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EFFECTS OF METEOROLOGY ON ANKARA AIR QUALITY

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ABSTRACT

The daily air pollution index (API) highly correlated with meteorological parameters over the whole urban area of Ankara and assimilative capacity of Ankara atmosphere are investigated in this study.SO_2 and PM_{10} concentrations measured at eleven monitoring stations all over the Ankara are used in API. Two meteorological variables namely, maximum daily wind speed and thermic excursion, and the previous day's air pollution index are found to be highly correlated (r=0.72) with daily air pollution index by the multiple linear regression analyses. API forecasting is applied for the whole urban area of Ankara. Product of average wind speed and mixing height are used for the determination of assimilative capacity of Ankara atmosphere. The air pollution dispersion index (ventilation index) which is proposed by the State of Colorado Department of Health in Denver is used. The assimilative capacity of Ankara is found to be highest in summer and lowest in winter, while the highest values of ventilation coefficient are observed during afternoon hours in both seasons.

Key Words: API; API Forecast; Ventilation Coefficient; Mixing Height; Ankara

1. INTRODUCTION

Air pollution problem in Ankara has been known since 1926 and Tincer et.al., (1975) underlined the possible future air quality problems and suggested that Ankara was not a suitable urbanization region. Air pollution problem in Ankara was mainly associated with fossil fuel combustion and up to now some precautions were taken. Combustion of high sulfur content of coal was banned and usage of low sulfur content of coal was encouraged by a Governmental Decision in 1985, however the effect of this effort on air quality was not observed because of the illegal entrance of poor quality coal to the Ankara. The sharp decrease in fossil fuel combustion based pollutants in Ankara was observed after 1990s, as a result of the switching from coal to natural gas usage for heating. The decrease in fossil fuel combustion based pollutants were the most dramatic between 1990 and 1995, their concentrations in the city are still decreasing but at a slower pace.

Ankara, which is the capital of Turkey, has been urbanized faster due to migration from countryside to the city results in greater emissions into atmosphere, mainly produced by the increase of traffic, as well as from the use of old and badly maintained vehicles. Therefore present day urban air pollution in Ankara is thought to be mainly associated with still domestic heating and traffic emissions which is accepted as the main source of the urban air pollution problem in most of the world cities (Mage et al., 1996; Mayer, 1999).

The occurrence of high concentrations of lower atmospheric pollution across Ankara is critically dependent upon the hilly topography of the region which lessens lateral transmission of air masses. Besides physical setting of Ankara, meteorology also plays an important role for dispersion and dilution of emitted air pollutants since meteorological factors such as wind speed, precipitation and mixing height all play important roles in determining the pollutant levels for a given rate of pollutant emission (Tayanc, 2000). Therefore, the aim of this study is to investigate the effect of meteorology on Ankara air quality.

2. MATERIALS AND METHODS

This study is based on hourly SO_2 and PM_{10} data generated at three curbside stations which were placed at the most crowded street corners of Ankara, namely Iskitler, Kavaklıdere and Kızılay, and eight non-curbside stations which were not under direct influence of traffic activities, by the Ministry of Health, Refik Saydam Hygiene Center, between October 1999 and August 2000. A fully automatic mobile laboratory was used for measurements at curbside stations therefore measurements at curbsides were not continuous, but performed for approximately one week in each month. However, measurements at non-curbsides were continuous as these stations were regular monitoring stations of Ankara Air Quality Monitoring Network.

SO_2 was measured by conductometry (DKK Model GRH-72M) and PM_{10} was measured by beta ray absorption (Model DUB-12).

There are two meteorological stations in Ankara operated by the Turkish State Meteorological Service, one located at Incirli, which is within the downtown area, and the other one at Etimesgut, which is at the outskirts of the city. As the measurements in this study performed at urban area, the meteorological data from the Incirli station was used.

3. RESULTS AND DISCUSSION

In this study, air pollution index (API) is used for the investigation of the effect of meteorology and used for forecasting the air pollution over the whole urban area of Ankara by the method developed by Cogliani (2001). The hourly highest concentrations in the day of SO_2 and PM_{10} are used for the evaluation of the daily air pollution index from October 1999 to March 2000. Unfortunately, there is no daily threshold values of major air pollutants for the determination of daily air pollution index that are fixed by the Turkish Ministry of Environment and Forestry. Furthermore, some deficiencies of air pollution index API proposed by EPA and a need for different API is reported in the literature (Murena, 2004). Therefore in this study the new API which is proposed at CITEAIR Workshop (2005) was used. Three air quality levels are derived from the threshold values given in Table 1, as: good, acceptable and poor. For a single station, a score is given depending upon the hourly highest concentration of SO_2 and PM_{10}. If the air quality level is good the score is 1, if the air quality level is acceptable the score is 3, if the air quality level is poor the score is 7. When the concentration is missing, the score is 0. The daily scores of SO_2 and PM_{10} are summed, the total score is from 1 to 2, from 3 to 6, more than or equal to 7. When total is 0 not valuable (NV) is attributed. The new score is given depending upon the summed scores. When total is 2 the new score is 0 indicating the good air quality level. When the quality of the air is acceptable the value varies from 4 to 6 and the new score is 1. For the poor air quality level, 2 is attributed as the new score if the values are from 8 to 14. When concentrations are missing the total score is 0 and new score 2 (poor air quality level) is attributed to missing data. This reference is made to SO_2 and PM_{10} concentrations measured at all available stations. Then, the sum of the new scores of the all available stations gives the daily air pollution index, I, of the whole city.

Table 1. Proposed Air Quality Index of SO_2 and PM_{10} (CITEAIR ,2005)

Air Quality Level	**Index**	**Class**	**PM_{10}[a]** (μgm^{-3})	**SO_2[a]** (μgm^{-3})
GOOD	Very Low	0 25	0 25	0 50
	Low	25 50	25 50	50 100
ACCEPTABLE	Medium	50 75	50 75	100 300
POOR	High	75 100	75 100	300 500
	Very High	>100	>100	>500

[a] corresponds to the maximum hourly value on a day

Air pollution levels over the Ankara calculated from the proposed API during the October 1999-March 2000 period is given in Table 2.Poor air quality dominates during this period. In fact, although overestimation is done in API calculation (the new score 2 (poor air quality level) is attributed if the total score is 0), the results are reasonable as the application period is in winter. Low air quality in winter is frequent in Ankara atmosphere as a result of the lack of ventilation (will be discussed in proceeding section) and high emissions.

Meteorological data are examined in the preliminary analysis to extract the meteorological variables that is strongly correlated to daily air pollution index. Therefore one by one correlation between the daily air pollution index and the meteorological variable (daily highest temperature, daily lowest temperature, daily average temperature, daily highest wind speed, daily average wind speed, daily average barometric pressure, daily highest mixing height, daily average mixing height and daily average barometric pressure) is investigated.

Table 2. Percentage of Occurrence of Pollution Levels during October 1999-March 2000 period

Pollution Level	**%** occurunce
GOOD	1
ACCEPTABLE	14
POOR	85

Daily highest wind speed and daily thermic excursion, which is calculated from the hourly temperature data, show a high correlation with daily air pollution index (R^2=43 % and R^2=14 % respectively); therefore other meteorological variables that show a weak correlation with the daily air pollution index are discarded.

Daily vehicular traffic is known as the major air pollution source in most urban areas (Mage et al., 1996; Mayer, 1999). Daily traffic data is missing in this study; therefore previous day's air pollution index value I_{d-1}, which explains 29 % of the variability in daily air pollution index, is chosen instead of the daily traffic data as another correlation variable to the daily air pollution index.

The calculated air pollution index I_c is obtained by the linear multiple partial correlation among the three independent variables:

- daily highest wind speed;
- thermic excursion ;and
- previous day's air pollution index.

Statistical summary of the linear multiple correlation analysis is given in Table 3. The calculated air pollution index (I_c) equation for Ankara during the October 1999-March 2000 is:

$$I_c = 14.3101 - 0.503V + 0.178 I_{d-1} + 0.145 \Delta T \quad (1)$$

Table 3. Statistical summary of the linear multiple partial correlation analysis

Model	R^2	r	Adjusted R^2	Std. Error of Estimate
(Constants), maximum wind speed, thermic excursion, I_{d-1}	51.23	0.72	49.72	2.03

Correlation between the calculated air pollution index I_c and the air pollution index I is 0.72. The good agreement between I and I_c values during the measurement days is seen in Figure 1.

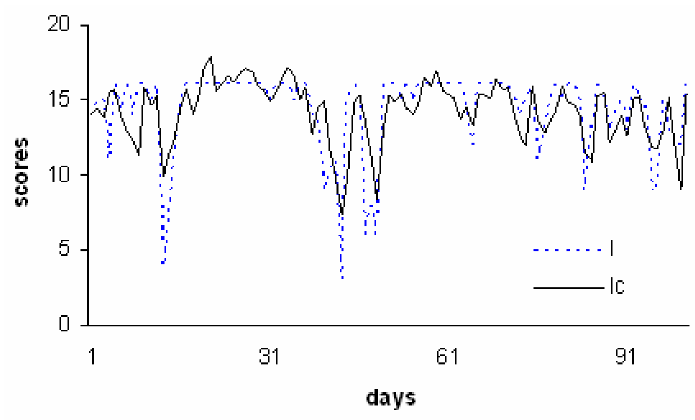

Figure 1. I and I_c trends versus observation days during the period October 1999-March 2000

Verification of the I_c obtained from the examination of a specific period is performed by using the three independent variables that is measured outside that period. Independent variables measured between January-March 2003 are used and the correlation is found as 0.45 while the standard error is 1.95. I and I_c trends versus observation days during the period January-March 2003 is given in Figure 2. Although the correlation decreases from 0.72 to 0.45, this could be accepted as a good forecast. Because lower correlations are seen most of the air pollution index forecast models (Jiang et al., 2004).

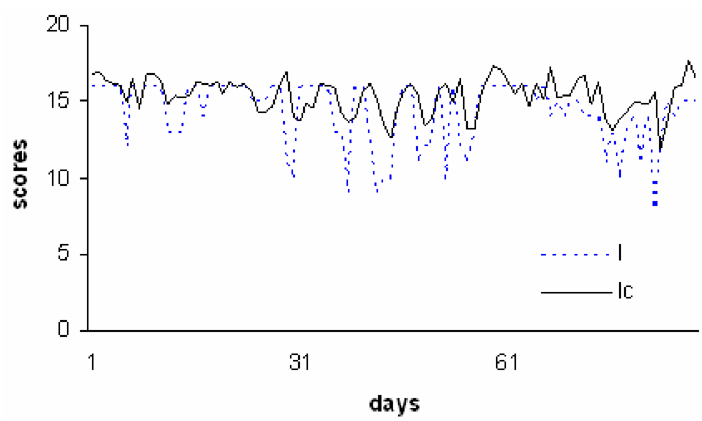

Figure 2. I and I_c trends versus observation days during the period January-March 2003

In this study assimilative capacity of the atmosphere which is defined as the maximum pollutant load that can be discharged into the atmosphere without violating the best-designed use of air resources in the planning region (Manju et al., 2002) is also determined in terms of ventilation coefficient. Ventilation coefficient is product of mixing height and average wind speed through the mixing layer.

The air pollution dispersion index (ventilation index) which is proposed by the State of Colorado Department of Health in Denver is used to determine the ventilation coefficients for Ankara during the measurement period. In this study, surface wind speeds which are obtained from Incirli Meteorology Station and mixing heights which are obtained from EPA's PCRAMMET program are used. The categories used for air pollution dispersion are POOR: 0-2000, FAIR: 2001-4000, GOOD: 4001-6000 and EXCELLENT: ≥6001. The percent occurrence of each ventilation category during the sampling period is given in Figure 3.a. As can be seen from the Figure 3.a percentage of the poor dispersion conditions are dominant during the measurement period.

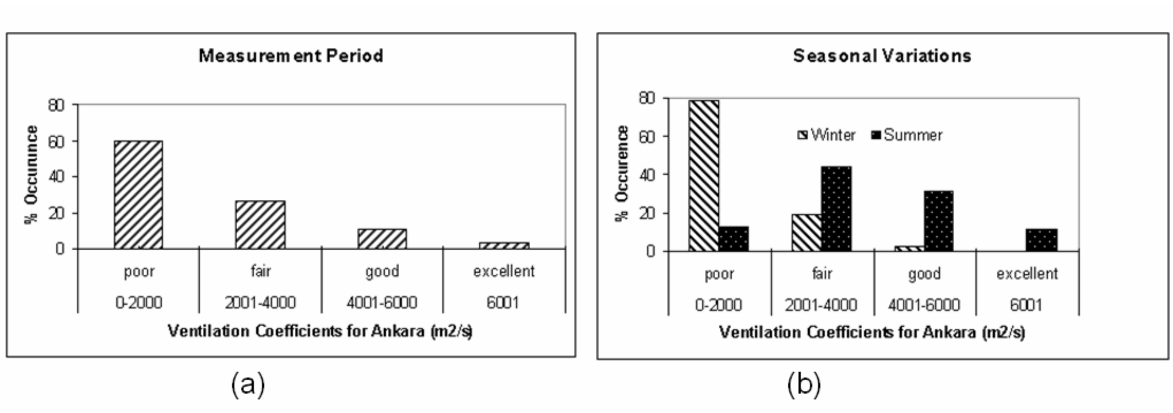

Figure 3. Variations of Ventilation Coefficients for Ankara (a) sampling period (b) seasonal

Seasonal variations of ventilation coefficients (dispersion conditions) are also investigated and depicted in Figure 3.b Seasonal variations in the ventilation coefficients show that poor dispersion conditions dominate over Ankara during the winter season while the increase in ventilation is obviously observed for summer season. Therefore, poor air pollution dispersion conditions besides the high source strength may explain the higher pollution levels over Ankara in winter season to a considerable extent.

Hourly computed ventilation coefficients during the winter and summer seasons are given in Figure 4. Lowest ventilation coefficients during the night and early morning indicate high pollution potential during this period. The highest values of ventilation coefficient are observed during afternoon hours due to increase in solar insolation. Viswanadham and Anil Kumar (1989) stated that when the incoming solar insolation increases as the day progresses the ventilation coefficient also increases during afternoon hours; further during evening hours when the incoming solar radiation ceases the ventilation coefficient also gradually decreases. Therefore, the assimilative capacity of the Ankara is at its best during noon. The lowest ventilation coefficients for both winter and summer are nearly same however the highest ventilation coefficient is about a factor of 4 higher in summer than in winter.

Diurnal variations of the mixing height also shows similar pattern in two seasons. The highest value observed is 2038 m in summer and 850 m in winter. The very low values of mixing height that are reflected in the ventilation coefficient during the late nights and early morning hours could be due to the occurrence of ground based inversions that hamper dispersion (Padmanabhamurty and Mandal,1979). The wind speed in summer is only slightly higher than the winter wind speeds. However, there is a significant difference between the summer and the winter ventilation coefficients. This could be due to the fact that the contribution by wind speed to ventilation coefficient is less in comparison to mixing height. Investigation of the wind speeds during the measurement period showed that almost 60 % of winds blew at a speed between 2 and 4 m/s and less than 8 % had a speed higher or equal than 5 m/s. Thus, the low wind speed surpassed over Ankara during the measurement period. Not only because of the physical setting but also lower wind speeds restrict the horizontal dispersion, therefore the main dispersion mechanism over Ankara is vertical dispersion.

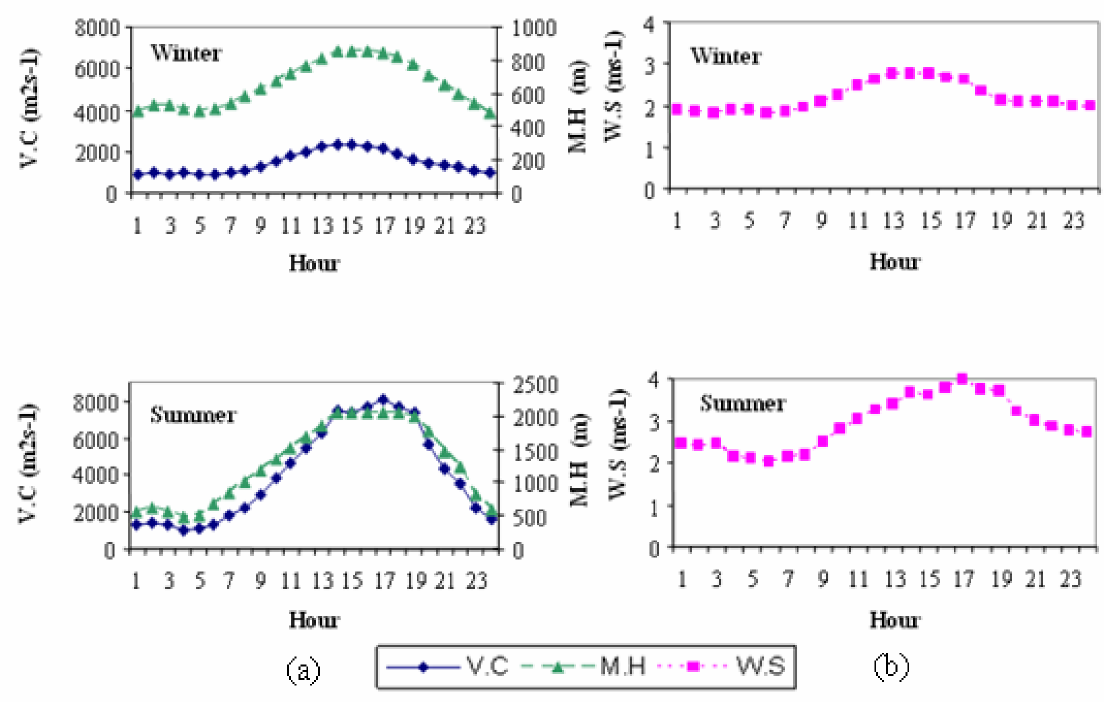

Figure 4. Seasonal diurnal variations of (a) ventilation coefficient (V.C) and mixing height (M.H) (b) wind speed (W.S)

4. CONCLUSION

Application of API forecast method in Ankara showed that meteorological parameters (maximum daily wind speed and thermic excursion) play an important role in forecasting the air pollution over Ankara.

The assimilative capacity of Ankara is found to be highest in summer and lowest in winter. The highest values of ventilation coefficient are observed during afternoon hours in both summer and winter. The contribution of mixing height to ventilation coefficient is higher in comparison to wind speed. Lower wind speeds surpass over Ankara, therefore the main dispersion mechanism over Ankara is vertical dispersion.

Reporting air pollution data to the public become a requirement or desire in most of the world cities (Brimblecombe, 2005). Although forecasting the next day air pollution is not a requirement yet, most of the cities report the next day's air pollution to the public. Unfortunately, there is no attempt to report neither the previous day's air quality nor the next day's air quality in Turkey. Therefore, this study may aid governmental officials in their efforts to regulate and improve air quality in Turkey.

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