TEMPORAL AND SPATIAL VARIATION OF AIR POLLUTION İN BURSA, KOCAELİ AND YALOVA, TURKEY

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Serpil Menteşe[1]

[1]Bilecik Seyh Edebali Universty, Turkey

Corresponding author: serpil.mentese@bilecik.edu.tr

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Abstract

Air pollution is a serious environmental problem. The anthropogenic air pollutants have been intensified in the atmosphere of industrial and densely populated cities. The aim of this study was to reveal temporal and spatial pattern of air pollution in Bursa, Kocaeli and Yalova. Because the cities are a densely populated industrial city in Turkey. For this study, outdoor inhalable particles (measured as particulate matter-PM_{10}), sulfur dioxide (SO_2), nitrogen oxides (NO, NO_2) and carbon monoxide (CO) data were used to put forward air quality for the period March 2013- December 2015. Data taken from four air quality monitoring station (Beyazit Street, Inegol, Kestel, Kultur Park, Uludag Universty, Alikahya, Golcuk, Korfez , İzmit Kandira, Yenikoy, Altinova and Armutlu) established by the Marmara Clean Air Center Directorate were used. The correlation between the PM_{10}, SO_2, NO, NO_2, CO concentration, year and month has been investigated utilizing bivariate correlation methods. Inverse Distance Weight (IDWI) techniques were used to analyze the spatial distribution of all pollutants. As a result, annual SO_2, PM_{10} and NO_2 concentrations show a decreasing trend in the last years. However, NO and CO concentrations show a increasing trend. Also, the maximum SO_2, PM_{10}, NO_2, NO, and CO concentrations peaked at the period of winter season. When the pollutants concentrations indicate higher values in city centers with high population intended for heating and around industrial enterprises (Bursa and Kocaeli)..

Key words: Bursa, CO, Kocaeli, NO, NO_2, PM_{10}, Regression, SO_2, Yalova;

Introduction

An increase in population, industrialization and urbanization cause environmental problems. As a result of this situation, the quality of air, water and soil, which are among the natural environment elements, deteriorates. Among these environmental problems, the pollution which exhibits its effect within the shortest time is air pollution [1]. Pollutants left in the atmosphere as a result of the combustion of fossil fuels used in heating, vehicles, power generating plants and industry constitute the main sources of air pollutant parameters in the urban atmosphere [2]. The air pollution levels of urban life also vary by vehicle traffic, energy generation and climatic factors.

The most common air pollutants in the atmosphere consist of SO_2 CO, NO, NO_2 and PM_{10}. SO_2 mixes into the atmosphere as a result of the combustion of poor quality fossil fuels containing a high rate of sulfur for industrial and heating purposes [3], and PM mixes into the atmosphere mostly from industrial organizationsand partially from the use of fossil fuels for heating. CO pollution results from cigarette smoke and exhaust gas [4], NO emissions result from industrial activities, especially traffic, and NO2 is a traffic-based pollutant [3].

Air pollution is an important environmental problem experienced in Turkey as it is in the world [5]. The World Health Organization (WHO), European Union (EU), European Environmental Protection Agency (EPA) and Turkish Air Quality Control Regulation

(HKKY) has set the target limit values for air pollutants. When these limit values are exceeded, pollutants cause negative effects on non-living things and living creatures. When their effects on human health are considered, air pollution is the most important problem in urban areas [6]. It is estimated that every year, 1,3 million people, especially in developing countries, die due to urban outdoor air pollution [7]. Thus, air pollution is one of the biggest environmental problems.

Methods

Sampling site

Bursa, Kocaeli and Yalova are located in the Marmara region of Turkey (Figure 1). Since 2016, Bursa has the population of 2.901.396, Kocaeli has the population of 1.830.772 and Yalova has the population of 241.665. Bursa is an industrial city in which many industrial organizations producing different products from food to textile, from automotive products to machinery and equipment operate, the population and the number of vehicles consistently increase and there are six industrial zones. Kocaeli is an industrial city which has more than 1000 industrial enterprises 300 of which include very dense traffic arteries (D100 and E-6(TEM)), three tire factories, automotive industry, paper mill, petrochemical industry and petroleum refinery. Moreover, TÜPRAŞ which is the biggest refinery of the Middle East is located in Kocaeli [8]. The tourism sector has an important place in the economy of Yalova.

In general, the Mediterranean climate type is common in Bursa province and it is dry and hot in summers, warm and rainy in winters. In Kocaeli, there is a transition climate type between the Mediterranean climate and the Black Sea climate. Moreover, in Yalova, there is a transition climate type between the Mediterranean and Black Sea climates. Summers in the province are dry and hot, and winters are warm and rainy.

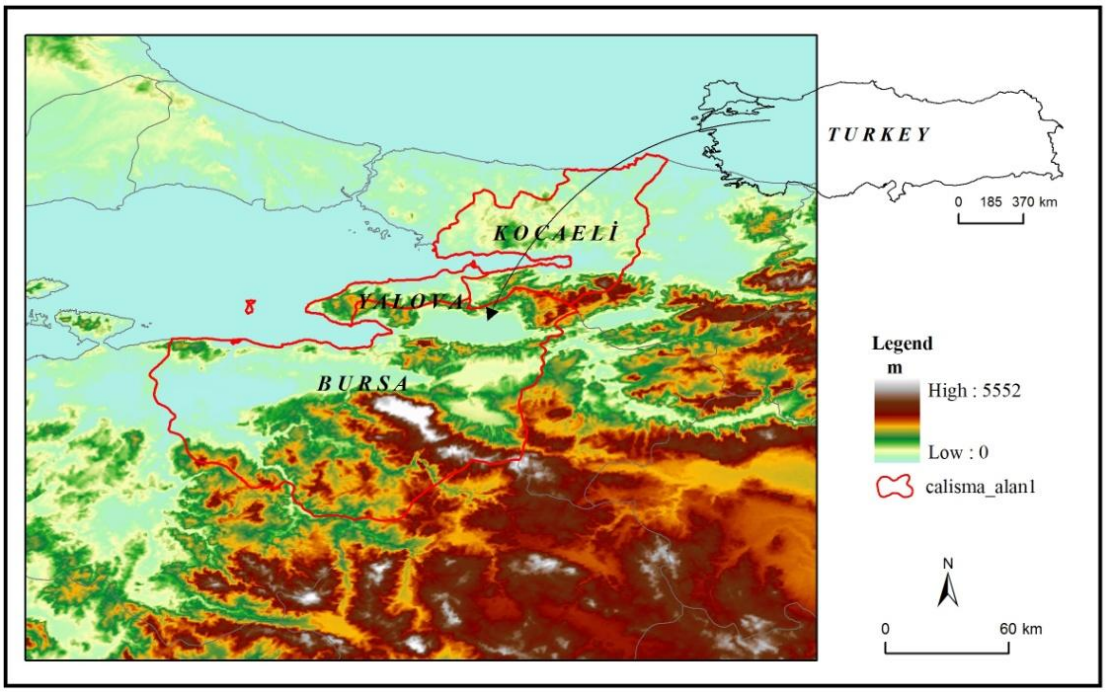

Figure 1: Location map of the study area.

2.2. Data

For this study, outdoor inhalable particles (measured as particulate matter-PM10) and sulfur dioxide (SO_2), nitrogen oxides (NO, NO_2) and carbon monoxide (CO) data were used to put forward air quality. Data taken from 11-13 ranging air quality monitoring stations (Beyazit Street, Inegol, Kestel, Kultur Park, Uludag Unv., Alikahya, Golcuk, İzmit, Kandira, Korfez, Yenikoy, Altinova and Armutlu) established by the Marmara Regional Clean Air Center Directorate were used**.** The monitoring stations were fully automated and provided daily readings of levels of SO_2, PM_{10}, NO,

NO2 and CO. For each day, air pollution data were extracted from all monitoring stations. Monthly averages were then calculated for all pollutants for further analyses. When data were missing for a particular monitoring station on a given day, the values from the remaining monitors were used to compute the average.

2.3. Statistics

The correlation between the PM_{10}, SO_2, NO, NO_2, CO concentration, year and month has been investigated utilizing bivariate correlation methods. Inverse Distance Weight (IDWI) techniques were used to analyze the spatial distribution of PM_{10}, SO_2, NO, NO_2 and CO in the study area and to predict the variable values of un-exampled places with the help from the values of exampled places. In the study, the multivariate statistical analysis was performed by SPSS Software. For mapping, ArcGIS Software was used.

3. Results and discussion

3.1. Temporal and Spatial Change of PM_{10}

Particle matter in the air are pollutants that should be monitored and checked due to their important environmental and health effects. This is because particle matter have negative effects on both health and the environment. When the annual PM_{10} change in the study area was examined, it was observed that the pollutant around Beyazit, Inegol, Kestel, Alikahya, Izmit, Korfez, Yenikoy and Armutlu tended to decrease between March 2013-December 2015. It was identified that the pollutant around Kandira increased. This tendency for increase was found to be statistically significant at 99% confidence level (r:0,547; p≤.001) in PM_{10} (Table 1).

Table 1. Correlation Table Indicating the Monthly and Annual Temporal Change of PM_{10}.

PM_{10}		**Year**		**Month**	
Place		Pearson Correlations	Sig. (2-tailed)	Pearson Correlations	Sig. (2-tailed)
Bursa	Beyazit Street	,031	,862	-,074	,677
	Inegol	-,083	,640	,120	,499
	Kestel	-,207	,239	-,058	,744
Kocaeli	Alikahya	-,178	,313	-,062	,727
	Izmit	-,263	,134	,009	,960
	Kandira	,**547****	,001	-,152	,392
	Korfez	-,199	,259	-,243	,167
	Yenikoy	-,172	,331	-,290	,096
	Armutlu	-,334	,054	-,079	,657

The tendency for decrease in PM10 is related to considering the limit values determined in air pollution control regulations and change in resources causing pollution. For example, while the source of pollution was mostly industrial processes and heating twenty years ago, nowadays, the most important source of pollution is traffic as well as industrial sources [9]. Furthermore, the use of quality fossil fuels and transition to natural gas in almost all provinces are the other factors which are effective in reducing the values of pollutants.

When the spatial change of PM_{10} in July was examined (Figure 2), the highest concentrations in all years were generally identified in and around Bursa (Kestel, İnegöl, Kultur Park). In other words, PM_{10} is at higher levels during summer in and around Bursa. The concentration levels were found to be at lower levels in other areas of the study field.

Although high concentration levels were encountered in and around Bursa in December, the highest concentrations were identified in and around İnegöl. When the sample months were compared among themselves, it was identified that the PM_{10} levels in December were higher than in July (Figure 2). The climatic features of winter are effective parameters in the formation of pollution.

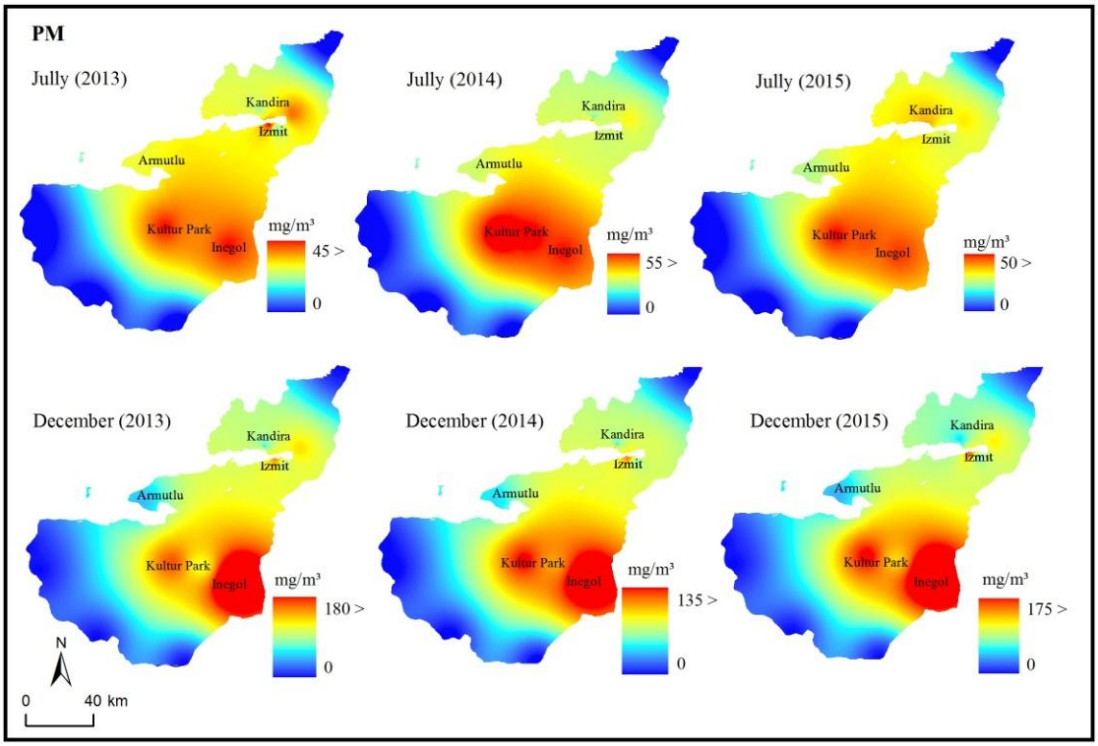

Figure 1: The Spatial Distribution of PM_{10} Concentration of the Study Area.

3.2. Temporal and Spatial Change of SO_2

The most important sulfur compound causing air pollution is SO_2. SO_2 results from industrial activities, fossil fuels used for heating, thermal plants and the use of diesel-fueled vehicles [8]. When the annual SO_2 change was examined, it was observed that the pollutant around Beyazit, Inegol, Kestel, Kultur Park, Uludag Unv., Golcuk, Korfez, Yenikoy and Altinova tended to decrease between March 2013-December 2015. This tendency for decrease in SO_2 was found to be statistically significant at 99% confidence level (r:0,497; p≤.001) only in İnegöl (Table 2).

Table 2: Correlation Table Indicating the Monthly and Annual Temporal Change of SO_2.

SO_2		**Year**		**Month**	
Place		Pearson Correlations	Sig. (2-tailed)	Pearson Correlations	Sig. (2-tailed)
Bursa	Beyazit Street	-,016	,929	-,203	,250
	Inegol	**-,497****	,003	,095	,594
	Kestel	-,309	,076	-,300	,085
	Kultur Park	-,202	,253	-,082	,645
	Uludag Unv.	-,304	,081	-,219	,213
Kocaeli	Alikahya	,061	,732	-,209	,235
	Golcuk	-,161	,364	-,027	,879
	Korfez	-,271	,134	-,441*	,012
	Yenikoy	-,238	,176	-,178	,314
Yalova	Altinova	-,110	,538	-,136	,444
	Armutlu	,004	,980	,229	,192

When the spatial change in SO_2 in July was examined (Figure 3), the highest concentrations in 2013 and 2015 were generally identified in around Bursa (Kestel, Inegol and Kultur Park) as in PM_{10}. Kandira was added to Bursa in 2014. This is because SO_2 concentrations indicate higher values in city centers with high population intended for heating and around industrial enterprises (8). The concentration levels were found to be at lower levels in other areas of the study field.

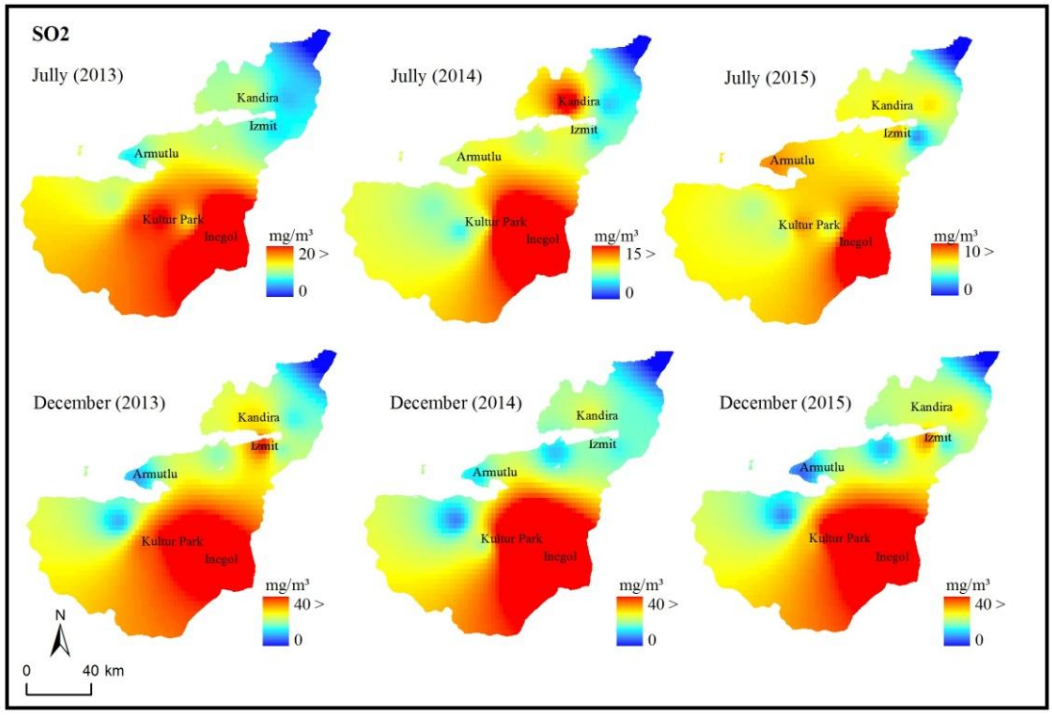

Figure 2: The Spatial Distribution of SO_2 Concentration of the Study Area.

The highest concentrations were observed in and around Bursa in December as it was in July. When the sample months were compared among themselves, it was identified that the SO_2 levels were higher in December than in July as it was in PM_{10} (Figure 3).

3.3. Temporal and Spatial Change of NO

The most important ones of NOx causing air pollution are NO and NO_2. In many cities in Turkey, decreases were observed in the levels of air pollutants with the transition to natural gas instead of fossil fuels [10]. However, the most important two main pollutants in natural gas are NO and NO_2 [11]. Laws have been approved for monitoring NOx emission due to reasons such as its effect on health, reaction with ground-level O_3 concentration, and acid rain, and the limit values that should be complied with have been set.

When the annual NO change was examined, it was observed that the pollutant in the study area tended to increase between March 2013-December 2015. However, this increase trend was not statistically significant in NO (Table 3).

Table 3: Correlation Table Indicating the Monthly and Annual Temporal Change of NO.

NO		**Year**		**Month**	
Place		Pearson Correlations	Sig. (2-tailed)	Pearson Correlations	Sig. (2-tailed)
Bursa	Beyazit Street	,084	,638	,206	,242
	Inegol	**,064**	,720	,281	,108
	Kestel	,152	,390	,267	,127
	Kultur Park	,082	,644	,300	,084
	Uludag Unv.	,081	,651	,385*	,024
Kocaeli	Alikahya	,111	,532	,094	,599
	Golcuk	-,021	,905	,083	,640
	Izmit	,076	,667	,215	,222
	Kandira	,213	,226	,482**	,004
	Korfez	,116	,514	,203	,251
	Yenikoy	,036	,838	,133	,454
Yalova	Altinova	,100	,574	,064	,721
	Armutlu	,108	,541	,190	,281

When the spatial change in NO in July and december was examined (Figure 4), the highest concentrations in 2013 and 2015 were generally identified in around Bursa (Kultur Park and Kestel) and Kocaeli (İzmit, Kandira). When the sample months were compared among themselves, it was identified that the NO levels in December were higher than in July (Figure 4).

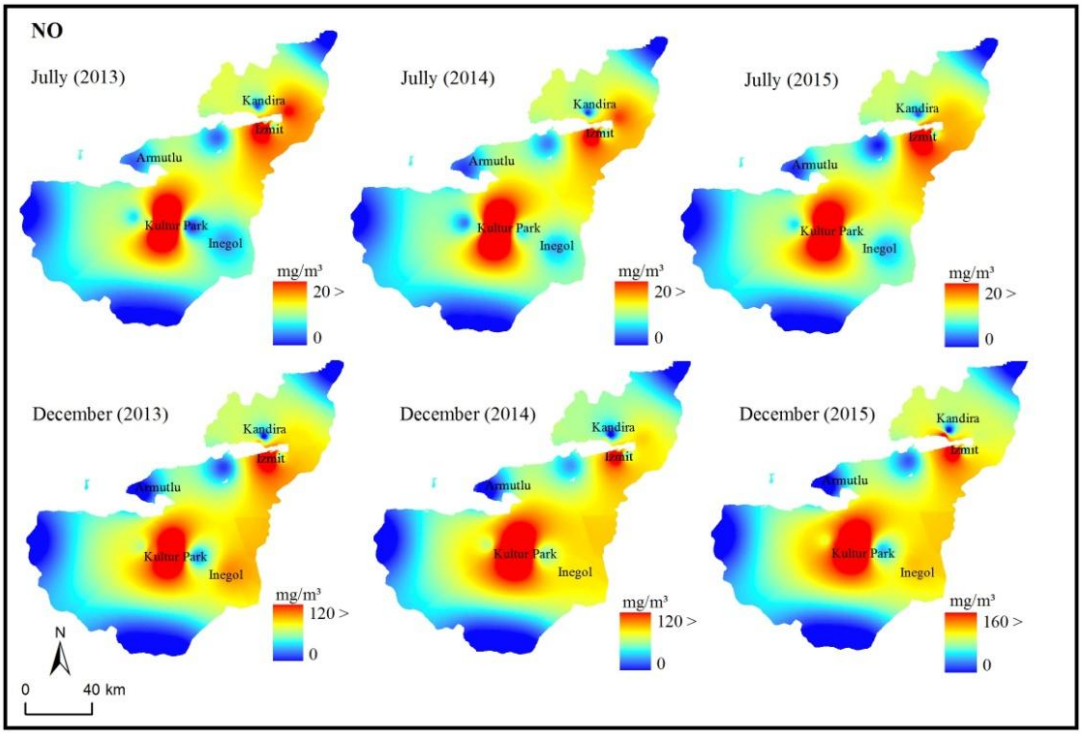

Figure 3: The Spatial Distribution of NO Concentration of the Study Area.

3.4. Temporal and Spatial Change of NO2

When the annual NO_2 change in the study area was examined, it was observed that the pollutant around Kultur Park, Alikahya, Golcuk, İzmit, Kandira, Yenikoy and Altinova tended to decrease between March 2013-December 2015. However, this decrease trend was not statistically significant in NO_2 (Table 4). It was identified that the pollutant in other parts of the study area increased. However, this increase trend was not statistically significant.

Table 4: Correlation Table Indicating the Monthly and Annual Temporal Change of NO_2.

NO_2		**Year**		**Month**	
Place		Pearson Correlations	Sig. (2-tailed)	Pearson Correlations	Sig. (2-tailed)
Bursa	Beyazit Street	,021	,906	-,144	,415
	Inegol	,105	,554	-,106	,552
	Kestel	,190	,281	-,087	,624
	Kultur Park	-,080	,653	,227	,196
	Uludag Unv.	,038	,831	-,075	,673
Kocaeli	Alikahya	-,013	,944	-,429*	,011
	Golcuk	-,053	,764	-,123	,490
	Izmit	-,033	,854	-,172	,330
	Kandira	-,026	,885	,181	,305
	Korfez	,030	,867	-,021	,905
	Yenikoy	-,020	,912	-,088	,619
Yalova	Altinova	-,139	,434	-,076	,668
	Armutlu	,109	,540	-,036	,839

When the spatial change in NO_2 in July and december was examined (Figure 5), the highest concentrations in 2013 and 2015 were generally identified in around Bursa (Kultur Park and Kestel) and Kocaeli (İzmit, Kandira) as in NO.

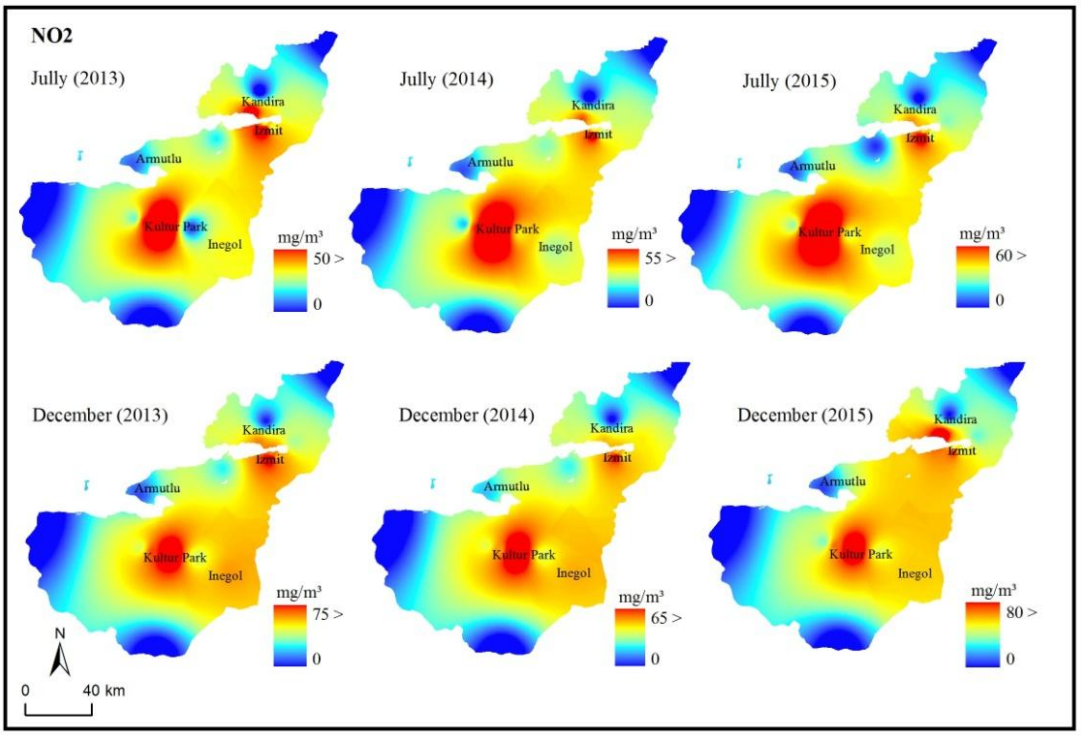

Figure 4: The Spatial Distribution of NO_2 Concentration of the Study Area.

Also when the sample months were compared among themselves, it was identified that the NO_2 levels in December were higher than in July as the other pollutants (Figure 5).

3.5. Temporal and Spatial Change of CO

CO is a colorless and odorless gas. CO is formed during the incomplete combustion of fossil fuels and constitutes one of the most important compounds of air pollution resulting from traffic exhaust smoke [10]. It is a poisonous gas that is difficult to distribute in situ and is not easily noticed.

When the annual CO change was examined, it was observed that the pollutant in the study area tended to increase between March 2013-December 2015. However, this increase trend was not statistically significant in CO (Table 6). Since there are not enough CO measurement stations in the study area, the spatial change of CO could not be performed.

Table 6: Correlation Table Indicating the Monthly and Annual Temporal Change of CO.

CO		**Year**		**Month**	
Place		Pearson Correlations	Sig. (2-tailed)	Pearson Correlations	Sig. (2-tailed)
Bursa	Beyazit Street	,028	,874	,006	,975
Kocaeli	Izmit	,156	,377	,188	,286

4. Conclusions

This study aimed to reveal temporal and spatial pattern of air pollution (PM10, SO2, NO, NO2 and CO) in Bursa, Kocaeli and Yalova. When the annual PM_{10}, SO_2 and NO_2 change in the study area was examined, it was observed that the pollutant around study area tended to decrease between March 2013-December 2015. This tendency for increase was found to be statistically significant at 99% confidence level. However when the annual NO and CO change in the study area was examined, it was observed that the pollutant around study area tended to incerase. But, this increase trend was not statistically significant.

The highest concentrations in 2013 and 2015 were generally identified around in Bursa. This is because pollutants concentrations indicate higher values in city centers with high population intended for heating and around industrial enterprises. Bursa is an industrial city in which many industrial organizations producing different products from food to textile, from automotive products to machinery and equipment operate, the population and the number of vehicles consistently increase and there are six industrial zones. When the sample months were compared among themselves, it was identified that all pollutants levels in December were higher than in July.

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