A STUDY OF VOLATILE ORGANIC CARBON POLLUTION ON A UNIVERSITY CAMPUS DUE TO TRAFFIC

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ABSTRACT

With increasing number of vehicles in metropolitan areas of Turkey, the hydrocarbon levels have also increased in the city air especially at certain crowded streets. As far as the effects of hydrocarbons on humans are concerned, some of them are known to be carcinogenic. People living in crowded sections of the city are exposed to exhaust fumes of the cars and busses. The same problem has started to be serious in the Middle East Technical University (METU) Campus in Ankara because of the excessive increase in the number of the cars entering the Campus. This is a big Campus where 20 000 students and about 1000 faculty members live. This study was performed to investigate the hydrocarbon pollution at the Middle East Technical University (METU) Campus due to traffic. The samples were collected at 11 locations on the campus, one of them being the control sample. The sampling continued for 3 months and passive sampling with Orsa-5 tubes have been carried out. The samples were extracted first with CS_2 in the laboratory and then analyzed for BTX compounds by using a Gas Chromatograph with FID.

The results of the study have shown that there is a considerable amount of hydrocarbon pollution on the Campus. The hydrocarbon levels in the ambient air at these sampling locations have also been compared with standards. The concentration of benzene and toluene have been found to be high which is thought to be due to the gasoline formulation in Turkey.

INTRODUCTION

Traffic, which is the main source of air pollution in various big cities of the world, causes serious air quality problems. Amount of air pollutants depend not only on emissions from vehicles but also on number of vehicles in traffic. On the other hand, individual and collective driving habits are also important. Especially hydrocarbon (HC) pollution in air results mostly from vehicles (about 53% of total HC pollution). Despite those disadvantages, the number of gasoline and diesel vehicles is ever increasing due to the advantages they provide, the increase in the living standards and population growth.

Emission limits for vehicles were put into practice by many countries since 1960. In Turkey vehicle emissions occupy a significant place in potential pollutant sources. Moreover, unconscious driving habits and lack of care for cars make the situation worse.

NMVOC's emitted from cars have various effects on human beings. Some are harmless to the human health, some are odorous, others cause severe diseases like cancer (e.g. benzene). Under the influence of sunlight, they are part of photochemical reactions in the atmosphere. Together with nitrogen oxides (NO_x), they are responsible for the formation of ozone.

A big increase in the number of personal cars, buses and minibuses has been observed on METU Campus in recent years. The air quality in the Campus is adversely affected especially from the cars that are used by students for transportation purposes. The increase in the number of student cars can also be seen in the growing park problem in the Campus. It is observed

that air pollution problem is worse near bus and minibus stops, and in the entrance-exit gates of the Campus.

Within the framework of this study, the air pollution due to VOC compounds was determined at different sampling points at METU Campus. The aim of the study was to find out the spatial distribution of VOC caused by traffic emissions and to determine the current VOC concentrations on METU Campus.

EXPERIMENTAL

Sampling Method

ORSA-5 diffusion samplers for passive sampling of ambient air were used in this project. ORSA-5 is a small glass tube filled with activated carbon. Both ends the tube are closed by diffusion barriers, made of cellulose acetate. The tubes are stored in small tight bottles. As soon as ORSA-5 is exposed to ambient air, air diffuses inside the tube while the organic compounds are adsorbed on the charcoal. The concentration of VOC in the ambient air is calculated on the basis of adsorbed mass and the diffusion coefficients of the individual compounds (Pannwitz, 1981; Pannwitz, 1983).

Simultaneous VOC measurements at many different places with active sampling would require a high amount of sampling equipment. However, for measuring over a long period of time (monthly mean values) passive sampling tubes are much more suitable. The firm Dräger has developed and tested the diffusion sampler ORSA-5 to measure the VOC pollution at work places, but also at roads where traffic density is high. (Pannwitz, 1991).

During the measurements the passive sampling tubes have to be protected against rain and have to be placed in such a way that air moves along to the axis of the tube (Pannwitz, 1981; Pannwitz, 1983). For this reason a PVC pipe of 100 mm diameter and 500 mm long was used. Two 90^o elbows were placed at the top of the 500 mm pipe, so no rainwater could get inside. The sampling tubes were fixed in the PVC tube in a perpendicular position. The sampler can be exposed to ambient air from one day to several weeks depending on the concentration of the VOC in the air. The average concentration of each compound in the ambient air should be higher than 2 $\mu g/m^3$ for exact calculation.

Sampling Locations:

Samples were taken at 11 different sampling points on METU Campus. Sampling point No:10 was chosen as a background point, because this point is in a remote area on the Campus and away from the traffic. The ORSA-5 tubes (type NIOSH, containing about 450 mg coconut shell charcoal with a particle size from 0.4 to 0.8 mm) were placed in the PVC shields and the PVC pipes were attached in a vertical position to an electrical post at a height where people cannot reach (about 2 m above the ground level). The sampling tubes were placed in the sampling locations each month, and kept there for one week. Each tube was collected at the end of the week, put in its original bottle with cap tightly screwed and brought to the laboratory in an ice chest. These bottles were kept in the refrigerator until they were analyzed.

Extraction of the samples

Charcoal in the sampling tubes was put into a tared vial and re-weighted. About 3.5 ml CS_2 is put into the vial and weighted (carbon disulfide (CS_2) was used to extract the sample). The vial was put into an ultrasonic shaker for an hour. After waiting for 30 minutes for complete

settling, 1 mL of the extracted sample was injected into a special glass pipette. The open end of the glass pipette was sealed with burner and kept in the refrigerator until GC analyses.

Analyses on Gas Chromatography:
The analyses of the extracted samples were carried out by capillary gas chromatography with a flame ionization detector. 1 μL of the extracted sample was injected into the gas chromatograph. The quantification of the components was performed based on the peak areas of the chromatogram. The compounds analyzed were **benzene, toluene, m-,p- and o-xylene and ethyl benzene (BTX)**. Since the concentrations of compounds other than benzene and toluene were very small, they were not reported here.

Table 1. Toluene and benzene concs. (ng/μl) at different sampling points (GC results) Samples from the sampling point No.1 for September and from points No.9,10 and 11 were lost for November.

Sampling points	1	2	3	4	5	6	7	8	9	10	11
	SEPTEMBER 2001										
Benzene	-	838,14	3,051	0,00	4,86	98,43	188,70	2,82	2,92	0,00	0,00
Toluene	0,00	95,90	11,43	0,00	8,21	0,000	0,00	10,88	0,00	0,00	52,64
	OCTOBER 2001										
Benzene	214,21	0,00	0,00	500,12	218,08	69,56	52,90	123,14	57,34	0,00	0,00
Toluene	0,000	0,00	0,00	46,83	0,00	0,000	45,57	20,39	21,18	0,00	0,00
	NOVEMBER 2001										
Benzene	293,59	486,82	206,15	356,09	332,37	235,35	33,74	297,02	-	-	-
Toluene	0,000	40,28	0,00	43,96	51,26	0,00	0,00	89,84	-	-	-

RESULTS AND DISCUSSION

The concentration of VOC in the ambient air is calculated on the basis of adsorbed mass and the diffusion coefficients. (Pannwitz1981, Pannwitz 1983)

$$c_i = \frac{K_{ORSA5} \times m_i}{DA \times D_i \times t}$$

c_i : Concentration of the contaminant measured in ng/cm^3, corresponds to mg/m^3
K_{ORSA5} :Device constant of sampler =0.8 cm^{-1}
m_i :Mass of the contaminant as determined in ng by gas chromatography ,corresponds to 10^{-9} g
DA :Desorption efficiency of the measured substance (less than or equal to 1)
D_i :Diffusion coefficient specific to the substance in cm^2 /s
t :Sampling time in seconds

The contaminant concentration is converted from mg/m^3 to mL/m^3 (ppm) as follows:

$$c_i \left[mL/m^3\right] = c_i \left[mg/m^3\right] \times \frac{24.1}{Molecular\ weight}$$

(Concentration calculations are done without pressure and temperature correction).

Table 2. Diffusion coefficient of selected organic compounds

Component	**Diffusion coefficient, cm^2/s** (25^oC/1013 hPa)
Benzene	0.0859
Ethyl benzene	0.0693
Toluene	0.0763
o-Xylene	0.0727

Table 3. Molecular weight of each component

Component	**Molecular Weight (g/mole)**
Benzene (C_6H_6)	78.11
Ethyl benzene(C_8H_{10})	106.17
Toluene(C_7H_8)	92.14
Xylene(C_8H_{10})	106.17

Concentration calculation for benzene (September 2001 /Sampling Point 2 (Prep School Junction)) is done below:

$t = 7 \times 24 \times 60 \times 60 = 604800$ second
$DA = 1(assumed)$
$D_i = 0.0859\,\text{cm}^2/\text{second}$
$K_{ORSA5} = 0.8\,\text{cm}^{-1}$
$Molecular\ weigth\ of\ benzene = 78.11\,\text{g/mole}$
Sealed extracted sample volume =1 mL
Volume of CS2 used for extraction = 3.44 mL

$$m_i = 838.141\,\text{ng}/\mu\text{L} \times \frac{1000\ \mu L}{1\ mL} \times 3.44\ mL = 2883205.04\ ng$$

$$c_i = \frac{0.8 \times 2883205.04}{1 \times 0.0859 \times 604800} = 44.397\,\text{ng/cm}^3$$

$$\text{ng/cm}^3 = \text{mg/m}^3$$

✓ $44.397\ \text{ng/cm}^3 > 0.002\ \text{ng/cm}^3$

For exact calculation of each component in the ambient air, the average concentration of component should be higher than 2 $\mu g/m^3$ ($2 \times 10^{-3}\,\text{ng/cm}^3$).

Ambient air benzene concentration in ppm for sampling point 2 is:

$$c_i\ [mL/m^3] = 44.397\ [mg/m^3] \times \frac{24.1}{78.11} = 13.698\,ppm$$

Ambient air benzene and toluene concentrations for September, October and November at each point are given below in Table 4, 5, and 6:

Table 4. Ambient air benzene and toluene concentrations as ng/cm^3 at sampling points

	SEPTEMBER		OCTOBER		NOVEMBER	
Sampling Point	**Benzene**	**Toluene**	**Benzene**	**Toluene**	**Benzene**	**Toluene**
1	-	-	11,183	0	15,436	0
2	44,405	5,720	0	0	25,214	2,348
3	0,164	0,691	0	0	10,889	0
4	0	0	26,299	2,773	18,242	2,535
5	0,257	0,489	11,559	0	17,399	3,021
6	5,155	0	3,644	0	9,775	0
7	10,00	0	2,744	2,659	1,785	0
8	0,146	0,633	6,438	1,201	15,954	5,432
9	0,152	0	3,001	1,247	-	-
10	0	0	0	0	-	-
11	0	3,132	0	0	-	-

Table 5. Ambient air benzene concentration in sampling points as ppm

Sampling Point	**September**	**October**	**November**
1	-	3,45	4,763
2	13,70	0	7,779
3	0,05	0	3,36
4	0	8,11	5,63
5	0,079	3,57	5,37
6	1,59	1,124	3,01
7	3,086	0,846	0,55
8	0,045	1,986	4,92
9	0,047	0,926	-
10	0	0	-
11	0	0	-

Table 6. Ambient air toluene concentration in sampling points as ppm

Sampling point	**September**	**October**	**November**
1	-	0	0

2	1,496	0	0,615
3	0,181	0	0
4	0	0,725	0,663
5	0,128	0	0,790
6	0	0	0
7	0	0,695	0
8	0,165	0,314	1,421
9	0	0,326	-
10	0	0	-
11	0,819	0	-

CONCLUSION

Passive sampling has been performed at Middle East Technical University Campus in Ankara, Turkey. When the results of the ambient air concentrations on the METU Campus are compared with the standards, results are found higher than standards. Table 7 gives some typical values of BTX concentrations in rural and urban areas.

Table 7. Typical ambient air concentration ranges of VOCs in rural and urban areas (Baumbach,1996)

Component	Rural Area concentration ($\mu g/m^3$)	Urban Area concentration ($\mu g/m^3$)
Benzene	1-5	5-30
Toluene	0.5-2	5-50
Xylene	0.1-2	5-50

Because of obtaining high concentrations of benzene and toluene (compared with the standards), it is thought that this may be due to the formulation of gasoline fuel in Turkey. The results of the study have shown that at the sampling points:

- Gate A1 (main gate to the campus)
- Prep School Junction (a heavy traffic junction)
- Cultural and Convention Center (where too many activities take place)
- Civil Engineering bus stop

high BTX concentrations have been measured.

REFERENCES

1) Günter Baumbach, Air Quality Control, Springer-Verlag Berlin Heidelberg, 1996.
2) Panwitzt, K.H., ORSA-5 Ein neuer Probenehmer fuer Organische Loesemitteldaempfe, Draeerheft,1981
3) http://www.utoledo.edu/~aprg/courses/iap/text/effects/criteria_effects.html
4) http://www.srigc.com/catalog/fiddetector.htm