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PRELIMINARY ASSESSMENT OF AMBIENT AIR QUALITY IN THE CITIES OF ANKARA AND KÜTAHYA

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ABSTRACT

Preliminary assessment studies were conducted for the cities of Ankara and Kütahya for the seven air pollutants regulated by the European Union directives. Passive sampling campaigns were conducted for sulfur dioxide, nitrogen dioxide, ozone, and benzene in winter and summer seasons. Based on the results of the preliminary assessments it was concluded that both cities were exceeding the European Union standards for all the pollutants. Coal combustion was found to be a significant source of pollution in whole of Kütahya and some parts of Ankara. Furthermore, traffic was observed to be the major source of pollution in Ankara, and a growing concern in certain parts of Kütahya.

Key Words: Air Quality Management, Preliminary Assessment, Air Quality Monitoring, Passive Sampling, Turkey

1. INTRODUCTION

According to Article 5 of the European Union (EU) ambient air quality framework directive, 96/62/EC, member states that do not have representative measurements of the levels of pollutants for all zones and agglomerations shall undertake series of representative measurements, surveys, or assessments. This assessment, referred to as “preliminary assessment”, can be considered as the first step in developing an air quality management policy for a region. It provides an overview of ambient air quality levels, air pollution sources and emissions, and other secondary information necessary for interpretation of the air pollution levels.

Turkey is a candidate country for the EU membership and will be required to align its environmental policies with those of the EU during the accession process. There are already on-going legislative activities to align the Turkish air quality regulations with the EU air quality directives. However, there have not been many technical assessments on air quality in the past to support implementation of the EU directives.

The current study was conducted under the Matra Pre-accession Program of the Dutch Government during the two-year period between 2003 and 2005. It provides the first preliminary assessments for Turkey for the cities of Ankara and Kütahya.
Ankara is the capital city of Turkey with a population approaching the 4 million mark. Major activities in the city are administrative and service related. Although some industry is found in and around Ankara, these are not deemed significant sources in terms of air quality. Ankara harbors traffic of roughly 900,000 vehicles, making traffic one of the chief sources of air pollution in the city. Most parts of the city made the switch from coal to natural gas heating in the early 1990's, and therefore, the role of heating in air pollution has decreased over the last 20 years. Ankara is located in a basin surrounded by hills where dispersion of pollutants is problematic at times. It was chosen for the first preliminary assessment study due to its large population and its importance as the capital city.

Kütahya is a small city with a population close to 200,000. With respect to its size, it has some significant industry in the power and mineral sectors. Owing to the abundance and proximity of lignite reserves in Kütahya, residential and industrial sources mostly utilize coal for their power and heating requirements. High sulfur and ash content of the local lignite, together with inefficient combustion techniques place Kütahya among the top cities with serious air pollution problems. It was chosen for the second preliminary assessment study due to its high air pollution levels.

The preliminary assessments were conducted for seven pollutants (i.e. sulfur dioxide (SO_2), nitrogen dioxides (NO_2), ozone (O_3), benzene, carbon monoxide (CO), particulate matter (PM), and lead (Pb)) that are regulated under three EU daughter directives, 1999/30/EC, 2000/69/EC, and 2002/3/EC. Initially, existing information on the ambient levels, sources, and emissions of the seven pollutants were compiled. It was observed that while there was information on SO_2 and PM to some extent, information regarding NO_2, O_3, Pb, CO, and benzene was either non-existent or inadequate.

In order to reduce the gap in the knowledge, several passive sampling campaigns were conducted in both cities for SO_2, NO_2, O_3, and benzene. Passive samplers are inexpensive yet efficient means to establish the pollutant levels over large areas, providing indicative results accurate to approximately ± 30%. In the assessment of PM, Pb, and CO, secondary information and limited existing data were utilized.

The focus of this paper will be on the results of the passive sampling campaigns in Ankara and Kütahya for the four aforementioned gaseous pollutants.

2. SULFUR DIOXIDE

The SO_2 passive sampling measurements were conducted in winter and summer to observe the seasonal effects. Approximately, 360 SO_2 passive samplers were used over 4 months (i.e. two months in winter and two in summer) in the city of Ankara, which has a geographical spread of 40 km x 30 km. For the city of Kütahya, 70 SO_2

passive samplers were employed over 2 months over an area of 15 km x 5 km. In each month, the passive samplers were exposed to ambient conditions for four weeks in Ankara. Two weeks of sampler exposure time was used in Kütahya.

A grid-based approach was employed for selecting sites for passive sampling since sources for both pollutants are ubiquitous within the urban environment. In this approach, the city was divided into grids and samplers with varying density were placed into each grid based on the population density and urban structure. With a balanced distribution of samplers, both background and specific conditions (e.g. traffic hotspots, industrial and commercial areas) were represented in the assessment.

The distribution of SO_2 levels over Ankara for the winter season is given in Figure 1. The average winter levels over Ankara varied between 20 and 110 $\mu g/m^3$. It was observed that pollution due to coal usage is still significant in some neighborhoods of Ankara. Levels as low as 20 $\mu g/m^3$ were observed in southeastern neighborhoods such as Çankaya, where natural gas is predominantly used, whereas levels 4 to 5 times higher were observed in the western neighborhoods such as Etimesgut, and in the east-northeastern neighborhoods such as Mamak and Altındağ. Although, natural gas is used in the central parts of the city, relatively high ambient SO_2 levels were observed due to high traffic emissions and transport of pollutants from the neighboring areas.

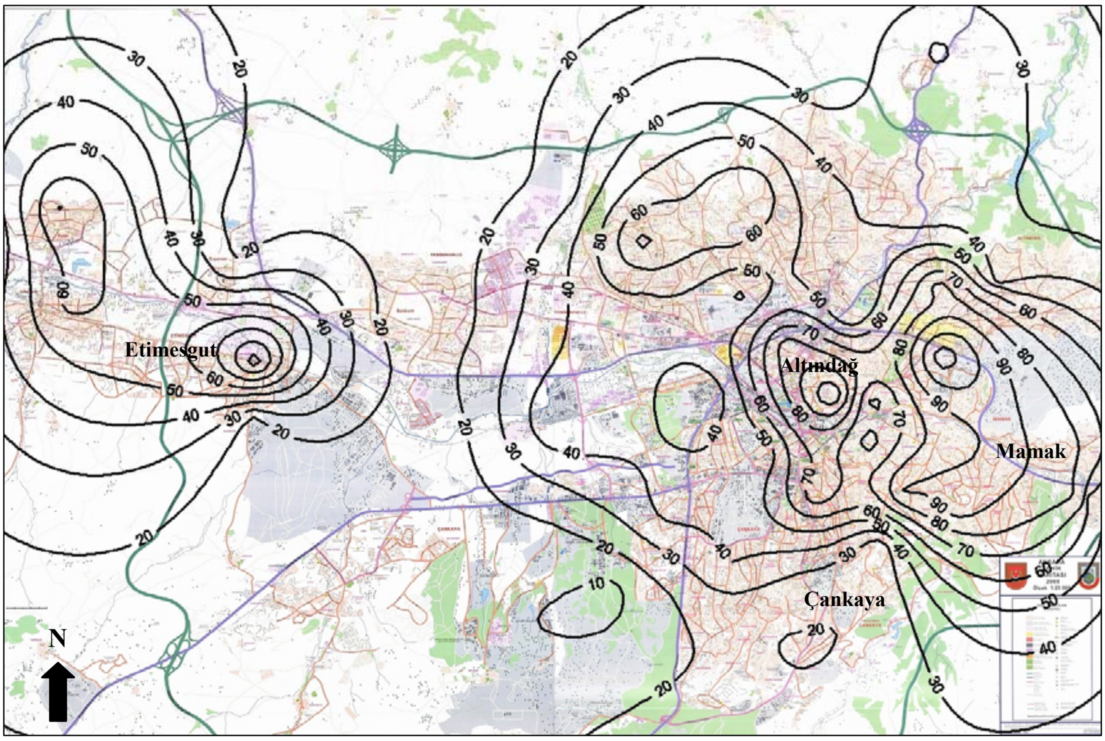

Figure 1. Winter SO_2 Levels ($\mu g/m^3$) in Ankara (Ref: Arpacıoğlu et al. 2004a)

The summer concentration distribution over Ankara was uniform as compared to winter, and average levels varied between 15 and 40 $\mu g/m^3$. This high difference between the summer and winter levels indicates that residential heating by means of coal is still an important source of air pollution in Ankara.

It should be noted that the traffic hotspots were removed in Figure 1 to have better representation of the background conditions. Maximum SO_2 levels as high as 80 $\mu g/m^3$ in summer and 130 $\mu g/m^3$ in winter were observed at locations close to traffic hotspots. On the average, traffic locations had SO_2 levels 1.3 and 1.6 times higher than the urban background locations for summer and winter, respectively.

The distribution of SO_2 levels in Kütahya for the winter season is given in Figure 2. The average winter levels over Kütahya varied between 60 and 290 $\mu g/m^3$. The maximum SO_2 concentration was observed in the city center, where daily activity (e.g. business, schools etc.) is higher and dispersion conditions are poor due to dense buildings. The effect of coal usage for heating is highly evident in the city. The southeastern parts of the city had relatively lower SO_2 levels. These parts of the city have newer buildings with better coal combustion efficiency and better dispersion conditions due to better urban planning.

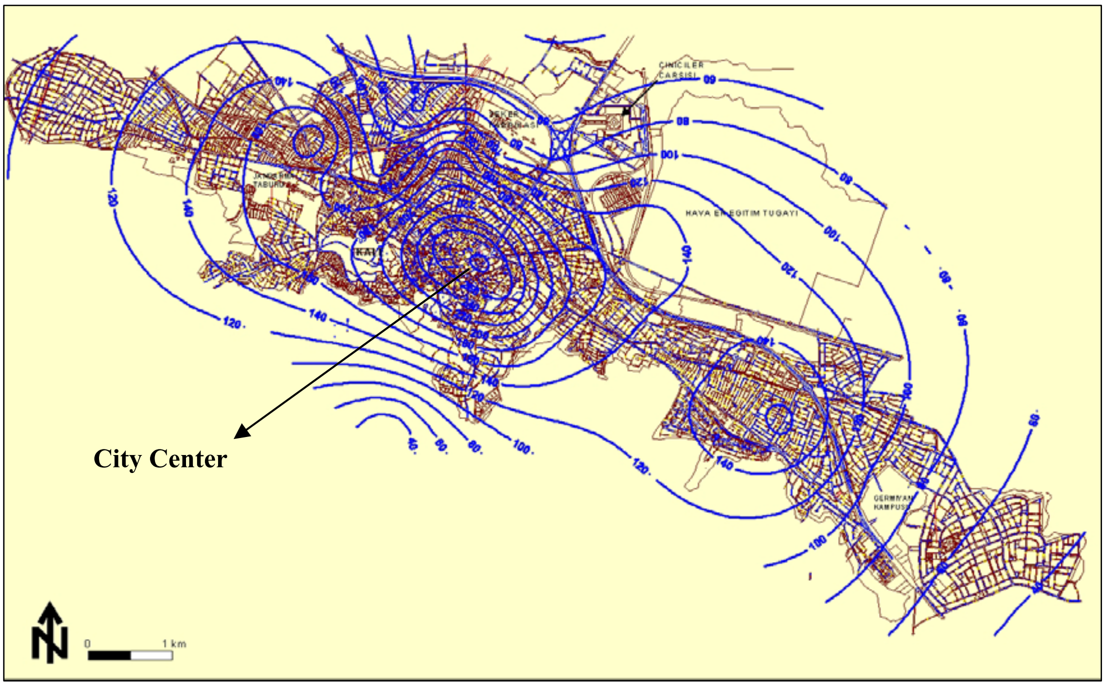

Figure 2. Winter SO_2 Levels ($\mu g/m^3$) in Kütahya (Ref: Arpacıoğlu et al. 2004b)

Average summer SO_2 levels over Kütahya varied between 35 and 100 $\mu g/m^3$. These rather high SO_2 levels indicate the use of low quality coal for heating (during relatively colder summer nights) even in the summer season, as well as for cooking and water heating. The summer SO_2 levels in Kütahya are comparable to the levels observed in winter in eastern parts of Ankara.

3. NITROGEN DIOXIDE

The NO_2 samplers were collocated with the SO_2 samplers following the same grid-based logic. Duration and quantity of NO_2 sampling were the same as SO_2 sampling. The distribution of NO_2 levels for the winter season over Ankara is given in Figure 3. The average winter levels over Ankara varied between 30 and 60 μg/m^3. High NO_2 concentrations were observed in different parts of the city (e.g. Keçiören, Kızılay, Sincan, and Mamak) where busy traffic or congestions are known to be frequent. These locations exhibited NO_2 levels higher than EU annual standard of 40 μg/m^3.

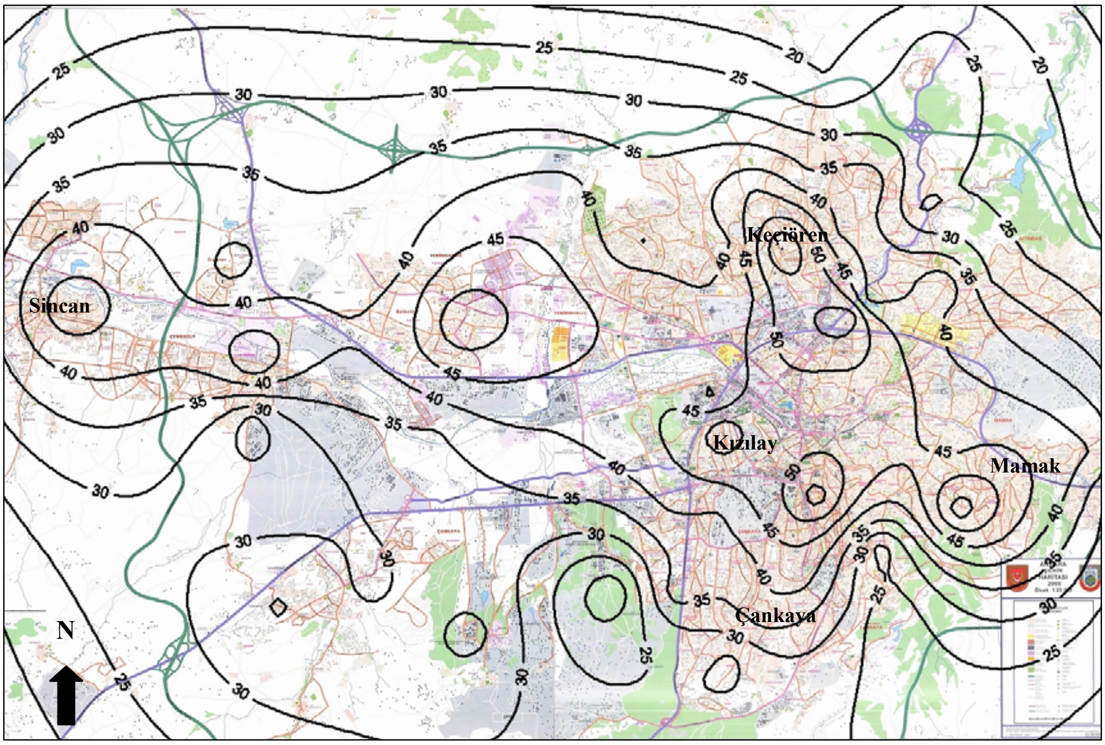

Figure 3. Winter NO_2 Levels (μg/m^3) in Ankara

The average summer NO_2 levels over Ankara varied between 10 and 70 μg/m^3. Although the maximum level observed in the summer (70 μg/m^3) was higher than that observed in winter (60 μg/m^3), the overall winter levels were generally 10 – 20 μg/m^3 higher than the overall summer levels. The winter NO_2 levels at the periphery of the city were approximately 30 μg/m^3, and 3 times higher than the summer levels at the same locations. This fact can be attributed to higher volumes of traffic observed in winter (due to schools opening, people returning from vacation etc.), and unfavorable winter meteorological conditions.

It should be noted that the traffic hotspots were removed from Figure 3 to have better representation of the background conditions of the city. The average NO_2 levels at traffic locations are about 20 μg/m^3 higher than those levels at the background locations. The effect of different traffic volumes (i.e. road types) in Ankara is shown in Table 1. As one would expect, the NO_2 levels increase with higher traffic volumes. On the average, annual levels near highways were almost twice high than back roads.

The distribution of NO_2 levels over Kütahya for the winter season is given in Figure 4. The winter levels in Kütahya varied between 20 and 48 μg/m^3. Highest NO_2 level was observed in the city center. At the city periphery, NO_2 levels decreased to 20 μg/m^3 level. The summer NO_2 levels in Kütahya varied between 10 and 46 μg/m^3. Highest NO_2 levels were observed at the city center (41 μg/m^3) and Afyon Highway Intersection (46 μg/m^3), where traffic intensities are higher than other parts of the city. Both the winter and summer levels indicate that traffic related NO_2 pollution is becoming important in the central parts of the city, if not all of Kütahya.

Table 1. Average NO_2 Levels with respect to Road Type

Road Type	Average Level (μg/m^3)	
	Summer	Winter
Highway	61 ± 29	58 ± 17
Boulevard	51 ± 12	56 ± 1
Street	34 ± 21	43 ± 12
Back Roads	22 ± 10	38 ± 10

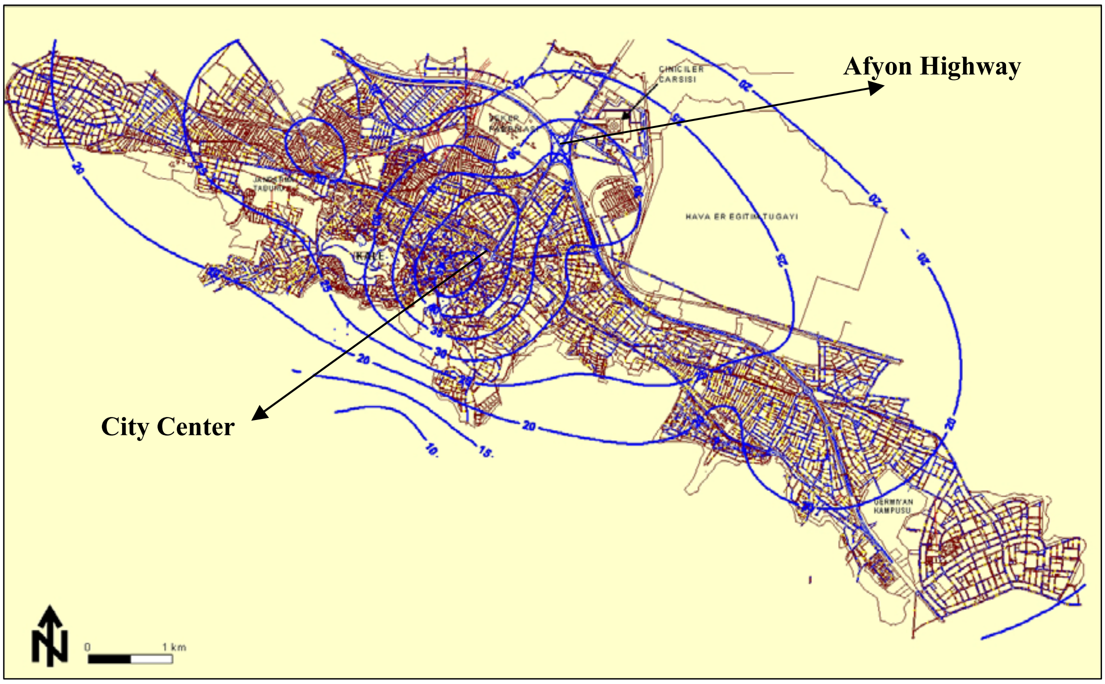

Figure 4. Winter NO_2 Levels (μg/m^3) in Kütahya

4. OZONE

Ozone passive sampling measurements were conducted in winter and summer to observe the seasonal effects. Approximately, 140 O_3 passive samplers were used over 4 months (two months in winter and two in summer) in the city of Ankara. For the city of Kütahya, 45 O_3 passive samplers were employed over 2 months. In each month, the passive samplers were exposed to ambient conditions for four weeks in Ankara. Shorter exposure times (two weeks) were employed in Kütahya.

A traverse-based system was employed for selecting passive sampling sites. In this approach, the city was crosscut along two axes. The samplers were placed at approximately every 2 km along the axis to obtain a profile of ozone through the city. This was done considering the fact that ozone is a secondary pollutant and certain time in the dominant wind direction is required before it could form.

Summer O_3 levels over Ankara are shown in Figure 5. As can be seen from this figure, O_3 levels were lower in the center of the city (around 70 $\mu g/m^3$), and higher at the city borders or outside the city (around 110 $\mu g/m^3$). There was roughly a factor of 1.5 difference in O_3 levels between the city periphery and the center. Similar trend was also visible in the winter O_3 levels; however, it was not as pronounced as in the summer. In the winter, O_3 levels were 10 $\mu g/m^3$ in the city center and 50 $\mu g/m^3$ in the south of the city. Due to the reduction in solar radiation intensity and duration in winter months, the photochemical reactions necessary for formation of ozone were not happening as much as in the summer months.

Summer O_3 levels observed over Kütahya are shown in Figure 6. The O_3 levels showed similar patterns to those in Ankara. Levels in the city center were observed around 70 $\mu g/m^3$ and in the city periphery around 120 $\mu g/m^3$. In the winter, the O_3 levels dropped dramatically to 20 – 25% of the summer levels.

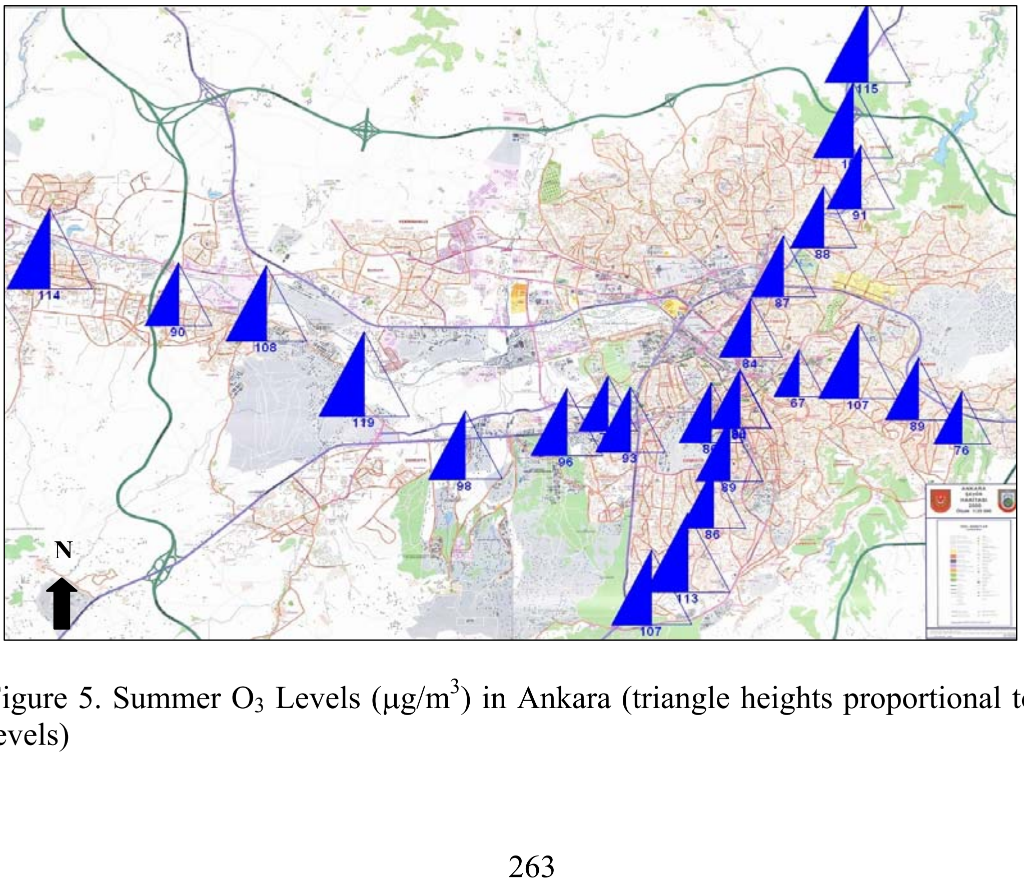

Figure 5. Summer O_3 Levels ($\mu g/m^3$) in Ankara (triangle heights proportional to O_3 levels)

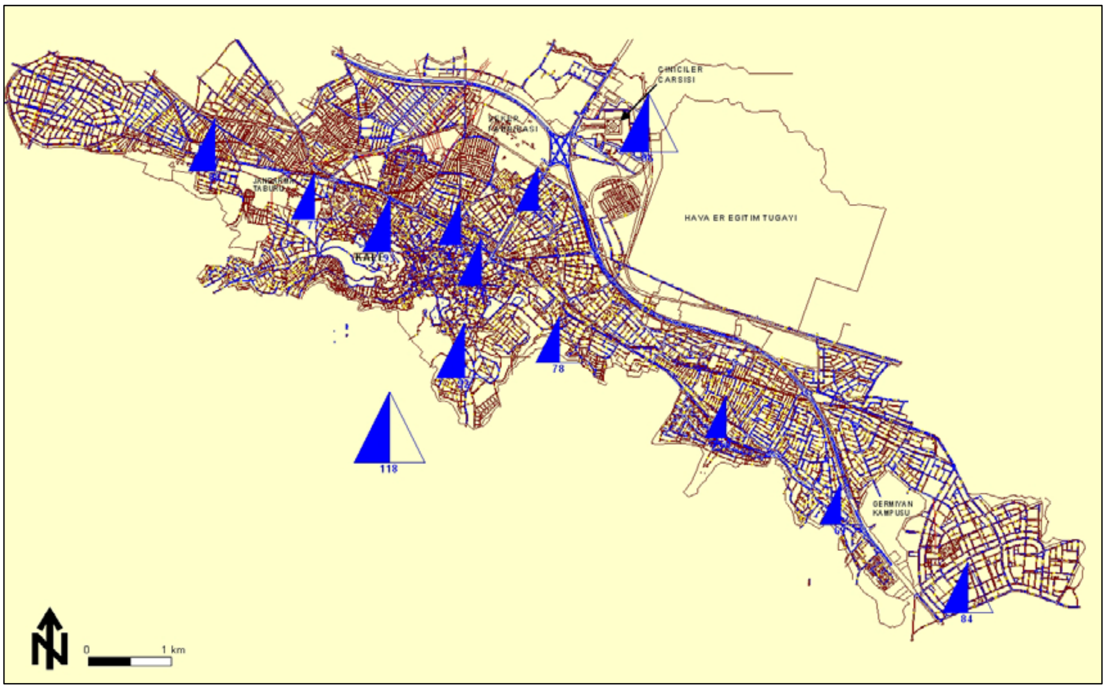

Figure 6. Summer O_3 Levels ($\mu g/m^3$) in Kütahya (triangle heights proportional to O_3 levels)

5. BENZENE

Benzene passive sampling campaigns were conducted for one month in the winter and one month in the summer for both cities. In selecting locations for the benzene samplers, a different approach was followed as compared to SO_2, NO_2, and O_3. In this approach, unique locations where measured benzene levels would represent certain typical conditions were selected. Thus, samplers were located at gasoline stations, shopping and hospital parking lots, traffic intersections, where hotspots and high human exposure were expected. In addition, locations such as schoolyards, residential neighborhoods were also sampled to determine the background conditions. These measurements provided a valuable initial insight into range of benzene levels to be expected in the Turkish cities.

Eight sampling locations were selected in Ankara. The description of locations and measured benzene levels in Ankara are given in Table 2. As observed in this table, all the measured benzene levels were higher than the EU annual standard of 5 $\mu g/m^3$. The residential areas had levels twice as high as the EU standard. As expected highest benzene levels were observed at the petrol station, where no vapor control mechanism was available. The winter benzene levels were generally higher than the summer levels. This was probably due to two factors:

- Less vehicular activity (hence less emissions) in summer time due to schools closing, people going out of town for vacation etc., and
- Unfavorable meteorological conditions (frequent inversions, low mixing heights etc.) that limit vertical and horizontal dispersion in wintertime.

Three sampling locations were chosen for Kütahya. The description of locations and measured benzene levels in Kütahya are given in Table 3. Highest benzene levels were observed in the petrol station as expected. Winter levels were higher than the EU annual standard of 5 $\mu g/m^3$, and 3 – 5 times higher than the summer levels, as also experienced in Ankara.

Table 2. Benzene Sampling Results for Ankara

Site Name	Description	Level ($\mu g/m^3$)	
		Summer	Winter
Hacettepe Hospital	Parking Lot	13	14
Kızılay Square	Curb-side	14	21
Petrol Station, Beşevler	Station Canopy	29	52
7th Road, Beşevler	Residential	10	18
Real Shopping Center	Parking Lot	12	-
Kurtuluş Primary School	School Yard	25	14
Bus Terminal (AŞTİ)	Bus Park	10	11
Koza Road, G.O.P.	Residential	12	8

Table 3. Benzene Sampling Results for Kütahya

Name	Description	Level ($\mu g/m^3$)	
		Summer	Winter
Governorship	Parking/Pedestrian Area	3	15
Çinigar	Intercity Bus Terminal	3	11
Petrol Station	Petrol Station	6	18

As observed in many other European cities, a decrease in benzene levels will be observed from the hotspots in the city centers to the city perimeters. It is expected that, in both Ankara and Kütahya, outer parts of the city will observe less benzene levels than the ones presented in these tables.

6. CONCLUSION

By means of passive sampling and some other basic information and methods, it was possible to obtain indicative results about ambient levels of pollutants to optimize and base further air quality monitoring and control strategies for Ankara and Kütahya.

By comparison of the passive sampling results and other relevant data with the standards, it is determined that for all pollutants regulated by the three EU daughter directives ambient air quality standards are being exceeded in both cities.

Inefficient combustion of low quality coal is a significant source of SO_2 pollution in Kütahya. The parts of Ankara that has not made the switch to natural gas are still observing high SO_2 levels, although not as high as Kütahya. Diesel traffic in both cities is also a major contributor to SO_2 levels at traffic hotspots due to high sulfur content of the fuels.

Traffic has become a major source of air pollution for Ankara, and is becoming a significant source for Kütahya as well. This could be clearly seen from high NO_2 and benzene levels observed in the cities, especially during winter season when activity rates are higher and meteorological conditions are conducive to adequate pollutant dispersion.

Ozone levels for the summer season are high in both Ankara and Kütahya. The role of high summer solar radiation intensity and duration is evident by comparing the winter and summer ozone levels. However, ozone levels should be further studied to understand better the mechanism of formation of this pollutant through its precursors in the Turkish cities.

Both cities were found to be in Regime-1 (non-compliance with the limit values) monitoring requirement under the EU air quality assessment scheme. Therefore, both cities are required to conduct mandatory high quality air quality monitoring. Both short and long-term exceedances of limit values were observed in the cities of Ankara and Kütahya.

7. ACKNOWLEDGEMENTS

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