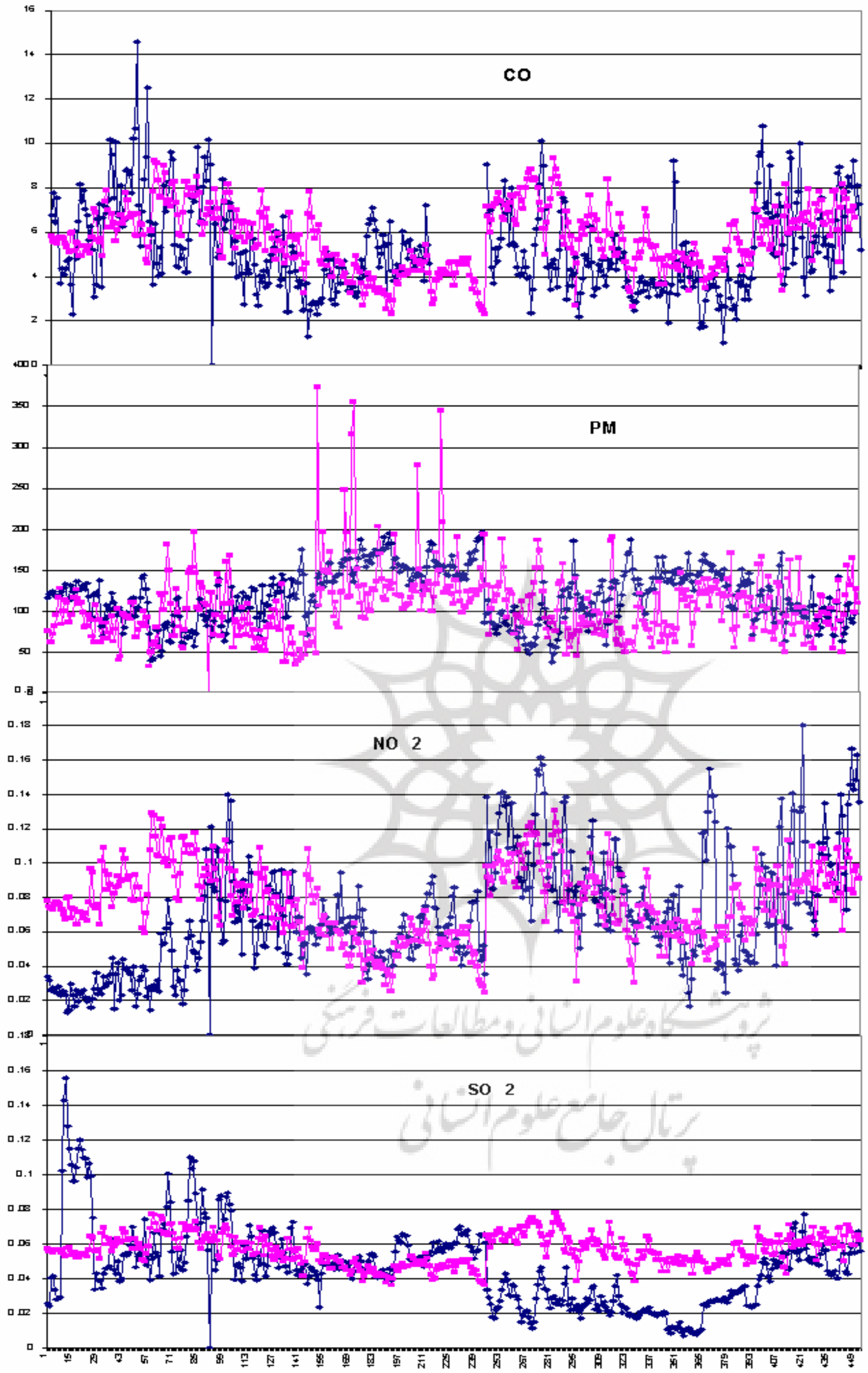

Figure 2. Comparison of observed (heavy) and predicted (plain) values of pollutants based on one lag day.