Comparison of PM10 and SO_2 Concentrations in the Cities Located at the Mediterranean Coast of Turkey

*Güray Doğan, Ahmet Tepe and Çiğdem Moral
Akdeniz University, Department of Environmental Engineering, Engineering Faculty, Campus Konyaaltı, 07058 Antalya

Abstract

In this study, PM10 and SO_2 concentrations in cities located at the Mediterranean Coast of Turkey were analyzed. These cities, namely Antalya, Adana, İçel and Antakya, are with similar geographic characteristics located in Mediterranean coast of Turkey. These cities are under influence of dust transport from Saharan desert, industrial emissions, winter heating emissions, sea salt and traffic emission. In order to understand the influences of these sources, diurnal, seasonal, weekday-weekend and long term variations in the PM10 and SO_2 concentrations were analyzed.
The diurnal variations of PM10 concentrations showed bimodal distribution, having higher PM10 values during rush hours, in all cities except Adana. This indicates that emissions from traffic were an important source of pollution. In Adana, a mono-modal distribution was observed during afternoon rush hour. This could be because of variation of wind direction from major roads or of variation of emissions from other anthropogenic sources. Winter season PM10 concentrations were statistically higher in all cities. Cities showed different trends in weekday-weekend variations.
Diurnal concentration variations in SO_2 were determined different in each city. In Adana and in Hatay bimodal distribution was observed with higher concentrations during night hours. For İçel, non-significant higher concentrations were observed after morning rush hours. However, no diurnal variation was detected in Antalya. HYSPLIT model was used to calculate backtrajectories. Backtrajectories are then clustered to observe similar air masses to the cities. Similar air mass flow patterns were found.

Key words: Particulate matter, sulfur dioxide, Eastern Mediterranean, dust transport, urban air quality

1. Introduction

Particulate matter and sulfur dioxide are two important parameters of urban air quality. These two parameters have adverse effects on health, environment and climate. PM10 can cause or aggravate cardiovascular and lung diseases, heath attacks and arrhythmias, affect the central nervous system, the reproductive system and cause cancer. Sulfur dioxide, on the other hand, aggravates asthma and reduce lung function and inflame the respiratory tract.

The same health effects can also be observed on animals as well. Besides, PM affects plant growth and ecosystem processes and can cause damage and soiling of buildings. SO_2 contributes to the acidification and eutrophication of soil and surface water. SO_2, also, causes injury to vegetation and local species loss in aquatic and terrestrial systems [1].

Starting from 1992, under the umbrella of European Environmental Agency (EEA), members started to measure and improve local air quality. Today approximately 30 countries established

*Corresponding author: Address: Akdeniz University, Department of Environmental Engineering, Konyaaltı Antalya. E-mail address: gdogan@akdeniz.edu.tr, Phone: +902422274400/4349 Fax: +902423106306

air quality monitoring stations in almost every urban area and monitor the concentrations of air pollutants. In Turkey, starting from 2008, these monitoring stations were established and air quality parameters have been reported to the EEA. Now, air quality of every city in Turkey is being monitored by at least one air quality monitoring station. In most of the cities PM10 and SO_2 are monitored.

The sources of PM10 and SO_2 are natural and anthropogenic. Natural sources of PM10 are sea salt, suspended dust, pollen and volcanic ash. Anthropogenic sources of PM10 are fuel combustion, mining activities, tires and brakes of cars and industrial activities. Even volcanoes are the most important natural source for SO_2; it is emitted only when fuels with containing sulfur are burned. The key anthropogenic contributions to ambient SO_2 derive from sulfur containing fossil fuels and biofuels used for domestic heating, stationary power generation and transport [1].

The influence of similar sources may result in various responses in different cities. In order to compare the influence of similar sources on different cities, in this study, four cities which are under the influence of similar cities are selected. These cities are Antalya, İçel, Adana and Hatay. All of these cities are located on the Mediterranean coast of Turkey. These four cities all experience the same climate and are under the influence of similar natural sources, such as dust transport and sea salt. In this study, the PM10 and SO_2 concentrations obtained from air quality monitoring stations located in downtown regions of these four cities were obtained from Ministry of Environment and Civilization web site and compared [2].

2. Materials and Method

2.1. Sampling Sites

The locations of sampling air quality monitoring sites are given in Figure 1. Antalya is located on the Mediterranean coast of southwestern Turkey. The downtown population of Antalya is over 1 million. The main sources of income in Antalya are agriculture and tourism. The only industrial facility in the city is ferrochrome factory. Similar to Antalya, Mersin is also located on the Mediterranean coast of Turkey. The population of downtown İçel is 880 000. Downtown İçel (also called Mersin) is a port city. The port in the city is the largest port of Turkey. Even tourism and agricultural activities are important sources of income; these activities are mainly held other towns of İçel. Adana and Hatay are located approximately 50 km and 25 km to the Mediterranean coast, respectively. Adana is the sixth largest city of Turkey. However 1.7 million inhabitants live in downtown Adana. Agriculture and agriculture related industrial activities are the major source of income in the city. Iron steel factory located approximately 60 km north (in İskenderun) is the main income source for Hatay. This iron steel industry is one of the largest iron steel factory of Turkey.

2.2. Air Quality Monitoring Data

In this study, hourly and daily averaged PM10 and SO_2 concentrations of Antalya, İçel, Adana (Valilik) and Hatay (Hatay 1) stations obtained from the web site of Ministry of Environment and Civilization were used [2]. The data coverage was from January 2008 to April 2014.

Figure 1. Locations of air quality monitoring stations

2.3. Backtrajectory Data and Trajectory Cluster Analysis

In this study, in order to understand the influence of air mass transport to the urban air quality, backtrajectories for every sampling day were calculated. HYSPLIT model was used for the calculation of backtrajectories.

Trajectory cluster analysis was performed to group back trajectories according to their movements before they reach to the air quality monitoring station. The corresponding PM10 and SO_2 concentrations of each cluster are calculated to observe any influence.

3. Results and Discussion

3.1. General description of datasets

Average and median concentrations of PM10 and SO_2 calculated from daily mean values with some statistical parameters are given in Table 1. Highest PM10 and SO_2 concentrations were detected in Adana followed by Hatay, İçel and Antalya. Highest daily PM10 and SO2 concentrations were observed in Adana and Antalya, respectively. Lower and upper quartile range represents the lowest 25% and highest 25% range. As this range gets larger, then the city can be said to be under influence of extraordinary sources, such as an industrial emissions, dust transport or forest fires. The narrowest lower and upper quartile range was obtained in İçel and both in İçel and Antalya for PM10 and SO_2, respectively. This indicates that there are not as much extraordinary emissions occupy the atmosphere of İçel and Antalya than Adana and Hatay.

Table 1. Statistical summary of PM10 and SO_2 concentrations in four cities (concentrations are in µg m^{-3})

Parameter	Number of Samples	Avg±STD*	Median	Range	Lower-Upper Quartile
Antalya PM10	2119	60±36	50	10-292	37-71
İçel PM10	2092	66±39	57	10-595	45-75
Adana PM10	1641	76±45	67	14-866	50-91
Hatay PM10	2094	72±51	56	9-642	38-88
Antalya SO_2	1669	7±15	3	0-179	2-6
İçel SO_2	1854	5±5	3	0-57	2-6
Adana SO_2	1722	10±10	7	0-125	5-12
Hatay SO_2	1731	9±12	5	0-122	2-10

*STD: Standard deviation

3.2. Comparison of the average PM10 results of four cities with the cities around Mediterranean

Each year, parties of EEA report the average values obtained from their air quality monitoring stations. In this study, to be able to compare the influence of being in close proximity to Mediterranean Sea, the annual average PM10 in 2012 data of four Turkish cities were compared with other European cities that are located on the Mediterranean coast. The PM10 concentrations of cities and cities downtown populations are given in Figure 2. As depicted from the figure, PM10 concentrations in Marseille, Toulon, Milano, Naples, Palermo, Salerno, Siracusa and Thessaloniki were higher than the EU limit value of 40 µg m^{-3}. In Spain, the concentrations were below the EU limit value. However, in Turkey, in all stations, PM10 concentrations were higher than the rest of the EU cities. As depicted from Figure 2, the population of cities did not seem to be a specific element in the PM10 concentrations. For instance, the population of Rome was higher than the population of Milano, however, the PM10 concentrations in Milano was observed higher. Similarly, in Turkey, downtown population of İzmir was much more than the population of Adana, but the PM10 pollution in Adana was higher than in İzmir.

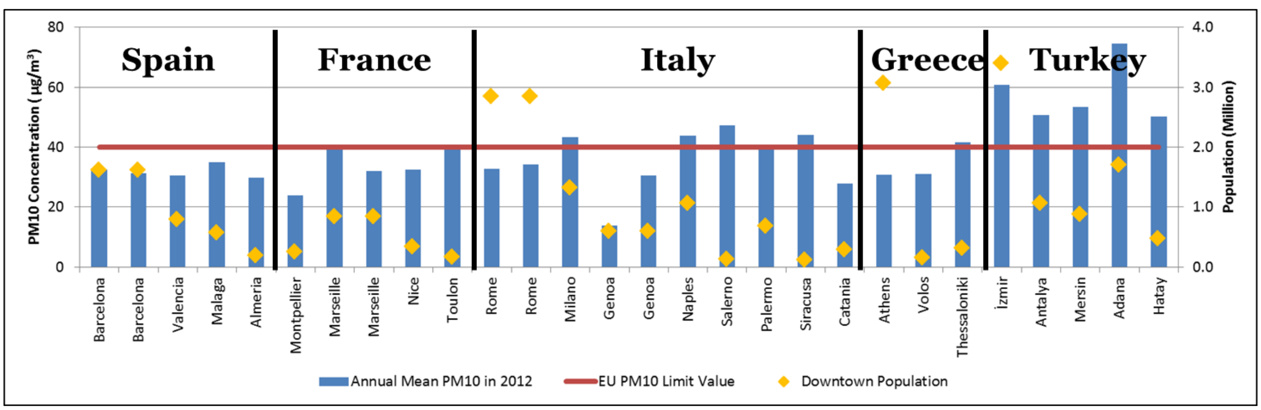

Figure 2. Annual mean PM10 concentrations in Mediterranean cities

3.3. Seasonal variation in PM10 concentrations and background PM10 concentrations

Winter (October-March) and summer (April-September) season's median PM10 concentrations together with background PM10 concentrations are given in Table 2. Mann-Whitney w-test was conducted to see if the winter median values in each city are higher than the summer median values. In all cities, winter season PM10 concentrations were statistically higher than the summer. The background concentrations for each season were also calculated to observe the influence of seasonal behaviours on PM10 concentrations. Background concentrations in Antalya and in Hatay were found to be lowest in winter and in summer, respectively. However, in winter background concentration in Hatay was the highest. This indicates that in Hatay both the emissions and the influences of emissions are higher during winter. The other three cities have background concentrations approximately same in both seasons. The median winter PM10 concentration in Hatay is approximately two times of the summer PM10 concentration. For Antalya, the difference in between winter and summer median concentrations is 15 $\mu g\ m^{-3}$. In İçel and in Adana, the differences are 8 $\mu g\ m^{-3}$and 10 $\mu g\ m^{-3}$, respectively. The higher median concentrations in winter might be due to two reasons. First of all, it might be due to fossil fuel combustion for space heating. Secondly, in winter mixing height is lower than in summer. Thus, even the emissions are the same in both seasons; the observed concentration in winter will be higher.

The difference in between median concentrations and background concentrations show the extraordinary influences to concentrations. In summer season, the median concentrations were found close to background concentrations. However, in winter the difference between median and background concentrations were in the range of 13-23 $\mu g\ m^{-3}$. This high range might be due to inversion mechanism which isolates the cities from surrounding fresh air.

Table 2. Seasonal median and background concentrations of PM10 in four cities (concentrations are in $\mu g\ m^{-3}$)

	Winter		Summer	
	Median	**Background**	**Median**	**Background**
Antalya	61	42	46	42
İçel	61	48	53	46
Adana	73	53	63	55
Hatay	83	60	40	36

3.4. Diurnal variations in PM10 and SO_2 concentrations

Diurnal variations let us to compare the general characteristics of cities. Diurnal variations in PM10 and SO_2 concentrations of four cities are given in Figure 3 and Figure 4, respectively. Except for Adana, bimodal distribution in PM10 concentrations was observed in the cities. The PM10 concentrations in three cities increase during morning and night rush hours. Therefore, motor vehicle emissions seem to be an important parameter in these cities. In all three cities, night rush hour concentrations were higher than morning rush hour concentrations. This might be due to fossil fuel combustion for space heating in winter. Adana showed mono-modal distribution peaking night. This could be because of the location of the sampling station. Sampling station in Adana is located on the north of a busy highway and during morning hours, wind might not blow from this heavy highway.

Diurnal variation in SO_2 concentrations in Adana and Hatay were similar. The SO_2 concentrations started to increase early in the morning and kept almost constant till 14:00. After that concentrations restarted to increase 18:00. Then the SO_2 concentrations gradually decreased. In İçel and in Antalya, SO_2 concentrations did not show significant variation throughout the day.

The differences in the SO_2 and PM10 concentrations diurnal variations demonstrated that the sources of these two pollutants were different.

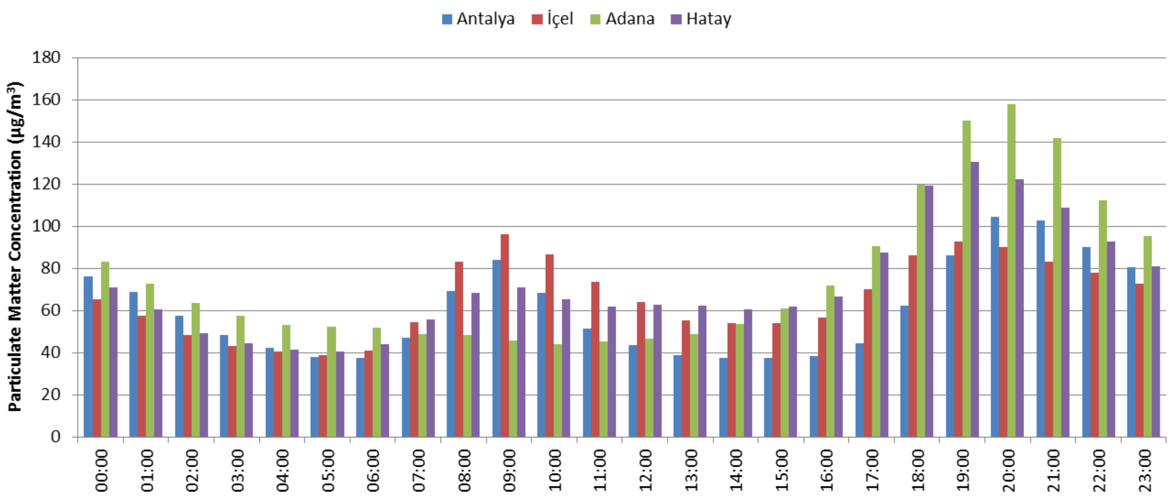

Figure 3. Diurnal variation in PM10 concentrations

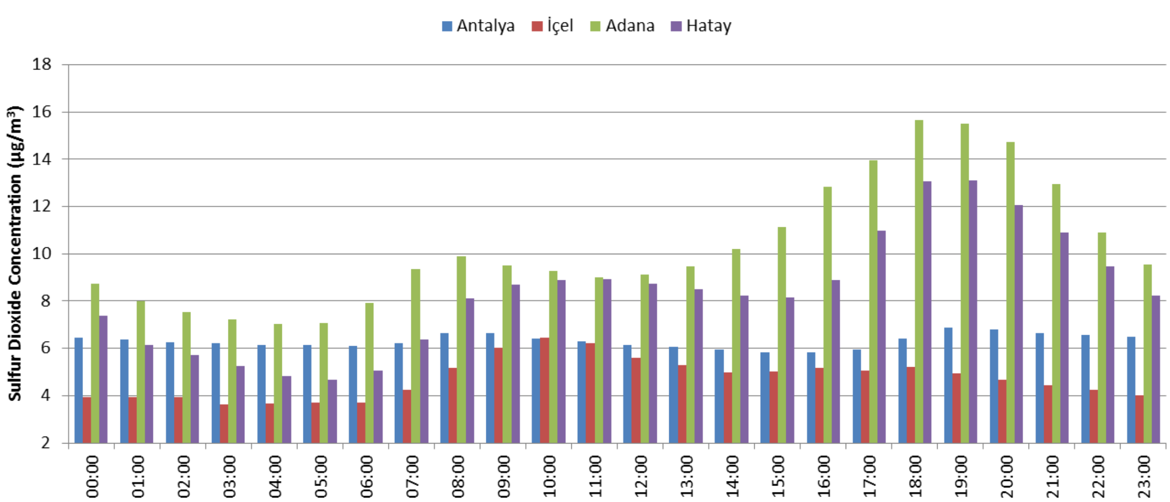

Figure 4. Diurnal variation in SO_2 concentrations

3.5. Trajectory cluster analysis

Cluster analysis is a good tool to understand the transport mechanism of air masses. In cluster analysis there is not any excepted method. The user must go through the clusters to group the trajectories. In this study, TrajStat program was used to group the trajectories. 120 hour back trajectories of each station was drawn and let the program to group these trajectories. 4 to 8 cluster results in each station was checked. For Antalya and İçel, five clusters were identified. For Adana and Hatay, seven and six clusters were determined, respectively. The results of the cluster analysis are given in Figure 5.

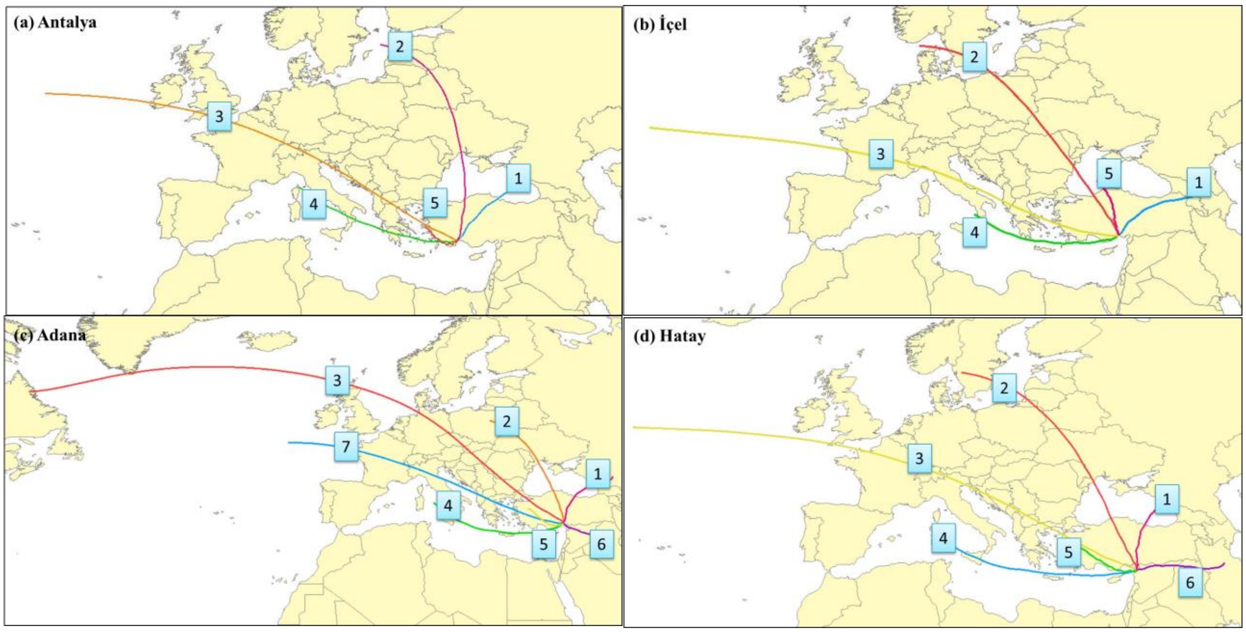

Figure 5. Clusters of four stations

Four of the trajectory clusters observed in the cities was common. These are trajectory approaching from Eastern Anatolia (Trajectory No: 1), trajectory approaching from north west Europe (2), trajectory approaching France and Balkans (3 and for Adana both 3 and 7) and trajectory approaching over Mediterranean (4). For Antalya, Adana and Hatay, there is one more trajectory cluster which starts over Western Anatolia and approaches to the cities (5). One more similarity in between Adana and Hatay is the trajectory passing over Syria and Iraq (6).

Even though there are certain differences, it is not very wrong to say that the cities are under the influence of air masses transported similar locations. The percentages of trajectories in each cluster and the median PM10 and SO_2 values observed in each cluster are given in Table 3. Most of the time air masses follow the Cluster 1 in Antalya and Cluster 5 in İçel, Adana and Hatay. The median PM10 and SO_2 concentrations in each cluster group do not show any significant similarity except Cluster 6 in Hatay and Adana. This similar cluster originating over Iraq and Syria might carry similar amount of dust to these two cities.

Table 3. Percent trajectories and median PM10 and SO_2 concentrations in each cluster (concentrations are in $\mu g\ m^{-3}$)

Stations	Parameter	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Antalya	%	29.4	11.5	15.6	20.6	22.8		

İçel	%	24.5	12.4	9.4	25.8	27.9		
Adana	%	19.9	17.7	2.0	16.7	22.6	10.7	10.4
Hatay	%	18.0	12.9	6.8	16.2	32.8	13.3	
Antalya	PM10	51	47	49	47	55		
İçel	PM10	62	53	59	54	57		
Adana	PM10	69.5	58	73	63.5	67	87	70
Hatay	PM10	48	52	54	51.5	54	90	
Antalya	SO_2	3	3	3	3	3		
İçel	SO_2	3	3	2	3	3		
Adana	SO_2	8	9	11	7	7	9	7.5
Hatay	SO_2	4	5	5	4	4	7	

4. Conclusions

- The highest PM10 and SO_2 concentrations were measured in Adana.
- Among the cities located on the northern Mediterranean, the highest PM10 concentrations were observed in Turkish sites.
- Similar PM10 diurnal variation was observed in Antalya, İçel and Hatay.
- Cluster analysis showed that most of the time air masses originating from similar locations arrive to the cities.
- Transport of dust from Syria and Iraq increases the PM10 concentrations in Hatay and Adana.

Acknowledgements

Ministry of Environment and Civilization is greatly acknowledged for providing data for this study. This study was supported by Akdeniz University Research Project Unit with Project No: 2014.01.0102.002.

References

[1] Air quality in Europe -2013 report. European Environment Agency. 107 pages.
[2] Ministry of Environment and Civilization, Air Quality Monitoring Stations Web Site, 2014. http://www.havaizleme.gov.tr (last accessed on 04.09.2014)