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**THE EFFECT OF LOCAL MOBILE SOURCES  
ON  
AIR QUALITY**

*T. C.  
Yükseköğretim Kurulu  
Dokümantasyon Merkezi*  
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Environmental Engineering  
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**By**

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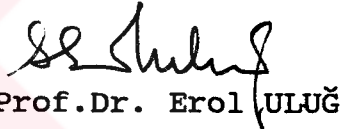
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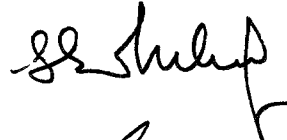


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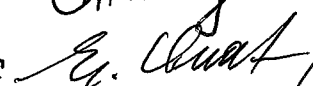
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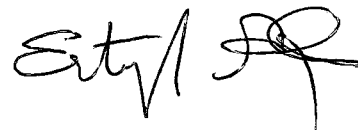
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## **ABSTRACT**

### **THE EFFECT OF LOCAL MOBILE SOURCES ON AIR QUALITY**

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In this study the effect of mobile air pollutant sources within METU campus are investigated by measuring atmospheric lead, smoke and particulate concentrations; and exhaust carbon monoxide and hydrocarbon emissions of 75 cars. Also dispersion models of CALINE-3 and ISCST were run in computer to obtain the concentrations of carbon monoxide, hydrocarbons, lead and particulates, theoretically.

The experimental findings were interpreted and statistical correlations are attempted. Theoretical findings are compared to find out which model is suitable for such a case. Exhaust emissions of hydrocarbons and carbon monoxide were represented graphically with respect to age of the car. Experimental lead, smoke and particulate concentrations were also interrelated.

**Key Words;** Mobile Air Pollution, Particulates, Lead, Total Hydrocarbons, Carbon monoxide, Dispersion Modelling.

**Science Code;** 615.02.01

## ÖZET

### YEREL HAREKETLİ KAYNAKLARIN HAVA KALİTESİNE ETKİSİ

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Bu çalışmada, ODTÜ kampüsündeki yerel hareketli hava kirliliği kaynaklarının etkileri, atmosferdeki kurşun, duman ve parçacık konsantrasyonları ve egsozdan çıkan karbon monoksit ve hidrokarbon gazlarının 75 arabada ölçülmesi yoluyla araştırıldı. Ayrıca, CALINE-3 ve ISCST dağılım modelleri bilgisayarda çalıştırılarak karbon monoksit, hidrokarbon, kurşun ve partikül konsantrasyonları teorik olarak bulundu.

Deneysel bulguların yorumları yapıldı ve istatistiksel korellasyonların yapılması denendi. Teorik bulgular, bu çalışma için uygun modelin bulunması amacıyla karşılaştırıldı. Hidrokarbon ve karbon monoksit kirleticilerinin egsoz emisyonları, arabaların yaşına karşı grafiksel olarak gösterildi. Deneysel kurşun, duman ve partikül konsantrasyonlarının birbirine ilişkileri araştırıldı.

**Anahtar Sözcükler;** Hareketli Hava Kirleticileri,  
Partikül, Kurşun, Toplam  
Hidrokarbon, Karbon Monoksit,  
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## NOMENCLATURE

- LAMBDA = Excess air coefficient
- (A/F) = Air to Fuel ratio
- K = Vehicle concentration (vehicles/km)
- RH = Relative humidity (%)
- T = Temperature (°C)
- [CO] = Carbon monoxide concentration (ppm)
- r = Correlation coefficient
- CH<sub>4</sub> = Methane Concentration
- t<sub>1</sub>, t<sub>2</sub>, t<sub>3</sub> = Sampling times
- C<sub>1</sub>, C<sub>2</sub>, C<sub>3</sub> = Concentration (ppm)
- [THC] = Total Hydrocarbon Concentrations
- [NMHC] = Non Methane Hydrocarbon Concentration
- Z<sub>0</sub> = Surface roughness
- C<sub>max(t)</sub> = The maximum concentration of pollutant at time t
- C<sub>max(h)</sub> = The maximum concentration of pollutant at time h
- t = The time
- b = The coefficient (various b values can be found from the referance)
- Z<sub>i</sub> = Convective mixing height (m)
- C<sub>pa</sub> = Specific heat of air
- d = Density of air
- T<sub>A(min)</sub> = Minimum temperature of air
- T<sub>A(t)</sub> = Temperature of air at that time
- H<sub>0</sub> = Surface heat flux (W/m<sup>2</sup>)
- t<sub>0</sub> = Time of sun rise
- t = Time of measurement
- U<sub>\*</sub> = Friction Velocity

$f_c$  = Coriolis Force

U2 = Mean wind speed in meters per second at  
height Z1 (default value of it is 10 m.)

AFVR = Average random flow vector (director toward  
which the wind is blowing)

P = Wind profile exponent (default values are  
assigned on the basis of stability)

Ta = Ambient air temperature in °K

Hm = Depth of surface mixing layer (m.), developed  
from twice-daily mixing height estimates by  
the meteorological preprocessor program

Stability = Pasquill stability category (1=A, 2=B, etc.)

$d\theta/dz$  = Vertical potential temperature gradient in  
degrees kelvin per meter (default values  
assigned on the basis of stability)

w = Highway width

NE = Element number

EL = Element length

PHI = The angle between the road and the wind  
direction

BASE = Element growth factor

$\Delta C$  = Change in the concentration

K = A constant

$Q_l$  = Emission (grammes/second)

H = Depth of the street canyon

Z = Height of receptor with respect to the source

r = Constant

$C_{air}$  = The concentration of the element in air

$C_{soln.}$  = The concentration of the element in the extracted

solution

$V_{\text{soln.}}$  = The volume of extracted solution

$V_{\text{air}}$  = The volume of air passed through the filter  
during the sampling period

$M_s/M_t$  = The fraction of area of filter sector used in  
the analysis.

$V_a$  = true air volume at atmospheric pressure, m<sup>3</sup>

$V_m$  = volume measured by primary standard, m<sup>3</sup>

$P_a$  = barometric pressure, mmHg

$P_m$  = pressure drop at inlet of primary standard, m<sup>3</sup>

$Q$  = flow rate, m<sup>3</sup>/minute

$t$  = time of flow, minute

$SP$  = mass concentration of suspended  
particulates,  $\mu\text{g}/\text{m}^3$

$W_f$  = final weight of filter, g

$W_i$  = initial weight of filter, g

$V$  = air volume sampled, m<sup>3</sup>

$Q$  = pollutant emission rate

$K$  = a scaling coefficient to convert concentrations  
to desired units.

$Y$  = distance in the Y direction

$VT$  = vertical term

Decay = decay term



## CHAPTER 1

### 1. INTRODUCTION:

Twentieth century has been a time for constantly increasing energy use in the world. The relative efficiency of different kinds of energy production is directly related to resultant pollution. In general, we inefficiently use the energy sources for conversion to electric power and transportation by means of the internal combustion engines (1). The resultant pollution is tried to be reduced by various attempts.

Internal combustion engines now and for the near future are one of the major atmospheric polluters. Wickstrom studied the alternative transportation systems on air pollution. Battery powered or direct energy conversion vehicles may independently exist at some future date. However for at least ten years, they cannot significantly replace internal combustion engines because of the limitations in their use (2).

Removal of the traffic from the central areas of cities can reduce emissions. Elmberg (1) has proposed a bypassing technique at Gottenburg Sweden. The centre of the city is divided into wedge shaped quadrants, travelling to the central area is supplied by public transport and emergency vehicles. Gottenburg has a population of 444,000 and planning of city traffic took seven years.

Motor vehicle restrains such as parking regulations, increased parking charges, vehicle free or pedestrian zones and road pricing could be applied. On the other hand in order to be successful they should be done with public transport improvements. Such measures will have social, economic and land use effects and they are not desirable from other aspects such as shifting of employment centres, lowering of city property values and adverse economic effect on low income residents. For example in San Francisco 25%

increase in parking tax did not make people use public transport (2).

### 1.1 Main Pollutants from the Exhausts of Diesel and Petrol Engines;

The main pollutants from exhaust are carbon dioxide, carbon monoxide, carbon particles (soot), lead compounds, organic compounds produced from petrol, nitrogen oxides, unburned petrol and water vapour. These compounds may also react with each other and produce some secondary effects like photochemical smog (3).

### 1.2 Description of Traffic Pollution;

In 1965 there were 80 million cars in USA. It was 145 million in 1985 and it is still increasing.

In 1977 studies showed that;

75% of atmospheric Carbon Monoxide

35% of atmospheric Hydrocarbons

29% of atmospheric Nitrogen Oxides

was due to highway vehicles (2).

These numbers may give us idea about the extend of emissions and pollution from traffic. In large cities such as Ankara and Istanbul if we stop the emissions of stationary sources, we will still have pollutants in the atmosphere and this will be due to the mobile sources.

In 1969 although there was only 45,000 motor vehicles in Ankara, 65% of the atmospheric pollutants was estimated to be from mobile sources. Today since the number of vehicles have increased to 220,000 the atmospheric pollutants due to these sources estimated to be 77% (1989). This shows that motor vehicle pollution is 2-3 times more than stationary source pollution (4).

### 1.3 Scope and Objectives of the Study;

The aim of this study is to show the extent of local traffic pollution and its effect on air quality. We can divide the study into three parts:

Theoretical Approach; emissions from local mobile sources will be estimated by using emission factors, traffic counts and other available data.

By using two dispersion models (ISCST and CALINE-3) we are going to estimate the concentrations of carbon monoxide, hydrocarbons and lead.

Practical Approach; emissions of lead, smoke and particulates from motor vehicles will be measured by using a High Volume Sampler (HVS) and an atomic adsorption spectroscopy. For the measurement of carbon monoxide and hydrocarbons a carbon monoxide and hydrocarbon analyzer (Beckman 590) will be used.

## CHAPTER 2

### 2. LITERATURE REVIEW

#### 2.1 Classification of Mobile Sources

Mobile sources can be divided into the following categories:

- Conventional transport vehicles
- Farm equipment
- Merchant vessels
- Locomotives
- Lawn and garden implements
- Snowmobiles
- Outboard motors
- Transport refrigeration units
- Helicopters

Studies may be done to estimate the emissions of each category (5).

#### 2.2 Products and By-Products of Combustion

##### 2.2.1 Products of Combustion

Complete combustion produces carbon dioxide and water. But, incomplete combustion produces, firstly, unburned hydrocarbons such as paraffins, olefines, aromatic hydrocarbons, secondly, partially burned hydrocarbons like aldehydes, ketones, carboxylic acids and carbon monoxide; lastly, thermally cracked compounds as well as derivative products like acetylene, ethylene, hydrogen, soot, polycyclic hydrocarbons.

##### 2.2.2 By-Products of Combustion

From atmospheric nitrogen, oxides of nitrogen; from fuel additives, lead oxides, lead halogens; from fuel impurities, sulphur oxides are produced.

Oxidants; sun light acts on exhaust gas constituents to produce

the following oxidants: Organic peroxides, ozone and peroxy acetyl-nitrates (PAN) (6).

### 2.3 Sources of Pollution within the Vehicle

Sources of pollutants within the vehicle are as follows;

Evaporative losses from fuel tank and carburettor produces significant portion of atmospheric hydrocarbons, such evaporative losses are functions of movement of the vehicle, highway type and design, or nature of the traffic flow.

Crank case losses are caused by ventilation of the crank case. It is controlled in the USA by ventilation of the crank case through the carburettor into the engine.

Dust produced by wearing away of tires, brake linings and clutch plates.

Exhaust gases are the greatest concern because it is related to traffic volume and level of service (maintenance).

#### 2.3.1 Major Pollutants from Exhausts

- Lead
- Unburned hydrocarbons
- Carbon monoxide (CO)
- Nitrogen oxides (NOx)
- Carcinogens
- Particulate matter (PM)
- Odour
- Oxides of sulphur

For total hydrocarbons, that refers to the sum of unburned hydrocarbons, carcinogens and odour creating substances,

following compounds have been identified to: (7)

ethane	toluene
ethylene	ethylbenzene
acetylene	methylcyclohexane
propane	xylene
propylene	paraffins
butane	olefine
isopentane	aromatics
methylcyclopentane	formaldehyde
benzene	acetaldehyde
isooctane	acrolein
n.pentane	acetone
2methyl 1butene	propion aldehyde
n.butane	crotonaldehyde

#### 2.4 Effects of Exhaust Emissions

-Unburned fuel is not toxic in atmospheric concentration levels, but it is slightly anaesthetic in high concentrations.

-Aldehydes, which are produced in exhaust emissions in important quantities, have irritant action on eyes and respiratory system and can be recognized by their characteristic odour even smelt at low concentrations.

-Poly nuclear aromatic compounds which are fine particles, and which can persist in the air for long time are found in the exhaust gas. Some of them such as benzopyrene is carcinogenic. But their concentrations are higher in industrial areas than road tunnels (7).

-Nitrogen oxides exist in small quantities and are converted to nitrogen dioxide. Quantity of nitrogen monoxide in exhaust gases is two times the quantity of nitrogen dioxide which is more toxic than nitric oxide. Nitrogen oxides concentrations found in

streets is less than 10% of the concentration that is required to affect laboratory animals. So they are not a danger for health. Adsorption of nitrogen oxides by carbon particles may cause adverse effects.

-Smoke is produced from poorly maintained diesel engines having very fine carbon particles resulting from incomplete combustion of fuel. Smoke itself is not a health hazard. But Buchan and Charlson (2) state that carbon particles may act as a nuclei for haze formation and absorption of gases such as sulphur dioxide and nitrogen oxides. Bowen (2) states that in these conditions, it causes lung damage.

-Finely divided carbon and rubber from tires and asbestos from brakes and clutches. If exposure to this dust increases then it causes asbestosis but, the amounts are often very small and there is no evidence of health hazard.

Also lead, carbon monoxide and hydrocarbons have some undesirable effects, that are explained later in this chapter.

## 2.5 Engine Types and Air to Fuel Ratio

### 2.5.1 Engine Types;

There are three types of engines; diesel, spark ignition and direct injection engines. Diesel engines work with diesel oil. But spark ignition engines work with gasoline.

Spark ignition engines use more volatile fuel than diesel engines.

Spark ignition engines operate in the range of a stoichiometric mixture ratio (see Section 2.5.4). Diesel engines always operate with excess air ( $\text{LAMBDA} > 1$ ). An insufficient amount of excess air leads to an increase in soot, carbon monoxide and hydrocarbon

emissions (6).

#### 2.5.1.1 Comparison of Diesel and Spark Ignition Engines

The quantitative composition of exhaust gases from diesel and spark ignition engines differs from each other as shown in Table 2.1. Also in Table 2.2 composition of exhaust gases from internal combustion engines is shown (8).

Automobiles equipped with diesel or spark ignition engines were compared. Unfortunately, a diesel engine produce 30-100 times more particulate matter than an equivalent sized spark ignition engine, and although this particulate matter is primarily composed of carbon, 10-40% by weight is mutagenic both with and without metabolic activation. Consequently the increased use of diesel-powered vehicles may have potential human health effects (9).

Improved fuel economy in light duty vehicles equipped with diesel engines versus those equipped with gasoline engines is expected to considerably increase the percentage of diesel vehicles on the market of new cars in the immediate future. Scientists have focused on the adverse health effect of diesel particles (10).



TABLE 2.1

Quantitative Composition of Exhausts (maximum concentrations in volume percent) (9).

Components	Petrol Engine	Diesel Engine	Note *
Nitrogen	74-77	76.-78	N-T
Oxygen	0.3-8.0	2.0-18	N-T
Water Vapour	3.0-5.5	0.5-4.0	N-T
CO <sub>2</sub>	5.0-12.0	1.0-10.0	N-T
CO	5.0-10.0	0.01-0.5	T
NOx	0.0-0.8	0.0002-0.5	T
Hydrocarbons	0.2-3.0	0.009-0.5	T
Aldehydes	0.0-0.2	0.001-0.009	T
Carbon Black (soot)	0-0.04 g/m <sup>3</sup>	0.01-1.1	T
3,4-Benzpyrene	Upto 10-20 μg/m <sup>3</sup>	Upto 10 μg/m <sup>3</sup>	C

\* N-T; Non-Toxic      T ; Toxic      C ; Carcinogenic  
(in mg/m<sup>3</sup>)

TABLE 2.2 Composition of Exhausts From Internal Combustion Engines (10).

nitrogen	oxygen
hydrogen	carbon dioxide
water vapour	carbon monoxide
nitrogen oxide	formaldehyde
acetaldehyde	acrolein
carbon black (soot)	sulphur dioxide
hydrogen sulphide	carbon disulphide
methane	ethane
propane	isooctane
dimethyl butane	hexane
ethylene	propylene
butylene	iso-butylene
acetylene	cyclopentane
cyclohexane	methyl cyclopentane
benzene	ethyl benzene
toluene	xylene

### 2.5.1.2 Types of Gaseous Fuel Systems

There are various attempts for new types of gaseous fuel systems;

- Liquified Petroleum Gas (LPG)
- Compressed natural Gas (CNG)
- Liquified natural Gas (LNG)

They are cleaner than petrol, ignite more rapidly and combustion is nearly complete. Therefore, little unburned fuel is obtained in the exhaust. However, conversion of large portion of the vehicles to these fuels may not be feasible. Large scale conversion may be considered only in heavily polluted areas. (1)

### 2.5.2 Air to Fuel Ratio

Since a combustion process occurs in the engine, it is useful to define a mixture ratio or air to fuel ratio (A/F). This is the ratio of the mass of air required per unit mass of fuel for combustion.

$$(A/F) = \frac{\text{Mass of air}}{\text{Mass of fuel}} \dots\dots\dots 2.1$$

For stoichiometric purposes, (A/F) ratio should be around 14.5. So it is better to define an equivalence ratio:

$$\text{LAMBDA} = \frac{(A/F) \text{ Stoic}}{(A/F) \text{ Actual}} \dots\dots\dots 2.2$$

If LAMBDA < 1, more air is being supplied than required. If LAMBDA > 1, less air is supplied than required for complete combustion of fuel. So we should give enough air to completely combust the fuel so that less dangerous pollutants will be emitted (7).

## 2.6 Effects on Emissions

Emissions are sensitive to a number of variables including speed, travel mode, ambient temperature, operation mode, fuel composition and load.

### 2.6.1 Effect of Ambient Temperature

Several investigators have noted that total hydrocarbon and carbon monoxide emissions are elevated when vehicles are operating at reduced ambient temperatures (11).

Two studies have been conducted at different ambient temperatures, one is at  $-6.7^{\circ}\text{C}$ ,  $4.4^{\circ}\text{C}$ , and  $21.1^{\circ}\text{C}$  (11) and the other one is at  $-6.7^{\circ}\text{C}$ ,  $4.4^{\circ}\text{C}$  and  $20^{\circ}\text{C}$  (12) with six gasoline fuelled vehicles (including no catalyst, early model catalyst, and late model catalyst) and a methanol fuelled vehicle. The results of a study (12) have shown that the emissions were substantially reduced by the late catalyst control technologies at all temperatures examined. Diesel emissions are not so sensitive to ambient temperature. Most of the published data identify emissions, in terms of the total hydrocarbon emission rates.

It can be said that organic emissions in motor vehicles during idle operation vary significantly among control and engine

technologies, with the emission rates substantially reduced by functioning catalyst systems.

In the study by Stump et al. (11) two types of fuels and driving schedules were used. Hydrocarbon and carbon monoxide emissions were significantly increased by reduced ambient temperature. Nitrogen oxides emissions also increased, but to a lesser extent. Paraffins and aromatic hydrocarbon emission fractions were sensitive to fuel composition. With low temperature cold starts tests, a 5 minute idle resulted in reduced carbon monoxide emission rates and elevated nitrogen oxides emission rates. Hydrocarbon emission rates were not predictably sensitive to preliminary idle.

#### 2.6.2 Effect of Speed on Emissions

Effect of speed on urban carbon monoxide and hydrocarbon emissions in Figure 2.1, and on nitrogen oxide emissions in Figure 2.2, are shown. These relations represent urban driving conditions and assumes a natural mode of operation, including a cold start. The average speeds are for passenger cars and light duty trucks are in proportion to their use. Allowance is made for deterioration and scrubbing of vehicles as they are aged and they are replaced by new controlled vehicles.

The speed-emission relationship is not certain for oxides of nitrogen. But it appears that there is a positive relation, since nitrogen oxides formation is related to combustion temperature.  
(13)

FIGURE 2.1

Urban Carbonmonoxide and Hydrocarbon Emissions for 1975 Model year cars (1).

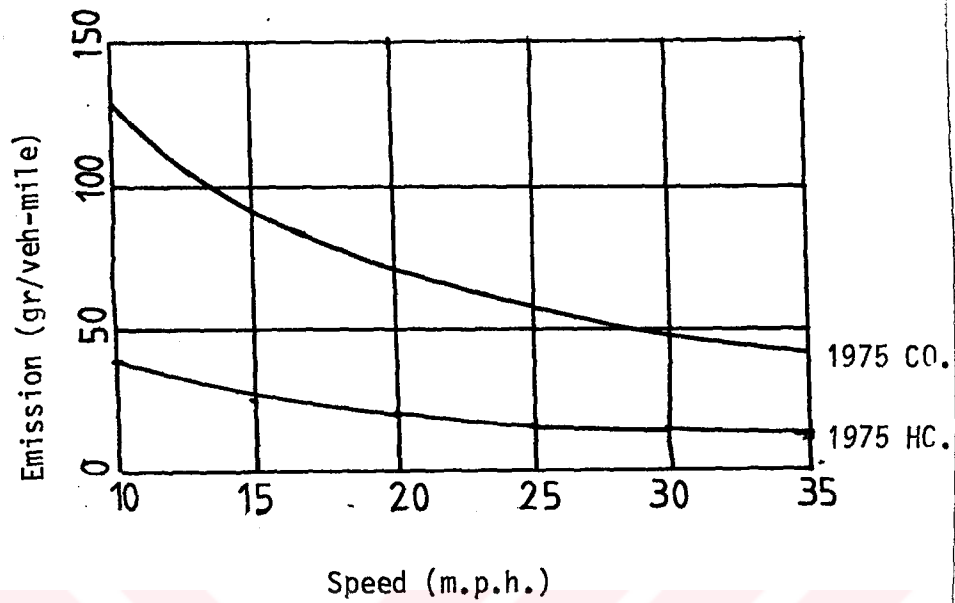
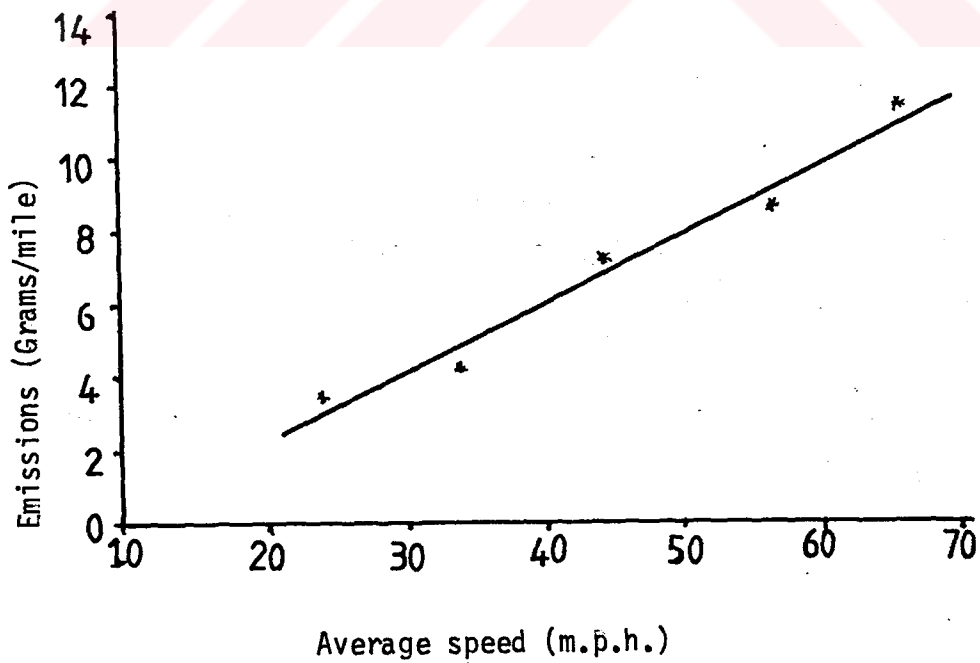


FIGURE 2.2

Effect of Average Speed on Nitrogen Oxides Emissions (1).



### 2.6.3 Effect of Travel Mode

**Table 2.3** gives the exhaust pollutant emissions in grams per vehicle-mile for automobile, diesel bus, diesel locomotive, and electric rail. (13)

**TABLE 2.3 Exhaust Emission Factors for Various Travel Modes**  
(grams per vehicle mile)

Pollutant	1.Automobile	2.Diesel bus	2.Diesel locomotive
Carbon monoxide	85.00	20.41	6.35
hydrocarbons	9.50	3.36	4.54
NOx	6.17	33.57	6.80
SOx	0.18	2.45	5.90
Particulates	0.30	1.18	2.27

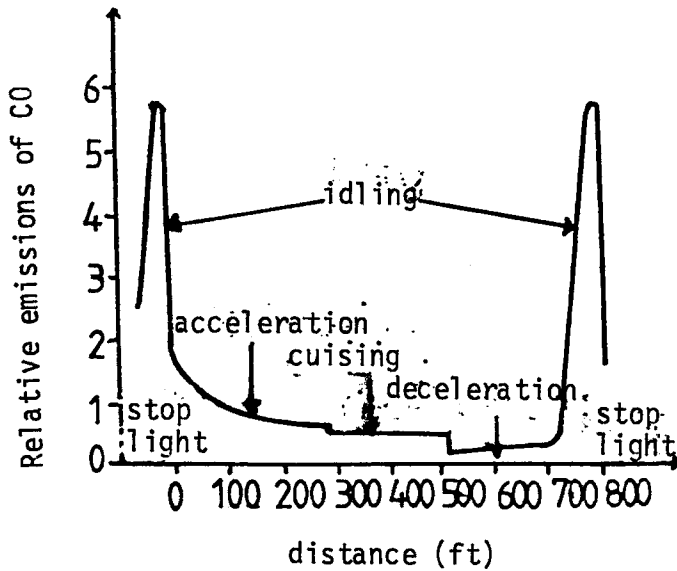
1972 emission factors based on 25 mph and cold start operation

### 2.6.4 Effect of Operation Mode

The operation mode is important for the amount of pollutant generated. **Figure 2.3** shows the carbon monoxide emissions related to the operating cycle as measured along a length of roadway in Great Britain (13). Readings were taken of three automobiles travelling an 800-feets section of road. The motion cycle represents the vehicle stopping at a traffic signal, idling, accelerating to 30 mph, operating at that speed and decelerating for a stop at the next traffic signal. This type of operation is typical for most city streets, causing pollutants to be concentrated at intersections or other locations where idle and deceleration phases occur (7). **Table 2.4** shows the relation of emissions to vehicle miles of travel.

**FIGURE 2.3**

**Effect of Operation Mode on Emissions (1).**



**TABLE 2.4 Percentage of Pollutants Emitted per mile for Different Engine Operations (1).**

Engine operation	Gross Hydrocarbons	Carbon Monoxide	Oxides of Nitrogen
Idle	5.9	7.5	0.03
Cruise	14.1	14.3	21.4
Acceleration	56.2	62.2	78.5
Deceleration	23.7	16.1	0.17

**2.7 Emission Factors for Mobile Sources**

An emission factor is an average value which relates the quantity of a pollutant released to atmosphere with the activity associated with the releases of that pollutant. It is usually expressed as the weight of pollutant divided by a unit weight, volume, distance or duration of the activity that emits the pollutant. Using such factors, emissions from various sources could be estimated. For traffic the emission factors are in the form of weight of pollutant/vehicle-unit distance travelled.

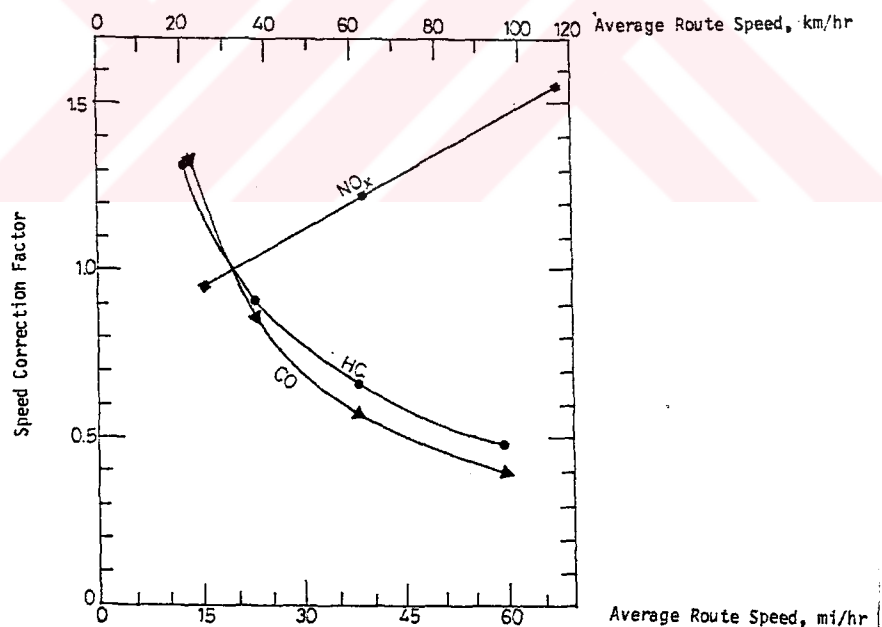
The emission values represented in Table 2.5 for carbon monoxide, hydrocarbons and nitrogen oxides are for an average speed of approximately 19.6 mile/hr (31.5 km/hr) (14). These values can be modified to make them representative of the area for which emission estimates are being prepared, by using the average speed adjustment factors contained in Figure 2.4 (14).

**TABLE 2.5** Relative Effects of Emissions From Different Vehicles (1).

Pollutant	Automobile 1970	Automobile 1975	Bus (diesel arterial)
CO	0.24	0.02	0.02
HC	1.56	0.14	0.10
NO <sub>2</sub>	3.27	1.63	3.50
SO <sub>2</sub>	0.18	0.18	0.52
Particulates	0.25	0.25	2.08

Measured in grams per vehicle mile

**FIGURE 2.4** Average Speed Adjustment Factors for the Calculation of Emission Factors (14).



Crank case and evaporative hydrocarbons, particulate, and sulphur oxide emission factors for average values that can be considered



independent of speed. Emission estimates for these pollutants are calculated by simply multiplying the VMT (Vehicle Miles of Travel) by the emission factor.

The emission data for highway vehicles are based on the generalized test cycle that involves operation typical of everyday driving patterns. Because this driving cycle is intended to represent typical driving, it cannot apply in scientific purposes, i.e. to a particular segment of a particular roadway at a particular time. Driving modes include; idling, constant speed, acceleration and deceleration. Since all driving patterns can be divided into one of these four mode emissions can be determined by summing these emissions for a particular driving pattern. (13)

**TABLE 2.6 Average Emission Factors For Highway Vehicles Based On Nationwide Statistics (14).**

Year	CO(gr/Km)	HC(gr/Km)	Particulates
		Exhaust	Exhaust (gr/Km)
1965	55.	5.7	0.24
1970	48.	4.8	0.24
1975	31.	3.0	0.24
1980	14.	1.5	0.24
1990	8.7	0.99	0.24

## 2.8 Major Pollutants Coming From Mobile Sources;

### 2.8.1 Carbon Monoxide

It is a colourless, odourless and tasteless gas. Inhalation of 0.3 % by volume of carbon monoxide for 30 minute causes death (13). Carbon monoxide is a hazard to man since it tends to be assimilated by the blood molecule and hemoglobin, interfering with the transport of oxygen from the lungs to all parts of the

body. In the lung capillaries, the hemoglobin molecule combines with oxygen. This hemoglobin-oxygen complex is carried through the blood stream and, when it reaches a body cell requiring oxygen, the bond is broken and the oxygen is released for use by the cell.

This oxidation process within the cell ordinarily produces some carbon monoxide, this carbon monoxide combines with hemoglobin to form carboxyl hemoglobin for a return trip to lungs. There the carbon monoxide is released and exhaled from the body. So normal human blood always contain an equilibrium concentration of carboxy-hemoglobin. This value varies from individual to individual, but it is in the order of 0.5 %. It should not exceed to 2 %. (15 and 16).

#### 2.8.1.1 Methods To Control Mobile Source Carbon Monoxide Emissions

Inspection and maintenance (I/M) and oxygenated fuels might be used for CO emission control. A problem in most I/M programs is that vehicles are not tested under load. So it is impossible to obtain real NOx emission data, even hydrocarbon and carbon monoxide emissions of on road vehicles is different than idling or fast idling vehicles (17).

Using oxygenated fuels results in 8 - 11% reduction in ambient carbon monoxide levels. Although most cars run dirtier when cold, few gross polluters pollute so much that they dominate the same emissions even when their engines are hot (17).

The study of Bravo et al. (18) proposed a relationship for carbon monoxide emissions. This equation shows important parameters effecting carbon monoxide emissions.

$$[\text{CO}] = 0.062K - 0.94T + 23.49[\text{CH}_4] - 5.36RH - 18.93 \quad \dots 2.3$$

Where;

K = vehicle concentration (vehicles/km)

RH = relative humidity (%)

T = temperature (°C)

[CO] = carbon monoxide concentration (ppm)

[CH<sub>4</sub>] = methane concentration (ppm)

### 2.8.2 Lead

It is a heavy metal; the occurrence of heavy metals in atmospheric particles is of considerable interest due to the possibility of deleterious biological and ecological affects, and also because of their potential use as tracers of pollutant aerosol origin. Lead, despite its declining commercial use in gasoline in many developed countries is one of the most widely studied heavy metals due to the continuing arguments on its possible hardly noticed neurological effects on children, its known toxicity and the widespread use of metal most notably in gasoline additives (19).

The level of exposure to lead can be seen from blood lead levels which is an indicator of dose (20).

#### 2.8.2.1 Usage of Lead and Halides in Transportation

Lead in the form of triethyl or trimethyl lead is added to gasoline to increase its octane number. Bromide in the form of ethylene dibromide along with chloride in the form of ethylene dichloride is also added to scavenge lead from engine cylinders during combustion. In consequence, Mushak et al. (20) have suggested that Bromine or Chlorine might serve as an indicator of atmospheric vehicular lead. It is obvious that chloride would be of limited use since its neutral levels in the ambient air are highly variable. But bromine levels seems to have greater usage for this purpose, since its background level is low in most

places, and its emission from industrial sources is very rare. The mean value of Br/Pb ratio was 0.41 or seasonally it ranges from 0.36 in summer and 0.48 in winter. Major contribution of particulate lead is due to motor vehicle emissions (21).

#### 2.8.2.2 Formation of Lead Particles

The combustion of leaded gasoline in automobile engines is a major source of sub-micron particles in the atmospheric air of urban areas. Tetra ethyl lead ethylene dichloride and bromide are combined with combustion to form volatile lead salts. The salts remain in a vapour phase in the exhaust gases and their condensation takes place as the gases cool. A secondary increase in the mass concentration of particulate matter occurs closer to the exhaust exit as some of the high molecular weight compounds condense. Condensation may take place initially by homogeneous nucleation leading to the formation of high condensation of very small particles (22).

#### 2.8.2.3 Some Studies About Lead

The inhalable particulates in the ambient atmosphere in Riyadh (22) during the working day (7am to 4pm) in 1984 was measured. Coarse particulates (2.5 to 15  $\mu\text{m}$ ) and fine particles (< 2.5  $\mu\text{m}$ ) were analyzed using atomic adsorption unit to determine lead content. Results showed that;

About 11-16% of lead was less than 2.5  $\mu\text{m}$  and they are directly from vehicle exhaust emissions.

About 84-89% of lead was in the form of 2.5 to 15  $\mu\text{m}$  sized particles. They were not from the vehicle exhaust directly but they were produced as a result of agglomeration with other airborne particulates (22).

If dibromo and dichloroethane not added to leaded gasoline as scavengers, than lead compounds will deposit in the engine. The common understanding was that these compounds are completely decomposed during combustion. But recently the presence of dibromoethane in automotive emissions and in ambient air was reported. The results showed that halogenation reactions of aromatic hydrocarbons and phenols occur during or after combustion of leaded fuel in the engine (23).

Rucheinski et al. (29) studied Br/Pb ratio in Cairo street dust. The most important result was that;

60 - 70% of lead were due to traffic emissions and 30 - 40% were from industrial emissions.

Study of Prevezano (2) showed area wide mobile source emissions. It incorporates EPA's emission factors, Federal test procedure and the changes of emissions with respect to model year. Results were; 1- 60 % of emissions occurred in urban areas and 40 % occurred in rural areas. 2- Lead contents varied with season, region and grade of gasoline.

However Hoggan et al. (24) showed that lead concentration in the ambient atmosphere was not dependent on the season. It was dependent on the wind speed. Lead concentration near highways decreased with increasing perpendicular distance from highway.

#### 2.8.2.4 Other Sources of Lead

Away from urban and industrialized centres, the atmospheric lead burden still is derived primarily from gasoline combustion. Other sources such as lead smelter, battery manufacturers, iron and steel producers, waste incineration and wind eroded soil will become more important in the future. But atmospheric lead concentrations and fluxes will continue to decrease

substantially, if use of lead in gasoline is further decreased (26). Table 2.7 shows the concentration of lead in industrial effluents as measured on plants and soils.

**TABLE 2.7** Concentration of Lead on Plants and Soils Around Industrial Plants (22).

Sample	Lead Found (ppm)		
	Wet Method	AAS	Standard Deviation
Soil sample	5-600	5-610	± 0.2
Plants	5-100	4.5-110	± 0.2
Battery Manufacturer	5-50	4.8-48	± 0.1
Television Tube			
Manufacture	200-400	200-400	± 1.0
Mining Drainage	0.02-2.5	0.01-3.0	± 0.01
Tetra Ethyl Lead			
Manufacture	45	45 ± 48	± 0.2

#### 2.8.2.5 Methods to Control Mobile Source Lead Emissions;

The level of emissions from mobile sources can be reduced by adjusting air to fuel ratio, and/or by using catalytic converters. However the presence of lead in gasoline renders these converters useless through the quick poisoning of the catalyst. Thus the incentive for lead phasedown and its eventual removal from gasoline is not only to significantly reduce lead pollution, but also to pave the way for reducing the hazards to human health.

The use of unleaded fuel is spreading rapidly around the world. It is already almost universally used in Japan, and it is predominant throughout the U.S. and Canada. Its use will be mandatory across the common market before the end of the decade. Australia introduced it in 1986, and Saudi Arabia and Korea in 1987 (25).

### 2.8.2.6 Health Effects of Lead

Significant attention has been focused on health affects of lead in urban areas, in continental North America, and globally. The geochemical cycling of lead in urban areas, in forests and bog ecosystems, lakes, oceans and atmosphere has been studied extensively. These studies show that atmospheric lead is derived largely from combustion of leaded gasoline, occurs primarily attached to aerosols smaller than 0.2  $\mu\text{m}$  in diameter, is efficiently scavenged by precipitation, has an atmospheric residence time on the scale of days, and may be transported long distances from emitting sources. Wet removal processes are more important than dry deposition except near heavily travelled roadways and in urban and industrial centres (26). Table 2.8 shows lead levels in blood in some countries.

**TABLE 2.8** Average Blood Lead Levels ( $\mu\text{g}$  100  $\text{ml}^{-1}$ ) in the General Population in Some Countries (24).

Year	Country	Men	Women	Children
1984	UK	10.9	8.0	9.9
1984/85	UK	-	-	12.6
1983/84	BELGIUM	13.5	-	-
1983/84	SWEDEN	5.3	-	-
1984	SWEDEN	-	-	4.2
1983/84	MEXICO	18.8	-	-
1983/84	MALTA	24.7	-	-
198?	GREECE	-	-	12-14
1985	GREECE	14.3	-	10.8
198?	INDIA	-	11.54	-
1981	CHINA	6.8	5.6	-
198?	CHINA	-	5.9-8.2	-
1981	JAPAN	6.5	5.2	-
1985	WEST GERMANY	-	-	6.2
1985	WEST GERMANY	6.0	5.7	5.0
1981	USA	8.3	6.2	-
1980	HIMALAYAS	-	2.9	-
1985	SAUDI ARABIA	-	-	9.2-10.7

? ;Did not specify year in eighties.



Low level lead exposure have been found to interfere with specific enzyme systems and blood production for humans. Other affects of lead exposure are behavioral. In children brain damage has been observed (22). High levels of lead in water, air or food has been known to cause adverse health affects like anaemia, kidney damage and encephalopathy. Long term environmental exposure to lead has been known to cause adverse neurological affects in children. The neurological lead is thought to endure behavioral abnormalities and to cause reduced intelligence and mental retardation. The USA EPA estimates that vehicle emissions accounts for 50% of the uptake of lead into the human bloodstream in the USA (25).

## 2.9 Hydrocarbons

Hydrocarbons may be divided as unburned hydrocarbons and carcinogens. Unburned hydrocarbons may cause eye irritation and vegetation damage (3).

In air pollution terminology, the term hydrocarbon generally refers to that class of organic substances, which, in the presence of sunlight and oxides of nitrogen, either in the atmosphere or in laboratory, give rise to the production of photochemical air pollution. This involves production of noxious substances such as ozone, nitrogen dioxide, aldehydes, peroxyacyl nitrates and aerosol species. They have some significance because of their effect on human health, plant life and atmospheric visibility at elevated concentrations (27).

### 2.9.1 Studies on Hydrocarbons

Studies on hydrocarbons emitted from mobile sources are concentrated on;

- Tunnel studies
- Dynamometer studies
- Ambient air

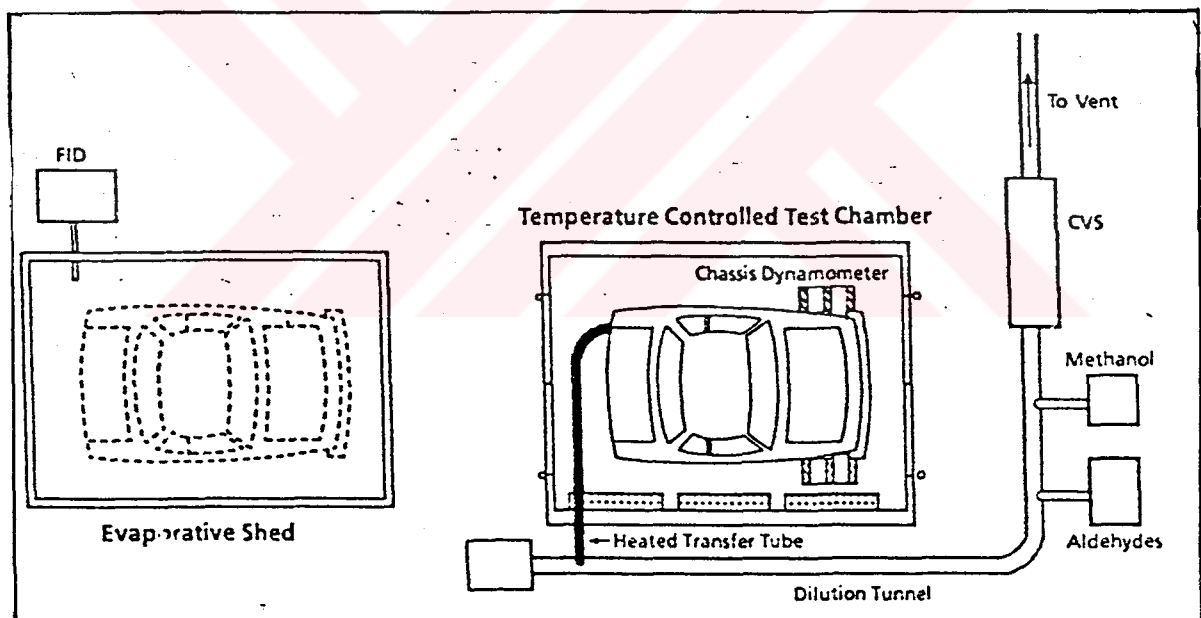


When organic materials are emitted from a combustion source much more of the organic matter is in the vapour phase due to the elevated source temperatures. Upon emission into the ambient atmosphere, these vapour phase materials cool and are condensed and adsorbed upon particles. So, if particles are collected at the temperature of the tailpipe of a motor vehicle, the particles will be depleted of organic matter relative to their state in the ambient atmosphere. This fact has been long recognized and source sampling systems for organic compounds generally incorporate equipment for cooling and collecting vapour phase organic.

### 2.9.1.1 Dynamometer Studies

The Chassis (auto exhaust and evaporative emissions sampling scheme) is shown in Figure 2.5 of (28).

FIGURE 2.5 Chassis Dynamometer Sampling Scheme (28).



Emission of non-methane hydrocarbons (NMHC) from vehicle exhausts are one of the largest anthropogenic sources of hydrocarbons. That is why the hydrocarbon composition from motor vehicle exhaust

determination is important (29).

Motor vehicle emissions are the primary source of most of the atmospheric hydrocarbons. For example in the study of Kawamura and Kaplan (30) low molecular weight dicarboxylic acids were analyzed in Los Angeles air. The study which involved collection of gasoline and diesel exhaust samples, under idling conditions, showed that distributions of dicarboxylic acid are similar to those of air samples. But their concentrations are 28 (gasoline) and 144 (diesel) times higher than the average concentration of atmospheric diacids. These results indicate that engine exhaust is an important source of diacids in the urban atmosphere. Organic acids were also detected in the motor exhaust from a single motor vehicle at idle conditions (31). The study showed that the distribution of individual acids were similar to that in the air, but the concentration was 17 times higher than for the average atmospheric content. Nelson and Quigley (29) performed a study on 67 vehicles on the road conditions and driven through an urban driving cycle on a Chassis dynamometer. Two equations were derived;

$$[\text{THC}] = \frac{t_1}{T} C_1 + \frac{t_2}{T} C_2 + \frac{t_3}{T} C_3 \dots\dots\dots 2.4$$

where;

$t_1, t_2, t_3$  = sampling times

$C_1, C_2, C_3$  = concentration (ppm)

$$[\text{THC}] = 12.8 + 1.18 * [\text{NMHC}] \dots\dots\dots 2.5$$

where;

[THC] = Total Hydrocarbons (ppm)

[NMHC] = Non Methane Hydrocarbons (ppm)

### 2.9.1.2 Tunnel Studies for Simulation of Hydrocarbon Sampling

Nelson et al (29) studied dilution of exhaust by several hundred

fold within the 5 minute residence time of air in the tunnel. They simulated the processes in the real atmosphere rather than in a laboratory dilution chamber. Because of a low level of lighting in the tunnel there is essentially no photochemical reaction or decomposition with OH radicals and ozone.

High volume air samplers were used to collect particulate matter generated by motor vehicles in the tunnel. Particles were collected on filters.

A soot sample is obtained from the walls of an exhaust room at the tunnel. The bulk of the particulate matter collected in the tunnel was diesel soot (32). Unlike a dynamometer, tunnel studies may represent tailpipe NMHC emissions for only a limited number of vehicle operational conditions expected in typical urban driving patterns. Dynamometer studies can simulate urban driving patterns to investigate the NMHC compositional changes that occur (33).

#### 2.9.2 Methods To Control Mobile Source Hydrocarbon Emissions;

Catalytic converters are very useful in reducing the emissions. An example of this is the study done by Lonnen et al.(33). The NMHC levels in the tunnel were a factor of approximately 4 lower than those in a similar study performed in 1970. This decrease probably reflects reduced vehicular tailpipe emissions due to the utilization of catalyst equipped vehicles.

Although American cars have been equipped with catalytic converters, these are extremely effective in oxidizing fuel hydrocarbons but benzene together with methane appears to be somewhat more refractory than most. As a result the benzene content as a fraction of the total hydrocarbon of automobile exhaust in American cars tends to be significantly higher than in European ones. Consequently it is likely that benzene will grow as a percentage of tailpipe hydrocarbons in the future. It is not widely

recognized in the atmospheric sciences that USA passenger cars have extremely efficient hydrocarbon control systems. While benzene percentages might increase, the concentrations of hydrocarbons in the exhausts of current and future USA cars is so small that their future atmospheric concentrations would be relatively unimportant in a health context. Europeans may not be so lucky because catalytic converters are not so widely used in their cars (34).

#### 2.10 Ambient Air Quality Standards As Related To Mobile Source Emissions

Highways and some other sources attract large number of vehicles to particular locations and thus directly contribute to localized concentrations of CO, HC and Pb that may approach or exceed ambient standards (35).

Motor vehicle hydrocarbon emissions are regulated also because of involvement in photochemical processes that result in the formation of ozone and other oxidants of public health concern. EPA has established a national ambient air quality standard (NAAQS) for ozone at 0.12 ppm (volume) (1 hr. average). There is also a NAAQS for CO at 9 ppm (volume) 8 hr. average (11).

But according to Greek et al. (36) carbon monoxide regulation as mandated under the national ambient air quality (NAAQS) has not effectively protected the health of USA's citizens. The direct cause and effect relationships between carbon monoxide and cardiac dysfunction indicate a clear and urgent need for the reevaluation of carbon monoxide standards in order to protect the health of urban people (36).

TABLE 2.9 Ambient Air Quality Standards (37).

Pollutant	Long Term Limits	Short Term Limits
	(in $\mu\text{g}/\text{m}^3$ )	
SO <sub>2</sub> + SO <sub>3</sub>		
General	150	400
Industrial Areas	250	400
Particulates (10 $\mu$ or smaller)		
General	150	300
Industrial Areas	200	400
Carbonmonoxide	10000	30000
NO <sub>2</sub>	100	300
NO	200	600
Ozone	-	240
Hydrocarbons	-	140
Chlorine	100	300
HCl	100	300
H <sub>2</sub> S	-	40
Lead	2	-
Cadmium	0.04	-

As seen from the **Table 2.9**, for lead there is no short term limit but according to US Federal Primary and Secondary Ambient Air Quality Standards average lead concentration should not be greater than 1.5  $\mu\text{g}/\text{m}^3$  (38). And normal street lead levels are in the order of 0.5 to 1  $\mu\text{g}/\text{m}^3$  (39).

Higher carbon monoxide concentrations result in less oxygen demand being delivered to the body, resulting in continuous impairment of mental and physical functions; hearing can be damaged. Although this hazard is reversible in time some urban concentrations remain so high that reversal does not occur. A comparison of Ambient Air Quality Standards is given in **Table 2.10**.

**TABLE 2.10** Comparison of Ambient Air Quality Standards with U.S. WHO<sup>1</sup> and EEC Levels for Selected Pollutants (37).

Pollutant (in ppm)	standards		
	1 hour	24 hour	1 year
SO <sub>2</sub>			
US		365	80
WHO	350	125	40-60
EEC	400 (30 min.)	400	80-120
Turkey	900	400	150-250
PM (10μ or less)			
US		260	75
WHO		70	60-90
EEC		300	
Turkey		300-400	150-200
CO			
US	40000	10000 (8 hr.)	
WHO			
EEC			
Turkey		30000	10000
NOx			
US			100
WHO	320		
EEC			
Turkey		300	100
Ozone			
US	235		
WHO	120	60 (8 hr.)	
EEC			
Turkey		240	
Lead			
US			1.5
WHO			
EEC			2
Turkey			2

In response to the promulgation of a natural primary ambient air quality standard for lead, estimates of motor vehicle lead emissions must be added to state implementation plans for meeting the provisions of the clean air act (40). US Primary and Secondary

US Ambient Air Quality Standards are shown in Table 2.11.

**TABLE 2.11 US Primary and Secondary Ambient Air Quality Standards (37).**

Pollutant	Standard	Averaging Time	Frequency Standard	Concentration	
				µg/m3	ppm
CO	Primary & Secondary	1 hr.	Ann. Max.	40000	35
		8 hr.	Ann. Max.	10000	9
HC	Primary & Secondary	3 hr.	Ann. Max.	160	0.24
		(6 to 9 a.m.)			
NO <sub>2</sub>	Primary & Secondary	1 year	Arith. Mean.	100	0.05
Photochemic. Oxidant	Primary & Secondary	1 hr.	Ann. Max.	160	0.08
Particulate Matter	Primary	24 hrs.	Ann. Max.	260	-
		24 hrs.	Ann. Geom. Mean	75	-
	Secondary	24 hrs.	Ann. Max.	150	-
		24 hrs.	Ann. Geom. Mean	60	-
		24 hrs.	Ann. Max.	365	0.14
SO <sub>2</sub>	Primary & Secondary	1 year	Arith. Mean	80	0.03
		3 hrs.	Ann. Max.	1300	0.5
	Secondary	24 hrs.	Ann. Max.	260	0.1
		1 year	Arith. Mean	60	0.02

**2.11 Dispersion of Emissions;**

**2.11.1 Meteorological Parameters Related to Dispersion;**

In the two dispersion models that are going to be used in the computer the meteorological data needed are;

- Surface roughness (centimetres)
- Average wind speed at 10m. height (meters/second)
- Wind direction (degree)
- Atmospheric stability class (A,B,C,D,E,F)
- Mixing layer height (meter)
- Averaging time (minute)
- Atmospheric temperature (degrees centigrade)

**Surface Roughness;** Mechanical turbulence is generated by air movement over surface roughness elements. An increase in the surface roughness increases the amount of mechanical turbulence

generated. This enhances both vertical and horizontal dispersion of pollutants in the surface layer especially for near ground releases.

Wind Speed and Predominant Wind Direction; is important for dispersion of pollutants. Predicted concentrations at any location are higher for low wind speeds. Also direction of the wind effect the concentrations of the pollutant at the receptor site. For all wind speeds, the maximum concentrations occur, for near parallel in direction to source, conditions.

Atmospheric Stability Class; The critical wind angle at which maximum concentration occurs is much more sensitive to atmospheric stability class than to wind speed. In fact for the most unstable class (A), the maximum is observed to occur under crosswind conditions, because of the increases in vertical and horizontal dispersion that occur under unstable conditions.

Averaging Time; Atmospheric concentrations of air pollutants are highly variable with time. Due to this time variable nature of the levels of atmospheric contaminants, the concentration of a pollutant at a receptor is measured by sampling over various time periods, like, 15 minutes, 1 hour or 6 hours. So this time periods are called as averaging time (41).

The number of statistical independent turbulent fluctuations occurring at a point in a turbulent medium is directly related to the averaging time. For short averaging times, a less variable family of turbulent fluctuations is to be expected. Hence pollutant dispersion is lessened.

Atmospheric Temperature; the difference between the air and gas temperatures effect the buoyancy of the pollutant so the dispersion is effected. That's why plume rise equation used in atmospheric dispersion estimates employs the temperature difference.



Mixing Layer Height; effective dispersion of gaseous or finely divided material released into the atmosphere near the ground depends on natural mixing processes on a variety of scales.

Because of the differences in temperature, air rises over land primary due to the daily cycle of radiative heating and cooling of the ground, but air rise may also be due to the overflowing of air from warmer or cooler regions of the earth (42).

The effective mixing layer of the atmosphere has important variations in depth as well as in mixing efficiency which is due to vertical transport caused by the density stratification.

Mixing layer height can be measured by some meteorological methods or it might be calculated by using some assumptions (43).

1) Convective Mixing Layer Height

The main assumption is that all the sunlight coming to the earth is absorbed by the air.

$$H_o > 5 \text{ W/m}^2$$

$$Z_i = \frac{2}{C_{pa} d_A [T_A(t) - T_{(min)}]} \int_{t_o}^t H_o dt. \dots\dots\dots 2.7$$

where;

- Z<sub>i</sub> = Convective mixing height (meters)
- C<sub>pa</sub> = Specific heat of air (Joule/Kg.°K)
- d = Density of air (Kg/m<sup>3</sup>)
- T<sub>A(min)</sub> = Minimum temperature of air (°K)
- T<sub>A(t)</sub> = Temperature of air at that time (°K)
- H<sub>o</sub> = Surface heat flux (Watt/m<sup>2</sup>)
- t<sub>o</sub> = Time of sun rise (hour)
- t = Time of measurement (hour)

2) Neutral Boundary Layer Height

$$z_i = \frac{0.2 U_*}{f_c} \dots\dots\dots 2.8$$

Where;

$$U_* = \frac{k U_{ref}}{\ln(Z_{ref}/Z_0)} \dots\dots\dots 2.9$$

$$f_c = 2\Omega \sin L_T \text{ (coriolis parameter)} \dots\dots\dots 2.10$$

$$L = - \frac{d_A C_p T_a U_*^3}{k H_0} \dots\dots\dots 2.11$$

$U_{ref}$  = Wind speed at anemometer height (meter/sec)

$Z_{ref}$  = Anemometer height (meter)

$Z_0$  = Surface roughness length (meter)

$k$  = Von Carman constant (approximately 0.4)

$L$  = Monin-Obukhov length (meter)

3) Stable Boundary Layer Height

$$H_0 < -5 \text{ W/m}^2$$

At low wind speeds there is no solution of this formulation.

$$z_i = \frac{L}{3.8} \left[ \left( 1 + 1.52 \frac{U_*}{L f_c} \right)^{1/2} - 1 \right] \dots\dots\dots 2.12$$

Where;

$$U_* = k \frac{U_{ref}}{\ln(Z_{ref}/Z_0) - \eta(Z_{ref}/L)} \dots\dots\dots 2.13$$

$$\eta(Z_{ref}/L) = -4.7(Z_{ref}/L) \dots\dots\dots 2.14$$

$L > 500\text{m}$ . than boundary layer is neutral.

## 2.12 Modelling Line Source Pollution and Comparison of Models

In order to estimate atmospheric concentrations of pollutants we may use dispersion models. There are various dispersion models. These models are empirical or semi empirical in nature. Validation of these models is generally difficult due to the lack of reliable experimental data. The possible models that can be used are;

Gaussian models; HIWAY1 and 2, GENERAL MOTORS (GM), AIRPOL4, TRAPS, CALINE2 and 3, GENERAL FINITE LINE SOURCE MODEL (GFLSM)

Numerical Models; DANARD, RAGLAND, M-ROAD, ROADS, ROADWAY (44). General information about these models are listed below:

### 2.12.1 Description of Some of These Models

HIWAY Model (3) This Gaussian model is originally developed for USA EPA. Highway emissions are considered to be a series of finite line sources. Sigma in the gaussian plume equation are specified as a function of atmospheric stability.

GM Model (3) This model is developed by Chock based on the General Motors experimental data. It uses infinite line source approach ; sigmas are found as a function of wind angle, distance from the centre of the road to the receptor and stability conditions.

AIRPOL-4 Model (3) Carpenter and Clemana developed this model with special solutions to evaluate Gaussian integral. Gaussian coordinate system is translated to a receptor coordinate system. The advantage of using two coordinate systems is that the Gaussian equation can be directly applied to each roadway point.

TRAPS Model (3) Developed in Texas by Bullin, Maldonado, and

Polasek. Concentration became large as U (wind speed) approach to zero. If wind speed is smaller than 2 mph TRAPS returns an error message and as U decreases it mispredicts the concentrations.

CALINE-2 Model (3) is a box model and developed by Ward et al. it assumes that pollutants are well mixed over the roadway up to a certain height. This is called as mixing cell. It uses both continuous line source and point source equations to calculate concentrations.

CALINE-3 Model (3, 54) developed by Benson (California department of transportation) uses a mixing zone concept. The region over the highway is the region of uniform turbulence and emissions.

GFLSM Model (3) is a Gaussian diffusion model, it does not have the infinite line source constraint. GFLSM performs well if the source is relatively finite in length. It can also be applied to long term concentration estimations. The values estimated from GM and GFLSM are approximately the same when the source is finite in length.

DANARD Model (3) Two dimensional Eulerian model. The grid is fixed in horizontal form -150 m. to 150 m. from the centre of the roadway. Vertical grid is 10 cells from the surface upto the mixing height. In the lowest 3 m. of the roadway pollutants are assumed to be mixed uniformly.

RAGLAND Model (3) (Ragland and Pierce) it solves the continuity of mass equation for two classes parallel or non parallel using the same boundary conditions as DANARD. Lateral diffusion is ignored in the non parallel case but model solves the equation in three dimensions including lateral diffusion in parallel case.

MROAD-2 Model (3) this is a two dimensional grid model using Eulerian code to solve mass conservation equation numerically.

Size of the grid is related to the user it allows several line sources, topography is included. Mixing of pollutant is uniform at 3.3 m. above the road. Wind profile is dependent on stability but can be specified by the user.

ROADS Model (3) (by Pitter) two dimensional conservation of mass model. It determines steady state concentration of pollutants by numerically solving advection, diffusion and chemical reactions.

ROADWAY Model (3) It assumes a surface layer with the superposition of the effects of vehicle wakes. It's unique part is vehicle wake theory, vehicle wake is a region of increased turbulence but decreased velocity relative to vehicle. So a turbulence field is calculated across the highway related to number of vehicles, vehicle speeds and ambient and atmospheric conditions by the use of turbulence fields.

### 2.12.2 Gaussian Distribution

Gaussian or normal distribution is defined as a bell shaped curve. (Figure 2.6)

Gaussian distribution assumes; no deposition or reaction at the surface. Its general equation is;

$$Y = \frac{1}{(2\pi\sigma)^{\frac{1}{2}}} \exp\left[-\frac{1}{2}\left(\frac{x-x'}{\sigma}\right)^2\right] \dots\dots\dots 2.15$$

where;

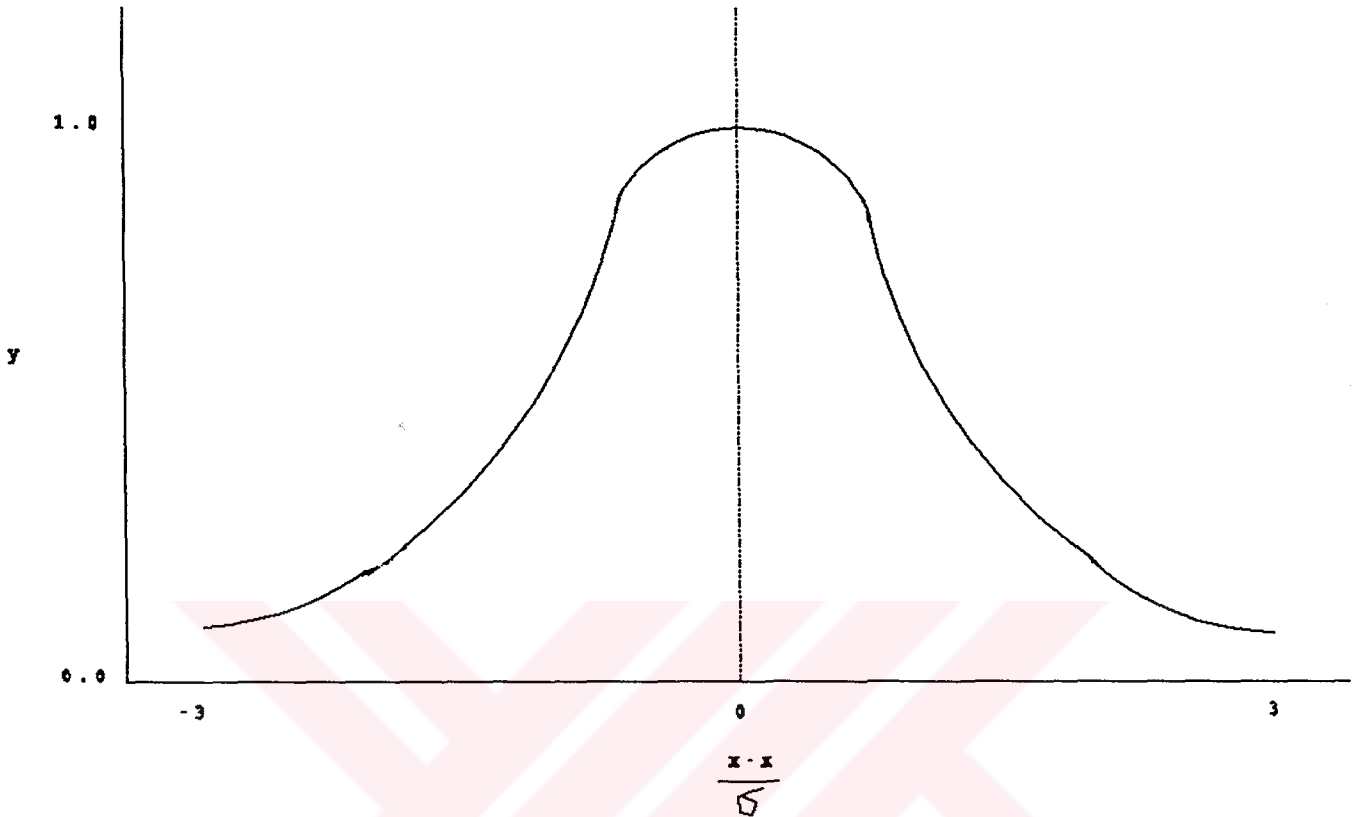
SIGMAY, SIGMAZ = standard deviation of plume concentration distribution in horizontal and vertical directions respectively (m,m)

U = wind speed (meters/second)

Q = uniform rate of pollutant emission (gram/second)

C = concentration (gram/cubic meter)

FIGURE 2.6 Gaussian Distribution curve (45).



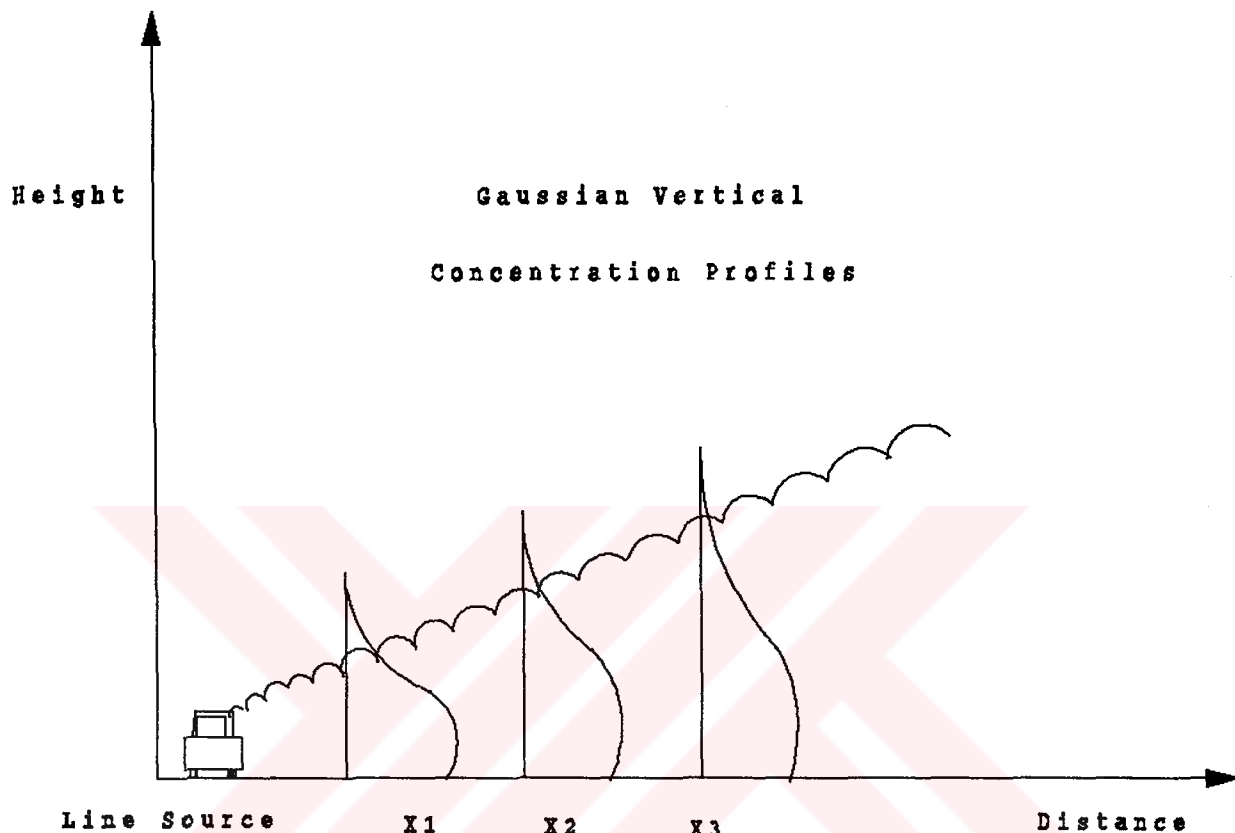
### 2.12.3 Gaussian Models

Extensive theoretical and experimental investigations of atmospheric diffusion have shown that the concentration of a substance at the receptor downwind from a source can generally be represented by a Gaussian function (46).

Data from ongoing model validation program for dispersion of pollutants from roadways in Texas (47) showed that pollutant concentrations do not increase as rapidly with decreasing wind speed as predicted by most models which are based on a Gaussian formulation. In fact the actual ground level concentration may

seem to decrease with decreasing wind speed when the speed drops below some critical value (2 m/s). So Gaussian equation is only valid for wind speed above the critical value.

**FIGURE 2.7** Gaussian vertical concentration profile (1).



References (48) and (49) can be used to prepare comparison of models **Table 2.12**.

There are also some unconventional dispersion models related to estimation of line source pollution. But they are not common. Beuriti and Al-Omishy (52) has stated that; the most commonly used basis for modelling pollutant dispersion is Gaussian plume formulation. So they created a program of this type to predict the concentrations of nitrogen dioxide (NO<sub>2</sub>) and hydrocarbons

that would result from traffic and meteorological conditions.

In some other studies turbulent diffusion behind the vehicles is tested. The wake of a moving vehicle was simulated using a specially constructed wind tunnel with a moving floor (50), (51).

The roadway model, in which the computer code incorporates the wake theory to predict air pollution concentrations along highways was modified with these new results.

In another study a statistical evaluation of three highway air pollution models (CALINE-3, HIWAY-2, and ROADWAY) using the tracer data from the General Motors sulphate dispersion experiments (49). The results suggest that the variability in the observations due to the random nature of the atmosphere is about 30 %. Comparisons of the model predictions paired and unpaired in time with measurements suggest that HIWAY-2 and ROADWAY perform best, but the performance of CALINE-3 is acceptable. In this study CALINE 3 and ISCST models are used. The characteristics of these models are explained in detail in the following sections.



TABLE 2.12; Listing and Comparison of Various Models (48, 49, 50, 51, 52, 53).

1

Model	Developed by	Type	Characteristics
GM	Chock	Gaussian	* finite line source * uses wind-road orientation angle * use distance from source * plume rise at stable and light wind conditions
HIWAY	EPA (Rao & Keenan)	"	* Series of finite line source * Each lane is straight, continuous line source with uniform emission rate
AIRPOL-4	Carpenter & Clemana	"	* Receptor coordinate is used * Up-wind and down-wind conditions can be predicted
TRAPS	Bullin, Maldonado & Polasek	"	* Concentration increases as U decreases to 0 * If U < 2mph returns a message
CALINE 2&3	Ward et al.	"	* Box model * Mixing cell concept * Continuous line and point source
GFLSM	Ashok & Patil	"	* Don't have finite line constraint * Can predict particle concentration
DANARD	Dufort & Frenkel	Numeric.	* 2 dimensional Eulerian model * Grids is fixed at +150, -150 meter from the road centre
RAGLAND	Ragland & Pierce	"	* Solves continuously mass conservation equation * Parallel-non parallel wind (3-dim.) (2-dim.)

<sup>1</sup>Continuoining at the next page.

ROAD-2	Kirch & Mason	"	<ul style="list-style-type: none"> <li>* Mixing is uniform up to a height</li> <li>* 2 dimensional grid model</li> <li>* Topography is included</li> <li>* Wind profile depends on stability</li> </ul>
ROADS	Pitter	"	<ul style="list-style-type: none"> <li>* 2 dimensional conservation of mass</li> <li>* Steady state concentration of pollution</li> <li>* advection, diffusion, chemical reactions are included</li> </ul>
ROADWAY	Eskridge, Hunt	"	<ul style="list-style-type: none"> <li>* Uses vehicle wake theory</li> </ul>
ISCST	EPA		<ul style="list-style-type: none"> <li>*ISCST is an extended version (1987) Gaussian of CRSTER single source model</li> <li>* It can calculate 1,2,3,4,6,8,12&amp; 24 hrs. of concentration or deposition values</li> <li>* If used with a year of meteorological data, it gives annual concentration or deposition</li> </ul>

### 2.12.3.1 ISCST (Industrial Source Complex Short Term Model)

The ISC (Industrial Source Complex) model contains two sub programs; ISCST (Industrial Source Complex Short Term model) and ISCLT (Industrial Source Complex Long Term model). ISC is designed to consider fugitive emissions, aerodynamic wake effects, gravitational settling and dry deposition and other complicated dispersion model analysis. The ISCST model is an extended version of the single source CRSTER model (EPA, 1977). It can calculate 1, 2, 3, 4, 6, 8, 12, and 24 hours of concentration or deposition values.

ISC can accept area, volume and stack sources. Volume option also covers line sources. It is a steady state Gaussian model. Area

source equation in ISC model is for a continuous and crosswind line source.

TABLE 2.13 Major Features of ISCST Model (53).

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Polar or cartesian coordinate systems

Plume rise due to momentum and buoyancy as a function of downwind distance for stack emissions.

Procedures suggested by Huber and Snyder (1976) and Huber (1977) for evaluating building wake effects.

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Procedures suggested by Briggs (1973) for evaluating stack-tip downwash.

Separation of multiple point sources.

Consideration of the effects of gravitational settling and dry deposition on ambient particulate concentrations.

Capability of simulating line, volume and area sources.

Capability to calculate dry deposition.

Variation with height of wind speed (wind profile exponent law).

Concentration estimates for 1-hour to annual average.

Terrain adjustment procedures for complex terrain.

Consideration of time dependent exponential decay of pollutants.

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The input requirements for the ISCST model consist of four categories.

Meteorological data

Source data

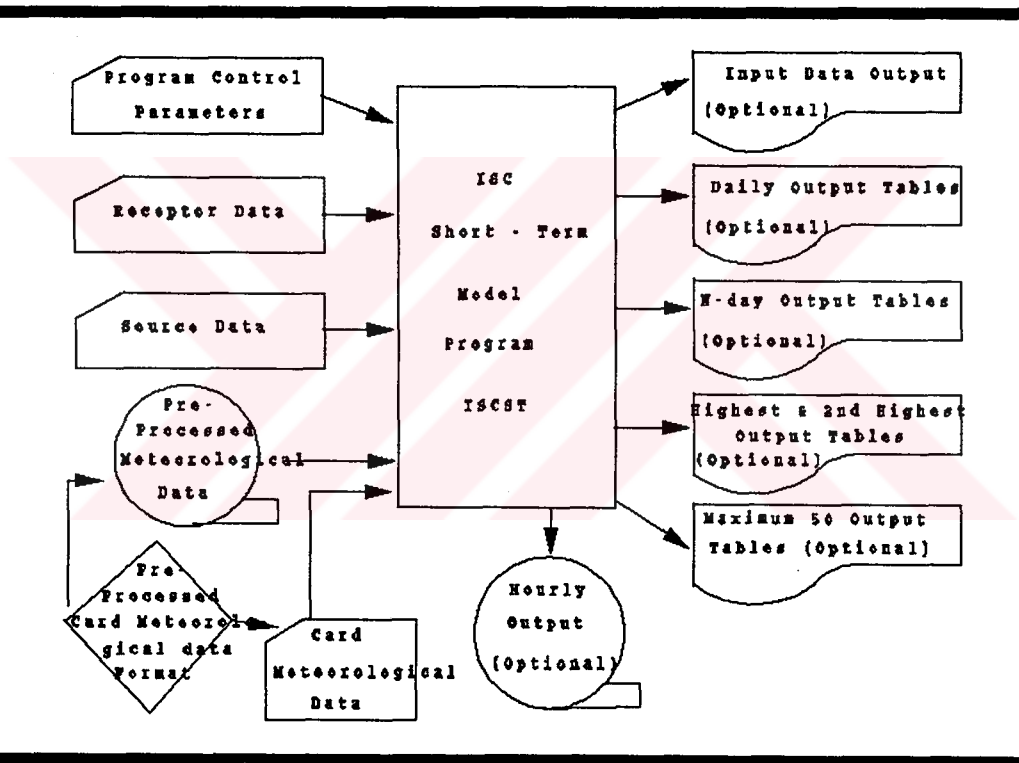
Receptor data

Program control parameters and options

The ISC model computer programs are suitable for application to pollutant sources in the following types of studies;

- Stack design studies
- Combustion source permit applications
- Regulatory variance evaluation
- Monitoring network design
- Control strategy evaluation
- Design of supplementary control systems
- New source review
- Prevention of significant deterioration

**FIGURE 2.8** Schematic Diagram of the ISCST Model (53).



Meteorological Data ISCST requires input of hourly estimates of wind direction, wind speed, ambient air temperature, Pasquill stability category, mixing height, wind profile exponent and vertical potential temperature gradient.

Source Data ISCST program accepts three source types; stack, area and volume. For each source, input data requirements include the source location with respect to a user specified origin, the source elevation. For each stack additional source input requirements include the physical stack height , the stack inner diameter, stack exit temperature, stack exit velocity. Horizontal dimensions and effective emission height are required for each area or volume source.

Receptor Data ISCST program uses either a polar or a cartesian coordinate system. Receptor locations in the cartesian coordinate system may be given as Universal Transverse Mercator (UTM) coordinate or as X (east - west) and Y (north - south) coordinates with respect to a user specified origin. **Table 2.14** shows hourly meteorological inputs required by the ISCST model.

**TABLE 2.14** Hourly Meteorological Inputs Required by the ISCST Model Program (53).

Parameter	Definition
U2	Mean wind speed in meters per second at height Z1 (default value of it is 10 m.)
AFVR	Average random flow vector (director toward which the wind is blowing)
P	Wind profile exponent (default values are assigned on the basis of stability)
Ta	Ambient air temperature in °K
Hm	Depth of surface mixing layer (m.), developed from twice-daily mixing height estimates by the meteorological preprocessor program
Stability	Pasquill stability category (1=A, 2=B, etc.)
dθ/dz	Vertical potential temperature gradient in degrees kelvin per meter (default values assigned on the basis of stability)

Table 2.15 shows default values of vertical temperature gradient ( $d\theta/dz$ ) and wind profile exponent ( $p$ ).

TABLE 2.15 Default Values for the Wind-Profile Exponents and Vertical Potential Temperature Gradients (53).

Pasquill stability Category	Wind profile exponent, $p$	Vertical potential temperature gradient ( $^{\circ}\text{K}/\text{km}$ )
A	0.10	0.000
B	0.15	0.000
C	0.20	0.000
D	0.25	0.000
E	0.30	0.020
F	0.30	0.035

#### 2.12.3.2 CALINE 3 (54).

CALINE 3 is a third generation line source air quality model developed by the California Department of Transportation. It is based on the Gaussian diffusion equation and employs a mixing zone concept to characterize pollutant dispersion over the roadway.

The purpose of this model is to assess air quality impacts near transportation facilities in what is known as the microscale region. Given source strength, meteorology, site geometry, and site characteristics the model can reliably predict pollutant concentrations for receptors located within 150 m. of the roadway. At present, the model can handle only inert pollutants such as carbon monoxide or particulates.

CALINE 3 divides individual highway links into a series of elements from which incremental concentrations are computed and summed to form a total concentration estimate for a particular receptor location.

The receptor distance is measured along a perpendicular from the receptor to the highway centreline. The first element is formed at this point as a square with sides equal to the highway width. The lengths of subsequent elements are described by the following formula.

$$EL = W * BASE^{(NE-1)}$$

PHI < 20° , BASE 1.1  
20° < PHI < 50° , BASE 1.5  
50° < PHI < 70° , BASE 2.0  
70° <= PHI , BASE 4.0

Where ;

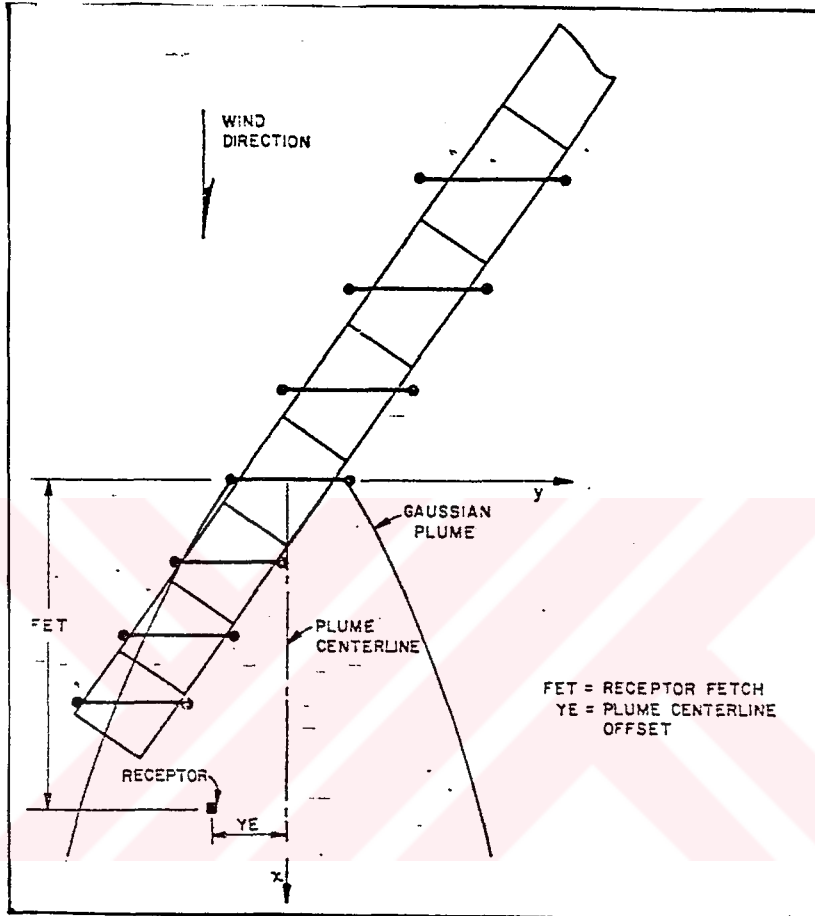
w = Highway width  
NE = Element number  
EL = Element length  
PHI = The angle between the road and the wind direction  
BASE = Element growth factor

Each element is modeled as an equivalent finite line source (EFLS) positioned normal to the wind direction and centred at the element midpoint. A local x-y coordinate system aligned with the wind direction and originating at the element midpoint is defined for each element. (Figure 2.9)

Downwind concentrations from the element are modeled using the crosswind finite line source model (FLS) Gaussian formulation.

**FIGURE 2.9**

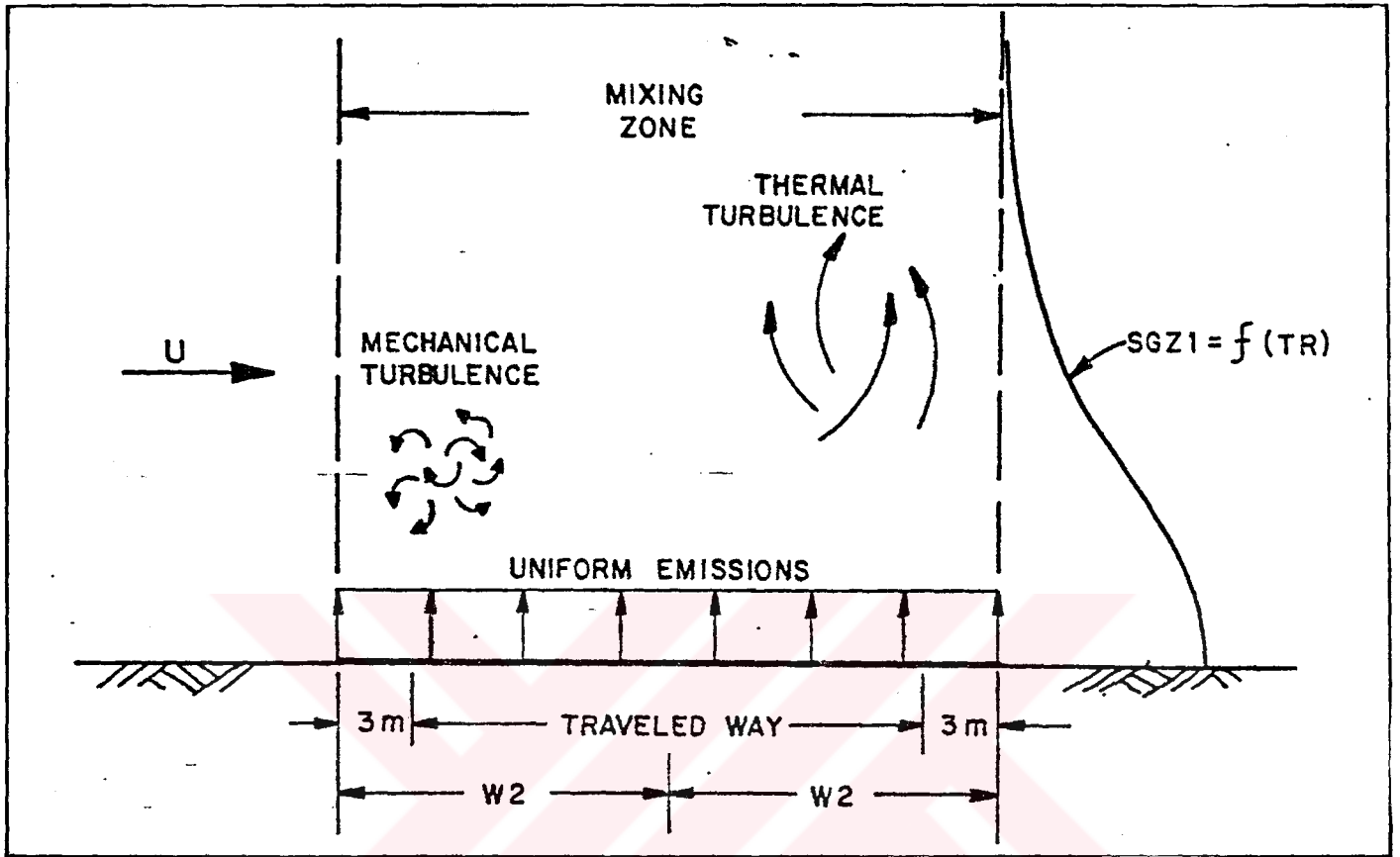
Element Series Represented By Series of Equivalent Finite Line Sources (54).



Mixing zone model; CALINE 3 treats the region directly over the highway as a zone of uniform emissions and turbulence. This is designated the mixing zone and is defined as the region over the travelled way plus three meters on either side. The additional width accounts for the initial horizontal dispersion imparted to pollutants by the vehicle wake effects. **Figure 2.10**



FIGURE 2.10 CALINE-3 Mixing Zone (54).



CHAPTER 3

3. OTHER STUDIES ON MOBILE POLLUTION

3.1 Air Pollution in Street Canyons

Figure 3.1 is an illustration of street canyons. Local effects in street canyons and around buildings can cause carbon monoxide concentrations to vary by as much as a factor of 3 to 10 from one side of the street to the other.

Observed distributions of carbon monoxide imply a helical air circulation in street canyons like in Figure 3.1 (1). Locations on the leeward side of the building are expected to have higher concentrations than on the windward side because of the reverse flow component. So the concentration,  $C$ , at a point is the sum of two contributions. One is the concentration,  $C_b$ , of the air entering the street from above (It is assumed that the concentration computed by the basic diffusion model represents  $C_b$ ), the second is  $\Delta C$ . Components on both the leeward and windward side of the building are shown in the Figure 3.1.

In a study by Heida (1969) the effect of automotive exhaust on air quality in narrow streets has been studied in Amsterdam. Streets studied were classified according to building height to street width ratio. It was seen that  $H/W$  ratio, traffic density and wind speed are the main factors governing pollutant concentrations. For carbon monoxide (55) an IR analyzer, for total hydrocarbons a flame ionization detector, for dust and lead High Volume Sampler were used.

Windward side

$$\Delta C = K \frac{Q_L}{w(u+0.5)} \frac{H-Z}{H} \dots\dots\dots 3.1$$

Leeward side

$$\Delta C = K \frac{Q_L}{r(u+0.5)} \dots\dots\dots 3.2$$

where;

$\Delta C$  = Change in the concentration ( $\mu\text{gram}/\text{m}^3$ ).

$K$  = Constant

$Q_1$  = Emission (grammes/second)

$H$  = Depth of the street canyon (meters)

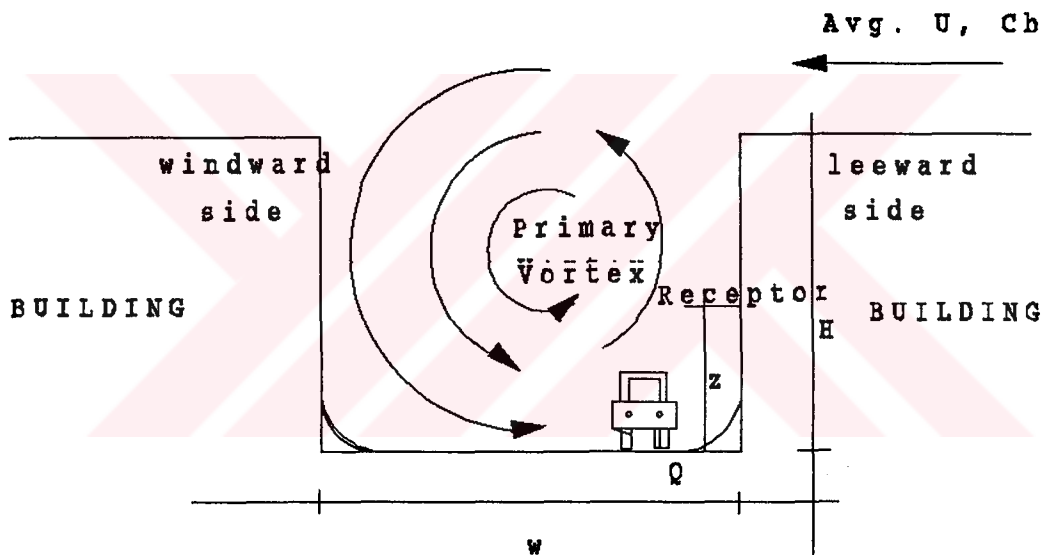
$Z$  = Height of receptor with respect to the source  
(meters)

$w$  = Width of the street (meters)

$u$  = Wind speed (meters/second)

$r$  = Constant

**FIGURE 3.1** A Description of Street Canyons (1).



3.1.1 Some of the Dispersion Models Used for Street Canyons

By measuring pollutants in various traffic conditions and making subsequent statistical analysis separate emission factors for passenger, light duty and heavy duty vehicles, can be obtained.

The important feature of urban street canyons is that under certain ambient wind conditions the flow within urban street canyons is somewhat isolated from the upper air flow and can partially trap pollutant emissions for an extended period of time. Hence, in order to predict pollutant concentrations at street level in urban areas, the rate of pollutant exchange between street canyons and the upper air should be considered. (37).

### 3.2 An Overlook to Methanol Fuelled Vehicles

Although catalytic converters greatly reduce emission levels, automobile exhaust emissions remain one of the leading causes of urban air pollution. Recent attempts to further decrease emissions have prompted interest in "clean fuels" among which methanol is frequently considered. Methanol combustion produces less particulates, reactive hydrocarbons, carbon monoxide, and oxides of nitrogen than gasoline; however unacceptably high levels of formaldehyde are generated. Also appropriate catalytic technology is being developed for the complete oxidation of unburned methanol or its partial oxidation product, formaldehyde. Methanol oxidation with catalysts produce carbon dioxide, formaldehyde, carbon monoxide and methyl formate as major products. This reaction proceeds rapidly over Platinum and Palladium, near complete conversion at room temperatures (56).

In a study of Gabele (28) both the exhaust and evaporative emissions from a prototype General Motors vehicle, with variable fuel was examined. The test was conducted at 4.4°C, 24°C and 32°C and for other fuels M0, M25, M50, M85 and M100 (100% methanol). The data indicate that increasing the fuels methanol content does not affect the exhaust organic emission rate, but formaldehyde and methanol comprise increasingly great portions of the organic material while hydrocarbons comprise less. Increasing fuel methanol content has no significant effect on exhaust regulated emission rates (organic material,

carbon monoxide and nitrogen oxides) nor on the composition of total hydrocarbons, except for methane which increases substantially. The effect of ambient temperature on both evaporative and exhaust emissions is similar to its effect on gasoline cars; organic and carbon monoxide exhaust emissions increase substantially at the lower temperatures, and the evaporative emissions increase steadily with increases in temperature.

Although a conventional gasoline engine can be made to operate with methanol with few modifications, engines burning pure methanol (M100) are difficult to start at ambient temperatures below 60°F and they emit greater quantities of formaldehyde than equivalent gasoline engines.

Because methanol has about half the energy content of gasoline, about twice the volume of methanol will be needed to drive a car the same distance (28).

### 3.3 Personal Exposure Monitors (PEMs)

In street canyons the pollution effecting people might be measured by Personal Exposure Monitors (PEM). It best shows the quantity of pollution that we face everyday (57).

In the early 1980s, new miniaturized instrumentation became available for measuring human exposures to pollutants continuously. Early tests revealed that people have difficulty in writing down the large quantity of data generated by these instruments as they walk, drive or engaged in their normal activities. Several solutions were considered using microprocessors to manipulate the readings of the PEMs. Two hardware systems were developed, one that computed and stored concentrations with the command of the user and the other one logged the event codes as well (58).

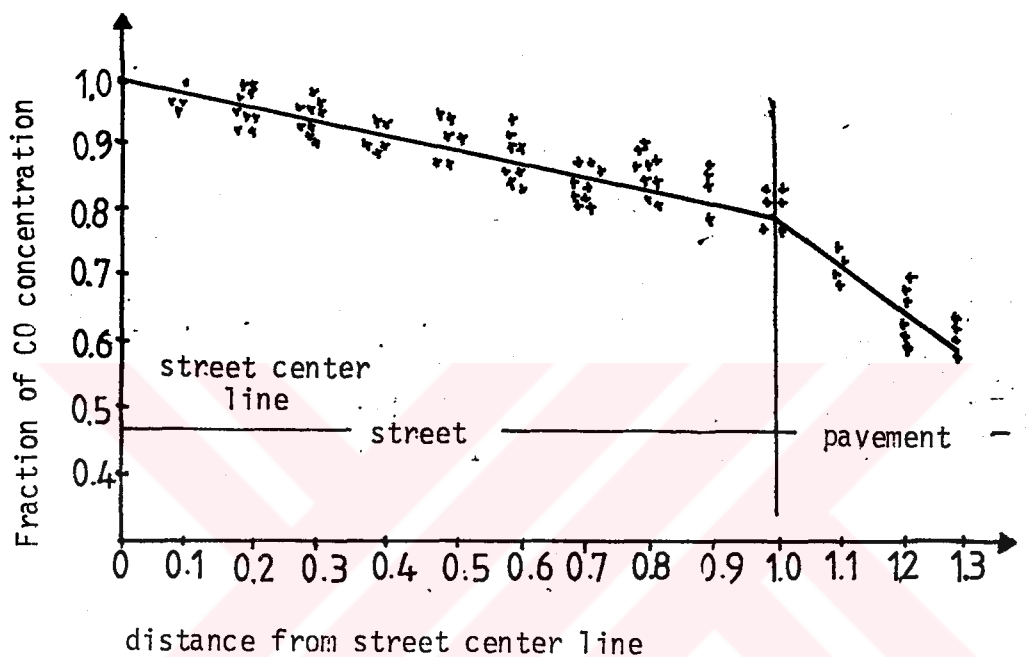
There are also some micro-environmental studies related to PEMs

done in three sites subsequently; California, Honolulu, and Washington D.C. from motor vehicle exhausts. The intent of the Washington study was to develop a model of commuter exposure to motor vehicle exhaust using carbon monoxide as indicator pollutant. Consequently it is found that there was link to link and day to day variability affecting carbon monoxide concentrations inside the automobiles. Carbon monoxide concentration inside the automobiles increased from 0 to 12 ppm, while ambient levels were 2-3 ppm (57).

PEMs are small scale carbon monoxide measuring devices but for larger scale measurements we have different measuring techniques. Some examples of such measuring techniques are explained: One of them is a Donald H. Steadman (17) study with a light source on one side of a highway on ramp, and infrared detectors and a personal computer (PC) on the other, it was possible to determine remotely the percentage of carbon monoxide in the exhaust of passing cars in less than one second per vehicle. Briefly the remote sensor measures the increase in Infrared (IR) adsorption by carbon monoxide and carbon dioxide are well correlated, the computer determines their ratio and calculates the percent carbon monoxide equivalent to a tailpipe measurement of carbon monoxide at that instant.

In another study which was done by Rashidi and Moscouidi (1980) carbon monoxide concentration at different locations with analyzer model PEM giving continuous readings on chart recorders was measured with traffic flow and vehicle speeds for six months. This was done in eight streets at different hours of the day. Measurements was done at 1.5 meter from the ground the results of the study is shown in **Figure 3.2**. At moderate vehicle speed and high traffic flow carbon monoxide concentration were in the level of 150 ppm.

**FIGURE 3.2** Variation of Carbon Monoxide Concentrations Across the Street Relative to the Street Centreline Rashidi et al.(1980).



### 3.4 Driving Cycles and Vehicle Testing Procedures

The basic concept that has been developed over the years involves driving the vehicle over an artificial driving cycle in a test cell. Exhaust emissions are collected in such a way that it allows computation of how much of a given pollutant is in compliance with the standards. Unfortunately driving cycles and pollutant collection methods are different in the USA, ECE and Japan, making a direct comparison very difficult (59).

### 3.4.1 US Driving Cycle

The present US driving cycle was developed to represent a trip from the suburbs of a large city to work downtown. It begins with a cold start portion, followed by a hot engine stabilized portion, a 10-minute park and a final hot start portion. The overall distance driven is 11.1 miles over a duration of minutes. The average test speed is 19.7 mile/hr and the maximum speed is 57mph (59).

### 3.4.2 ECE Driving Cycle

Although US test cycles nature is transient, the ECE produce calls for a three-phase driving cycle that is repeated four times. Rather than a series of transients, each phase incorporates an idle, acceleration, constant speed mode and deceleration. It was not devised to be representative of city centre driving in European cities, and has a maximum speed of only 50 km/hr. So an extra urban cycle is added having a maximum speed of 120 km/hr.

The aim of the ECE test cycle and measurement is to make European standards as stringent as US tailpipe standards. Table 3.1 shows EEC car emission standards.

TABLE 3.1 EEC 1989 Emission Standards For Gasoline Vehicles (59).

Engine Capacity	CO	NOx+HC	NOx
C (cm3)	(gr/test)	(gr/test)	(gr/test)
C > 2000	25	6.5	3.5
1400 ≤ C ≤ 2000	30	8	-
C < 1400	45	15	6

### 3.4.3 Japanese Driving Cycle

It uses two different driving cycles. One starts with a warmed-up engine, and consists of six repetitions of a driving schedule



made up of simple models like the EEC cycle. The total distance driven is about 4 km for a duration of 14 minutes and a top speed of 40 km/hr. The other one is added to supplement the previous one, in particular by adding a cold start. It consists of 4 repetitions of the basic schedule for a total of also about 4 km over the same duration. But the average speed is higher and the top speed is 60 km/hr. Table 3.2 shows the type of driving cycle that is applied in each country.

In conclusion, many countries have initiated some sort of control of passenger car emissions. There are many levels of, emissions all of which can be related to some stage of the evaluation of three separate regulations, those of the United Nations, Economic Commission for Europe, of Japan and of the United States. Comparison of the stringency of the most recent stages of development of these regulations indicates that the US standards are more stringent, followed by those of Japan and the ECE. The latter, however are in the process of being tightened further and are expected to reach the same level of stringency as those of the USA.

TABLE 3.2 Summary of International Vehicle Legislation (59).

Country	Regulation	Country	Regulation
Argentina.....	ECE 15	Japan.....	National
Australia.....	(USA)	Luxembourg.....	ECE 15
Austria.....	US-83	Netherlands.....	EEC 88/76
Belgium.....	ECE 15	New Zealand.....	ECE 15
Canada.....	(USA)	Norway.....	US-83
Czechoslovakia.....	ECE 15	Poland.....	ECE 15
Denmark.....	ECE 15	Rumania.....	ECE 15
Eire.....	ECE 15	Singapore.....	ECE 15
Finland.....	ECE 15	Spain.....	ECE 15
France.....	ECE 15	Sweden.....	US-83
Germany (E).....	ECE 15	Switzerland.....	US-83
Germany (W).....	ECE 15	Turkey.....	ECE 15
Greece.....	ECE 15	United Kingdom..	ECE 15
HongKong.....	ECE 15	USA.....	Federal
Hungary.....	ECE 15	USSR.....	ECE 15
Israel.....	ECE 15	Yugoslavia.....	ECE 15
Italy.....	ECE 15		

## CHAPTER 4

### 4 EXPERIMENTAL

#### 4.1 Smoke, Particulate and Lead Measurement;

A high volume air sampler was used for lead sampling from the air. Location of the instrument was very close to the A entrance of METU.

The instrument was put to work at about 8<sup>00</sup> and it was shut down at about 18<sup>00</sup>. Sampling period was approximately 10 hours. Whatman no.1 glass fibre filter papers were used to collect samples.

Each day, temperature of ambient air was measured at approximately the same hour. These values were all recorded. Atmospheric pressure of each day was also measured. The purpose of recording the temperature and pressure is to make the necessary conversion for flow rate of the sampler. This was done by using a rotameter. While turning on and shutting down the instrument, rotameter readings were taken twice, and their average is used in calculations.

The second purpose of measuring temperature and pressure was to use them in the models as average air temperature and pressure. After 30 days, sampling was completed.

#### 4.2 Determination of Lead Concentrations

##### 4.2.1.1 Apparatus and Materials;

Shimadzu model atomic adsorption spectrophotometer was used. It uses flame atomization technique. The printer used to print the results in the form of a report is of the same model.

Hallow cathode lamp was used as radiation sources. Instrumental operating conditions for lead is shown in Table 4.1.

**TABLE 4.1** Operating Conditions of the Atomic Adsorption Device.

Instrumental Operating Conditions.	Pb
Wavelength(nm)	217
Band pass (nm)	0.3
Lamb current (mA)	7
Flame condition	(Air-C <sub>2</sub> H <sub>2</sub> )
Fuel (lt/min)	2
Oxidant (lt/min)	8
Prespraying (sec)	3
Integration time (sec)	5
Accuracy (%)	99

For sample preparation plastic containers were used. For other purposes like preparing nitric acid solution etc., polypropylene balloons or graduated cylinders were used.

Branson 2200 ultrasonic vibration shaker was used to prepare samples. All of these preparations used for lead measurement was done in the clean air room of Environmental Engineering Department: to avoid any lead interference which may come from dust found in the air.

Vacuum filtration device and cellulose acetate filter papers having the size of opening of 0.45  $\mu\text{m}$  and 47 mm in diameter were used to remove particles which may be insoluble. So that any interference to atomic absorption could be avoided.

#### 4.2.1.2 Reagents and Solutions;

The chemicals used were lead standard solution and analytical grade nitric acid from Merck.

Water used in all works in this experiment was demineralized water. Double distilled water was prepared in environmental engineering department, then it was converted to demineralized

water in chemistry department by using a milipore, Milli-Q water purification system.

#### 4.2.1.3 Cleaning Procedure;

Plastic containers that were used to prevent sample loss and contamination problems should be clean enough for the accuracy of the results. They were cleaned by nitric acid solution which was diluted to 10 % by volume (90 ml water + 10 ml nitric acid). Then these containers were rinsed with deionized water for 3 times and then dried in the oven for 90 minutes at 60°C.

#### 4.2.1.4 Analysis Procedure;

This analysis procedure was taken from the study of Mohammed Ali Anwari, (60) which was an application of Jernigan et al. study (61).

During this study a sector of known area from the filter paper was put into 25 ml. of 0.1 Molar nitric acid solution in the clean plastic containers. After all the samples are treated, they were put into ultrasonic shaker and exposed to ultrasonic vibration for 15 minutes. Two blank solutions prepared by using a clean filter paper was exposed to the same procedure. When ultrasonic vibration is finished the samples were filtered from a cellulose acetate filter by vacuum filtration. At this stage the samples were ready for atomic adsorption. The results of atomic adsorption can be seen in Chapter 5.

For the calibration of atomic absorption spectrophotometer, four standard lead solutions of 1, 1.5, 2 and 2.5 ppm were used. The instrument draws the calibration curve by itself.

## 4.2.2 Determination of Particulate and Smoke Concentrations by High Volume Sampler

### 4.2.2.1 Apparatus and Materials;

Sierra Instruments 310X Model High Volume Sampler was used for sampling. The analytical balance of Kern S2000 was used to weight the filter papers. Plastic bags were used to cover and preserve the samples and tweezers were used so that filter papers could be transferred from one place to another without touching.

For smoke concentrations; a reflectometer produced by WHO Evans Electro Selenium limited were used.

### 4.2.2.2 Analysis Procedure;

At the beginning of sampling period the filter papers were put into the desiccator to bring to a constant weight, then they were weighted and these weights were recorded.

At the end of each sampling day the filters were put in to the desiccator again so that water on the filter evaporates and they can be weighted constantly.

The difference in these two weights will give the weight of particles on the filter. If this value is divided by the corrected air volume, then particulate concentration in the air will be obtained. This calculations and presentation of data is given in Chapter 5.

For smoke concentration reflectometer was calibrated firstly by using the standard colours given together with the instrument. Nextly each sample was measured with the instrument the absorption values were found and they were calculated by using the equation 4.1. The required calculations could be seen in next chapter.

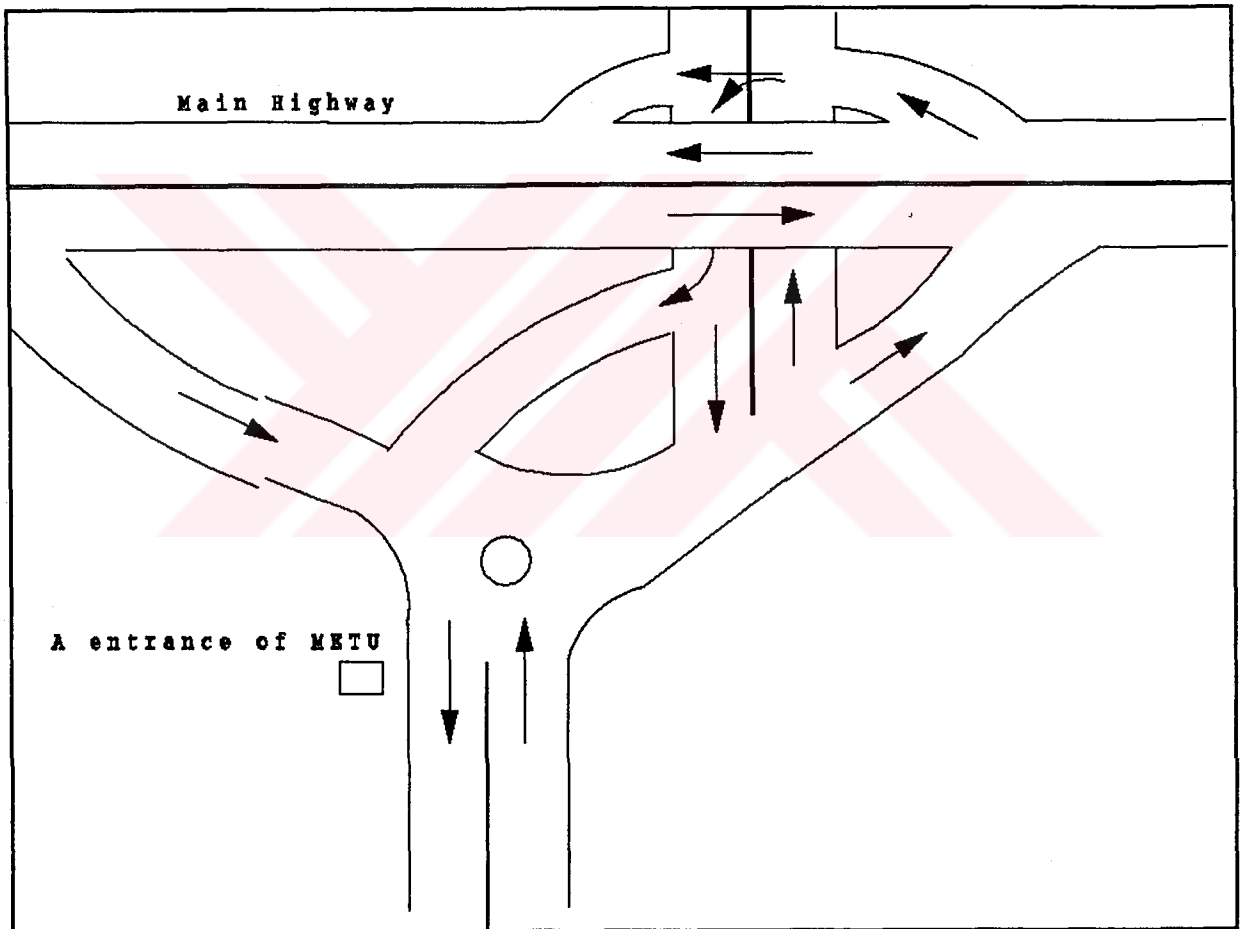
$$F/V(214,245.1-15,130.512*R+508.181*(R^2)-8.831144*(R^3)+0.0628057*(R^4)$$

.....4.1

### 4.3 Carbon Monoxide and Hydrocarbon Measurement;

Beckman 595 Hydrocarbon and Carbon Monoxide Analyzer was used to find the carbonmonoxide and hydrocarbon concentrations in the exhaust gas. This instrument was located at the same place shown in **Figure 4.1**.

**FIGURE 4.1** A entrance of METU and Main Highway



It was calibrated in the mechanical engineering department, by the use of a device which is approximately same in the measuring principles but more advanced. The only difference in measuring was Beckman measures the concentrations as hexane equivalent but the other device measures it as methane equivalent. So the values read should be converted from methane to hexane before calibrating the instrument.

It was put on work for 1 week and each day approximately 15 or 20 cars were measured. The results of this measurement can be seen in Chapter 6.



## CHAPTER 5

### 5. Mathematical Approach;

After the experimental results the theoretical part of the study is conducted. The purpose of this theoretical part is to obtain the concentration values for line source pollutants at certain locations and to perform a comparison of these results with the experimental results. Secondly to compare the results of the models with each other by considering the assumptions of each one.

#### 5.1 Selected Models to be Run and Data Required For The Study;

The models that were used are ISCST (Industrial Source Complex Short Term Dispersion Model) and CALINE-3 (California Line Source Model version 3). The reason for the selection of these models is that, for line source they were the only dispersion models available, also the comparison of various models (Chapter 2) shows that, they may give acceptable results.

The meteorological data used in the models were taken from the temperature and pressure recordings, and from Governmental Meteorological Works Department (such as mixing layer height, vertical temperature gradient etc.). The vehicle counts needed in the calculations were taken from METU Transportation Department. The listing of this data is:

Average temperature; 17.5 °C

Average pressure; 913 MBar

The averages are for september, october, november of 1986

Average wind speed ; 2.474 m/sec.

Average mixing layer height; 1911 m.

Average vertical temperature gradient; 0.532 °C/km.

Total number of vehicles; 3384 vehicles /day (with the assumption of 8 hour/ day of vehicle entrance and each



vehicles enters and goes out for only one time in a day)

The emission factors used for the calculation of flow rate is (14);

CO = 50 gr/mi

HC = 4.9 gr/mi

Pb = 0.048 gr/mi

Particulates = 0.38 gr/mi

These are 1975 emission factors because the cars produced in Turkey are all produced with the technology of 1970 s from the point of view of emission control.

#### 5.1.1 ISCST;

The required inputs to ISCST were given in chapter 2. By using these inputs we obtained the results. And these results are given in chapter 6. This model was run for carbon monoxide, hydrocarbons, particulate matter and lead emissions by using the emission factors from US EPA (1973) of 1975. (14)

#### 5.1.2 CALINE-3;

The required inputs to CALINE-3 was given in chapter 2. By using the same inputs this model was also run for carbon monoxide, hydrocarbons, lead and particulate matter. The atmospheric concentrations of these compounds were found according to 1975 emission factors taken from US EPA (1973). (14)

#### 5.2 Use of Emission Factors;

By using emission factors and well known Gaussian Dispersion formula (14) atmospheric concentrations may be calculated. This could only be done for checking the results of the models. Because models use the same approach.

### 5.3 Statistical Calculations;

In this part of the study the correlation of the results are attempted. The concentration of particulates, Pb concentration on these particulates and smoke concentration measured. These concentrations are statistically integrated and they are correlated to each other and their dependence are discussed.

For this purpose regression analysis is used to correlate the results. **Statgraphics** computer program is used to make the necessary regression. Correlation coefficients calculation tables is included in **Tables E.1, E.2 and E.3.**

Where;

Conc X = Particulate concentration

Conc Y = Lead concentration

Conc Z = Smoke concentration

CHAPTER 6

6. DATA ANALYSIS AND CALCULATIONS:

6.1 Experimental Results of High Volume Sampler Measurement Results;

This table shows high volume sampler measurements to find lead, particulate and smoke concentrations.

TABLE 6.1 shows high volume sampler measurements to find lead, particulate and smoke concentrations.

No. of days	Date	Initial Weight of paper (gram)	Final Weight of paper (gram)	Time (min.)
1	sept. 26	3.5673	3.6382	590
2	sept. 27	3.5863	3.6883	600
3	sept. 28	3.62	3.6991	600
4	oct. 1	3.5028	3.641	600
5	oct. 2	3.5924	3.664	590
6	oct. 3	3.6247	3.706	635
7	oct. 4	3.596	3.6993	640
8	oct. 5	3.5617	3.6538	600
9	oct. 8	3.5773	3.6791	619
10	oct. 9	3.6436	3.7607	625
11	oct. 10	3.7365	3.8354	615
12	oct. 11	3.411	3.7207	600
13	oct. 12	3.7258	3.7777	590
14	oct. 15	3.651	3.7695	615
15	oct. 16	3.7099	3.8358	625
16	oct. 17	3.6685	3.807	597
17	oct. 18	3.6601	3.8123	630
18	oct. 19	3.7232	3.8052	620
19	oct. 22	3.6769	3.7436	618
20	oct. 23	3.7414	3.7728	305
21	oct. 24	3.6727	3.7344	630
22	oct. 25	3.6897	3.7344	610
23	oct. 26	3.7027	3.7874	605
24	oct. 30	3.3565	3.76	615
25	oct. 31	3.5354	3.7106	620
26	nov. 1	3.7208	3.8226	570
27	nov. 2	3.7048	3.7771	595
28	nov. 5	3.7439	3.915	575
29	nov. 6	3.6758	3.7191	630
30	nov. 7	3.7314	3.8429	630
<b>AVERAGE</b>				<b>599.8</b>

Table 6.2 is a continuation of the Table 6.1; it contains

rotameter reading with respect to atmospheric temperature and pressure.

**TABLE 6.2** Rotameter reading with respect to atmospheric temperature and pressure.

No. of Days	Rotameter reading (ft <sup>3</sup> /min)	Temp. (°C)	Pressure (milibar)
1	30	26	914
2	28	26	913
3	26	25	911
4	26	21	915
5	25	21.5	913
6	25	20	913
7	25	19	915
8	26	21	916.5
9	25	24	915
10	24	23	915
11	21	15	915
12	22	15	918
13	22	15	921
14	22	14	920
15	21	15.5	919
16	21	18	915
17	21	18	912.5
18	21.5	19.5	913
19	21	18	909
20	22	10	908
21	21	7	907
22	22	9	912
23	22	10	911
24	22	14	908
25	21	16	909
26	22	17	912
27	23	19	909
28	23	20	911
29	23	16	909
30	24	13	911
ARITH. AVERAGE			913
STANDARD DEVIATION			3.556683

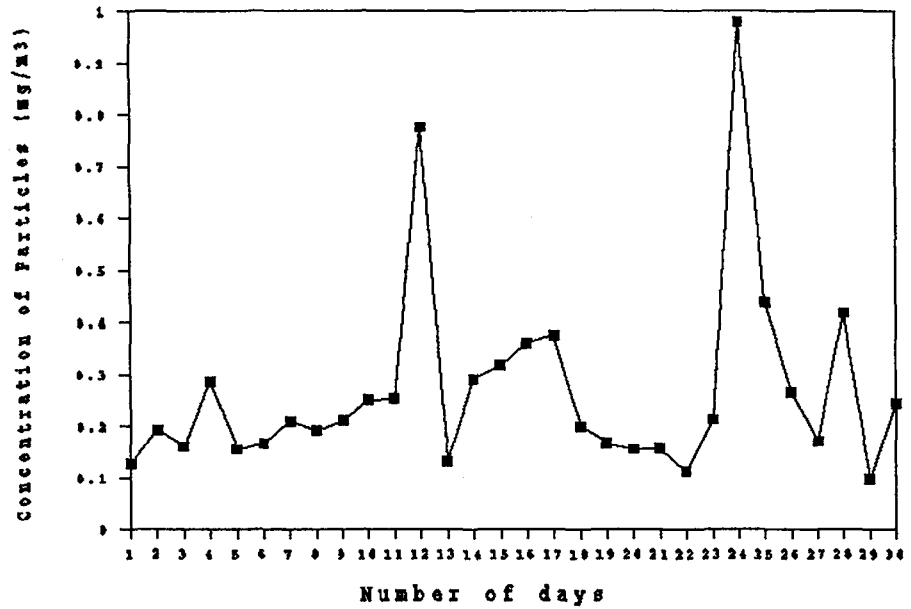
Table 6.3 shows the concentration of particles calculated by subtracting the initial weight of filter paper from the weight of filter paper after measurement. Then this concentrations are

sorted, from largest to smallest so that some data intervals could be chosen (for 0 interval we mean the values greater than 0).

**TABLE 6.3** Concentration of Particles Calculated.

No. of days	concentration of particles (mg/m <sup>3</sup> )
1	0.127155
2	0.192520
3	0.160968
4	0.286315
5	0.156276
6	0.165717
7	0.210090
8	0.191120
9	0.210459
10	0.250600
11	0.252649
12	0.776612
13	0.132784
14	0.291550
15	0.317309
16	0.360720
17	0.374612
18	0.199395
19	0.166715
20	0.155917
21	0.156877
22	0.111863
23	0.212727
24	0.979798
25	0.439517
26	0.265114
27	0.170789
28	0.417726
29	0.097605
30	0.243928
ARITHMETIC AVERAGE	0.269181
STANDARD DEVIATION	0.186022
GEOMETRIC AVERAGE	0.230474
STANDARD ERROR	± 0.035444

FIGURE 6.1 Concentration of Particles Versus Number of Days



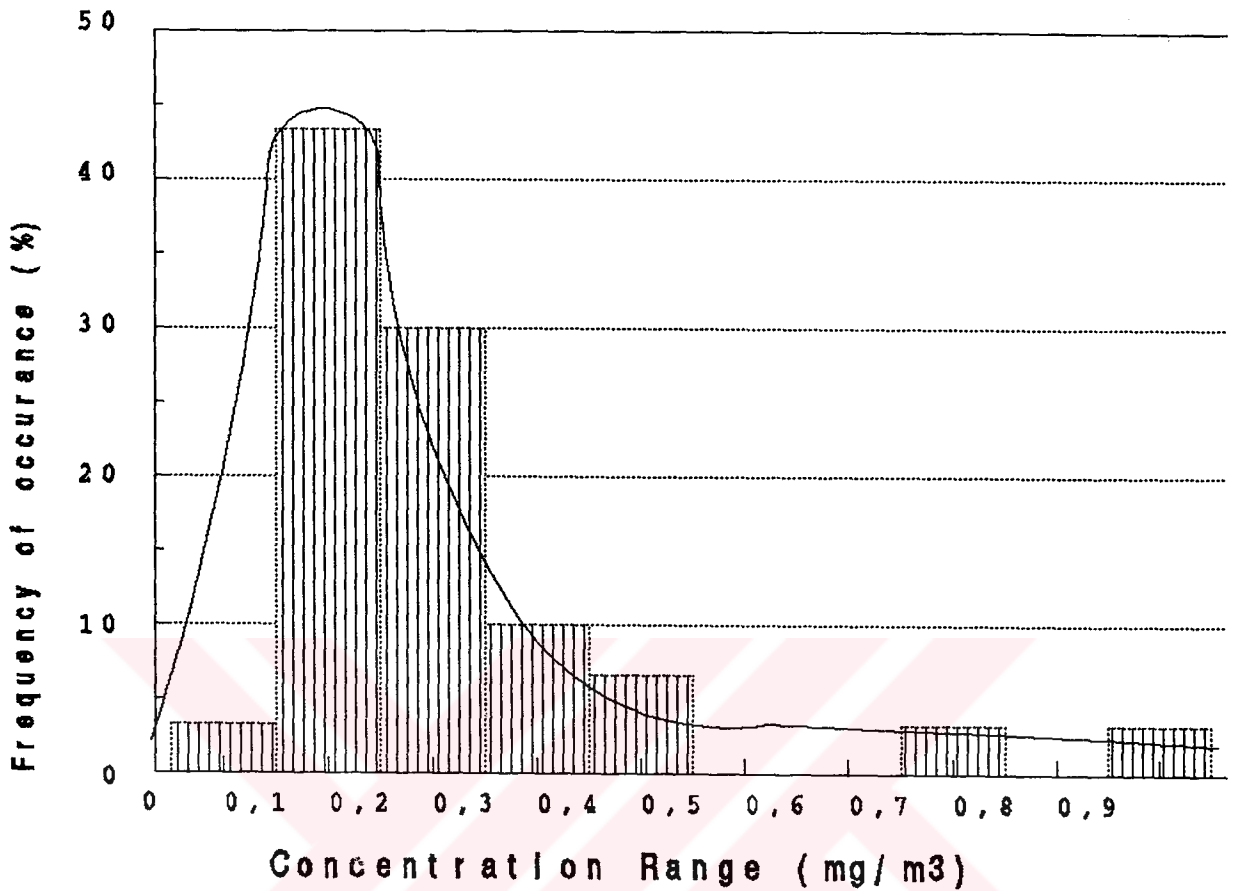
Nextly to find frequency of occurrence the number of observations occurring in that interval is counted and divided to total number of observations.

6.1.2 Lead Concentration in the Study Area;

To find lead concentration in atmosphere the chemical method explained in Chapter 5 is used. Here the absorption values read from **Flame Ionization Atomic Absorption** are listed. They are converted to concentrations with the formula given below

$$C_{air} (ng/m3) = \frac{C_{soln.} (ng/ml) * V_{soln.} (ml)}{V_{air} (m3) * (M_s/M_t)}$$

**FIGURE 6.2** Concentration of Particles Versus Frequency of Occurrence



Where,

- $C_{air}$  = the concentration of the element in air (ng/m<sup>3</sup>)
- $C_{soln.}$  = the concentration of the element in the extracted solution (ng/ml)
- $V_{soln.}$  = the volume of extracted solution (ml)
- $V_{air}$  = the volume of air passed through the filter during the sampling period (m<sup>3</sup>)
- $M_s/M_t$  = the fraction of area of filter sector used in the analysis.

After concentration of lead in the air is found frequency of occurrence is calculated as explained for particulates. Correlation coefficient for absorption and concentration values

is calculated.

**TABLE 6.4** The atomic absorption measurements and solution lead concentrations.

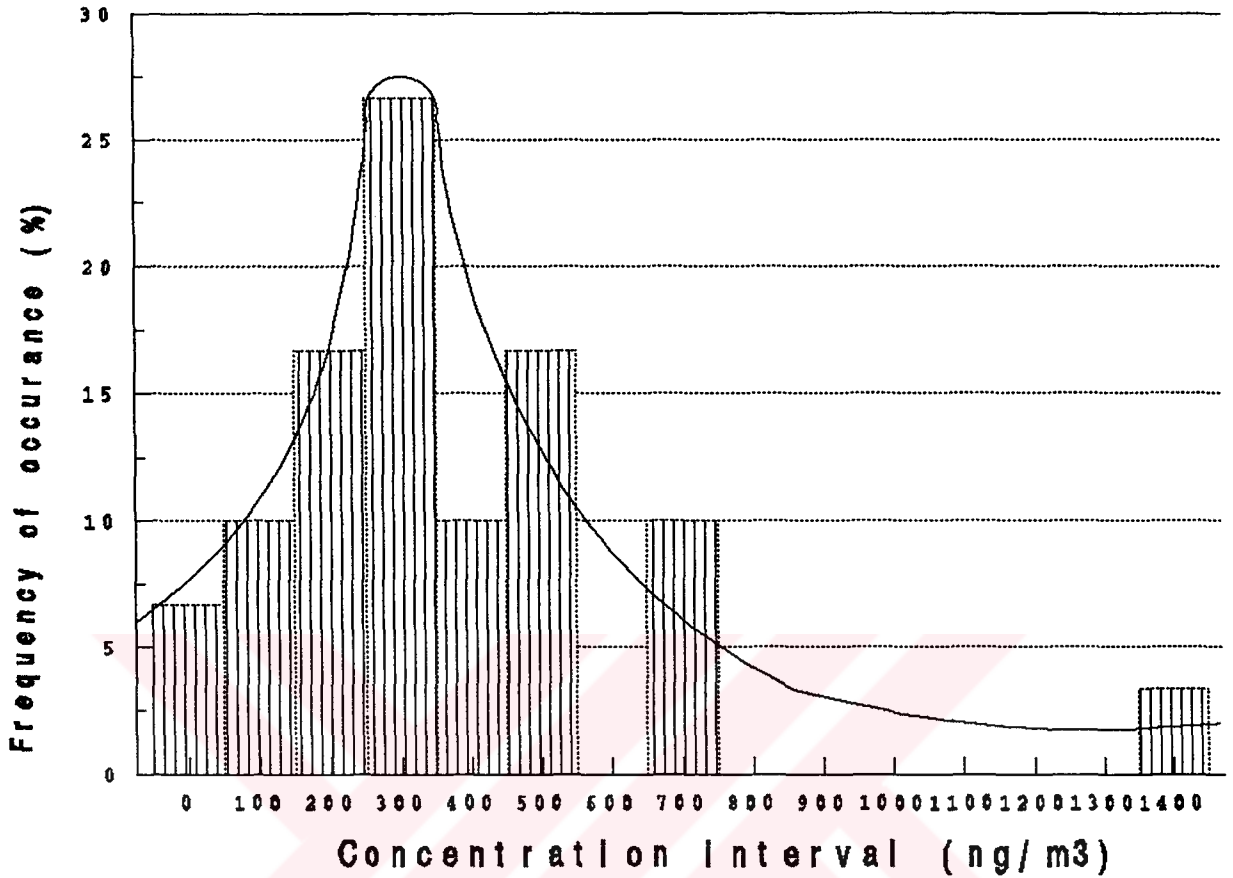
No of SAMPLES	ABSORBANCE	SOLUTION CONCENT. (ppm)	(SOLN CONC) - (BLANK) ppm
BLANK	0.011	0.2805	
BLANK	0.011	0.2805	
1	0.021	0.5313	0.2508
2	0.027	0.6983	0.4178
3	0.02	0.5012	0.2207
4	0.021	0.5403	0.2598
5	0.038	0.9683	0.6878
6	0.026	0.665	0.3845
7	0.035	0.8989	0.6184
8	0.033	0.8442	0.5637
9	0.042	1.0801	0.7996
10	0.033	0.8496	0.5691
11	0.034	0.8764	0.5959
12	0.037	0.9553	0.6748
13	0.039	0.9963	0.7158
14	0.072	1.8875	1.607
15	0.055	1.4202	1.1397
16	0.113	3.0393	2.7588
17	0.048	1.2361	0.9556
18	0.039	0.9889	0.7084
19	0.036	0.9355	0.655
20	0.039	1.0058	0.7253
21	0.054	1.3825	1.102
22	0.051	1.3246	1.0441
23	0.04	1.0142	0.7337
24	0.04	1.0188	0.7383
25	0.071	1.8659	1.5854
26	0.053	1.3777	1.0972
27	0.058	1.5038	1.2233
28	0.045	1.162	0.8815
29	0.054	1.3856	1.1051
30	0.042	1.0839	0.8034



TABLE 6.5 Atmospheric Lead Concentrations for Each Sample.

No of SAMPLES	AIR VOLUME m3	CONCENTRATION IN AIR (ng/m3)
1	557.585	87.82513
2	529.8129	153.9743
3	491.4002	87.69390
4	482.6848	105.0939
5	458.1623	293.1198
6	490.5953	153.0295
7	491.6936	245.5711
8	481.8948	228.4010
9	483.7031	322.7723
10	467.2773	237.8024
11	391.4521	297.2330
12	398.7829	330.4006
13	390.8592	357.5804
14	406.4477	771.9934
15	396.7733	560.8548
16	383.9532	1402.956
17	406.2869	459.2463
18	411.2426	336.3433
19	400.0826	319.6642
20	201.3891	703.2084
21	393.2995	547.0922
22	399.5946	510.1816
23	398.1612	359.8006
24	411.8193	350.0487
25	398.6188	776.5751
26	383.9843	557.9235
27	423.3276	564.2333
28	409.5979	420.2105
29	443.6241	486.3947
30	457.1011	343.1799
ARITHMETIC AVERAGE		412.3468
GEOMETRIC AVERAGE		342.274
STANDARD DEVIATION		260.2523
STANDARD ERROR		± 48.3277

**FIGURE 6.3** Concentration of Lead versus Frequency of Occurrence



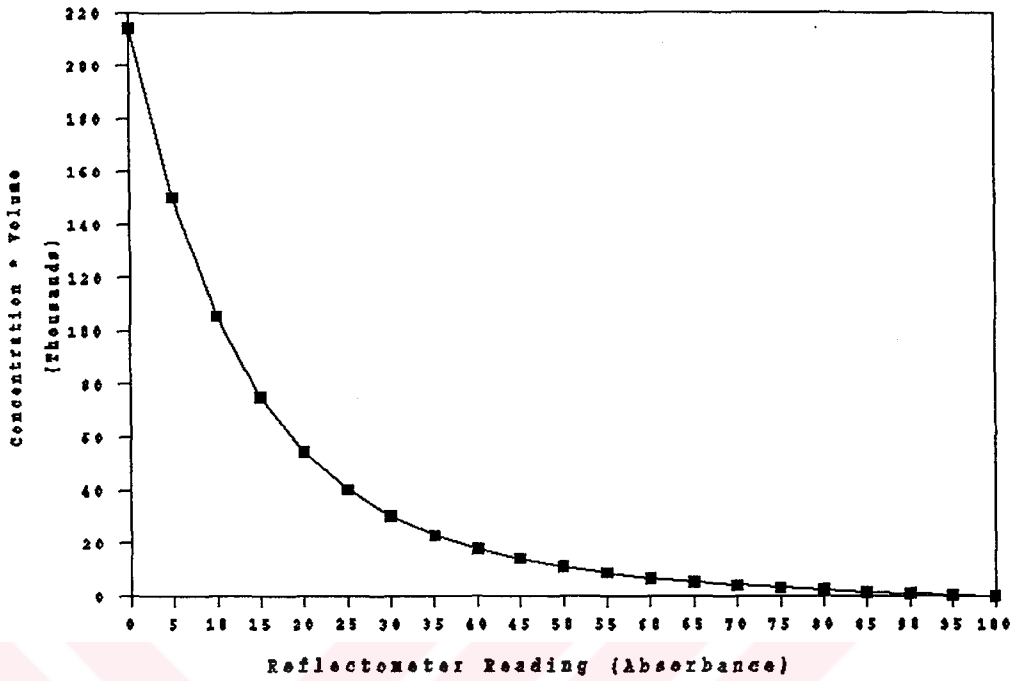
**6.1.3 Smoke Concentrations;**

For atmospheric smoke concentration measurements on the filter paper, reflectometer is used. Firstly reflectometer reading versus concentration (calibration curve is drawn). For this purpose the equation 4.1 was used.

**TABLE 6.6** Reflectometer Reading and Calculated Concentration Values For Calibration of the Instrument.

REFLECTOMETER READING	CONCENTRATION TIMES VOLUME OF AIR
0	214245.1
5	150232.4
10	105554.9
15	75002.57
20	54307.02
25	40142.27
30	30124.36
35	22811.40
40	17703.59
45	14065.75
50	11126.55
55	8759.555
60	6855.133
65	5318.460
70	4069.500
75	3043.016
80	2188.564
85	1470.494
90	867.9558
95	374.8885
100	0.03

FIGURE 6.4 Reflectometer Calibration Curve



Then reflectometer is used for 30 samples, reflectometer readings are measured and concentration \* volume values are found.

Volume of air filtered for each filter paper is given in the high volume sampler measurements section of this chapter. So concentration of smoke is calculated.

**TABLE 6.7** Reflectometer Reading and Concentration Values for the Measurement

SAMPLE NO.	REFLECTOMETER READING
1	31
2	16.5
3	35.5
4	30.5
5	31.5
6	22
7	10.5
8	15
9	14
10	16
11	23.5
12	24
13	30
14	12.5
15	16.5
16	9
17	10
18	23
19	31
20	45
21	36
22	27.5
23	17.5
24	50
25	44
26	16
27	16.5
28	9
29	41
30	11

TABLE 6.8 Actual Concentration of Smoke Values For Given Air Volumes Filtered.

VOLUME (m3)	CONC. (Mg/m3)
557.585	1.608753
529.813	4.043362
491.400	1.423171
482.685	1.877370
458.163	1.877113
490.595	3.024379
491.694	6.371370
481.895	4.807857
483.703	5.182648
467.277	4.679660
391.452	3.396517
398.783	3.225814
390.859	2.320829
406.448	6.563340
396.773	5.175503
383.953	9.029857
406.287	7.978457
411.243	3.390709
400.083	2.194093
201.389	2.096237
393.300	1.633624
399.595	2.587717
398.162	4.782317
411.819	0.822361
398.619	1.131562
383.984	5.597680
423.328	4.963718
409.598	8.560099
443.624	1.167164
457.101	6.512212
AVERAGE CONCENTRATION	3.934183 $\mu\text{g}/\text{m}^3$
GEOMETRIC AVERAGE	3.25679 $\mu\text{g}/\text{m}^3$
STANDARD ERROR	$\pm 0.4229$

Nextly to calculate the correlation coefficient for absorbance versus concentration the following calculations are done.

6.1.4 Hydrocarbon and Carbon Monoxide Concentrations in the Exhaust Gas of Sampled Vehicles Entering To METU Campus;

The concentrations of CO and total HC s in the exhaust gas is measured by the use of Beckman 590 Hydrocarbon and Carbon monoxide analyzer. The results of this measurement are listed below.

TABLE 6.9 Measurements of Beckman 590 for Day 1.

DATE 22th of Oct. 1990

Production Year of the car	Trade Mark	Licence plate	Type of Engine	HC Emissions (ppm)	CO (%)
1984	Military Jeep	CJ 8 738700	GASOLINE	460	3.4
1986	BMW	L 0236 (06)	GASOLINE	810	6.1
1985	Mitsubishi	D 1625 (06)	GASOLINE	370	1.3
1990	Ford	FHR 11 (34)	GASOLINE	300	2.5
1990	Dogan-L	KMF 61 (34)	GASOLINE	320	2.15
1989	Renault-9	U 6516 (06)	GASOLINE	420	3
1987	Renault-12	ERD 81 (34)	GASOLINE	280	3
1990	Sahin	T 3786 (06)	GASOLINE	550	4.1
1986	Taunus	EK 989 (06)	GASOLINE	2000	6.6
1986	Murat-131	E 9161 (06)	GASOLINE	850	4.8
1987	Peugeot	ZK 679 (06)	GASOLINE	830	4.9
1989	Kartal	R 7590 (06)	GASOLINE	620	2.8
1988	Sahin	Y 4146 (06)	GASOLINE	300	1
1986	Dogan	H 1521 (06)	GASOLINE	350	3.9
1986	Dogan	R 4174 (06)	GASOLINE	620	2.8
1985	Renault-12 GTS	F 5300 (06)	GASOLINE	840	4.8
<b>AVERAGE</b>				<b>620</b>	<b>3.572</b>

TABLE 6.10 Measurements of Beckman 590 for Day 2.

DATE 24th of Oct. 1990

Production Year of the car	Trade Mark	Licence plate	Type of Engine	HC Emissions (ppm)	CO Emissions (%)
1976	Renault-12	NL 753 (06)	GASOLINE	750	3.8
1987	Dogan	EK 600 (06)	GASOLINE	1000	3
1990	Renault-12	Y 7102 (06)	GASOLINE	300	3
1989	Renault-12	V 0206 (06)	GASOLINE	350	3.4
1968	Wolkswagen	EP 259 (06)	GASOLINE	1000	3.2
1968	Opel	HV 770 (34)	GASOLINE	550	2.6
1990	Renault-5	YL 305 (16)	GASOLINE	300	1.2
1980	Mercedes	VH 910 (06)	GASOLINE	200	2.4
1990	Opel	Z 1363 (06)	GASOLINE	250	1.3
1976	Murat-124	NU 960 (06)	GASOLINE	450	0.8
1990	Renault-9	Z 1691 (06)	GASOLINE	300	1.8
1988	Ford Taunus	M 7388 (06)	GASOLINE	350	2.3
1990	Sahin	V 0306 (06)	GASOLINE	600	3.3
1986	Suzuki	R 6264 (06)	GASOLINE	260	2.5
1966	Wolswagen	EU 519 (06)	GASOLINE	720	3.8
1990	Toyota	ABF 92 (06)	GASOLINE	300	1.3
1985	Serce	D 6905 (06)	GASOLINE	150	0.8
1976	Renault-12	NA 296 (06)	GASOLINE	150	2
1977	Renault-12	PE 576 (06)	GASOLINE	400	4.4
1973	Ford Taunus	UD 559 (06)	GASOLINE	800	4
AVERAGE				459	2.545



**TABLE 6.11** Measurements of Beckman 590 for Day 3.

DATE 25th of October 1990

Production Year of the car	Trade Mark	Licence plate	Type of Engine	HC Emissions (ppm)	CO (%)
1977	Renault-12	M 6626 (06)	GASOLINE	550	5
1980	Renault-18	ZU 601 (06)	GASOLINE	130	0.4
1985	Audi-80	ZS 214 (06)	DIESEL	30	0.05
1981	Murat-131	US 906 (06)	GASOLINE	700	4.4
1974	Citroen	NN 105 (35)	GASOLINE	2000	4.7
1971	Wolswagen	YC 897 (060)	GASOLINE	500	0.5
1975	Murat-131	LV 303 (06)	GASOLINE	410	3.4
1990	Toyota-Pikap	Y 3071 (06)	DIESEL	55	0.01
1990	Fiat-126 Bis	ABP 70 (06)	GASOLINE	120	0.55
1990	Kartal	Y 5256 (06)	GASOLINE	730	3.5
1978	Renault-12	SE 512 (06)	GASOLINE	1850	7.2
1984	Murat-131		GASOLINE	900	3.2
1990	Citroen	Y 3160 (06)	GASOLINE	190	0.7
1983	Murat-131	M 8520 (06)	GASOLINE	550	3.2
1976	Mercedes	RV 900 (06)	GASOLINE	50	0.15
1987	Murat-131	DS 715 (06)	GASOLINE	720	3.1
1982	Wolswagen	V 1010 (06)	DIESEL	1	0.01
1986	Dogan	K 3806 (06)	GASOLINE	340	3
1978	Renault-12	RP 479 (06)	GASOLINE	1010	5.9
1977	Ford	P 6240 (06)	GASOLINE	450	2.6
<b>AVERAGE</b>				<b>564.3</b>	<b>2.5785</b>

TABLE 6.12 Measurements of Beckman 590 for Day 4.

DATE 26th of Oct. 1990

Production Year of the car	Trade Mark	Licence plate	Type of Engine	HC emissions (ppm)	CO (%)
1973	Peugeot	HD 851 (06)	GASOLINE	760	8.9
1987	Renault-12	K 7669 (06)	GASOLINE	1350	7.8
1985	Kartal	TE 255 (35)	GASOLINE	600	1.2
1982	Golf GLD	YY 555 (06)	DIESEL	420	0.05
1979	Murat-131	TK 508 (06)	GASOLINE	950	5.6
1985	Renault-12	ZP 583 (06)	GASOLINE	370	3.4
1987	Murat-131	NP 286 (42)	GASOLINE	1250	5.4
1986	Golf GLD	B 5503 (06)	GASOLINE	1100	4.4
1976	Wolswagen	PN 221 (06)	GASOLINE	750	4.4
1990	Sahin	U 4253 (06)	GASOLINE	500	3.4
1990	Mercedes	U 1666 (06)	GASOLINE	240	2
1976	Murat-131	DL 065 (55)	GASOLINE	1300	0.1
1984	Audi	D 2855 (06)	DIESEL	65	0.075
1979	Renault-12	VF 573 (06)	GASOLINE	620	4
1970	Ford	FP 642 (06)	GASOLINE	780	7
1989	Kartal	S 8750 (06)	GASOLINE	550	4.8
1983	Dolmus	DL 549 (06)	DIESEL	500	0.05
1983	Murat-131	RZ 629 (35)	GASOLINE	600	2.8
1990	Sahin	V 2785 (06)	GASOLINE	350	3
1982	Dogan	Y 8288 (06)	GASOLINE	210	2.3
AVERAGE				663.25	3.53375

Lastly averages of concentrations for each day is given below;

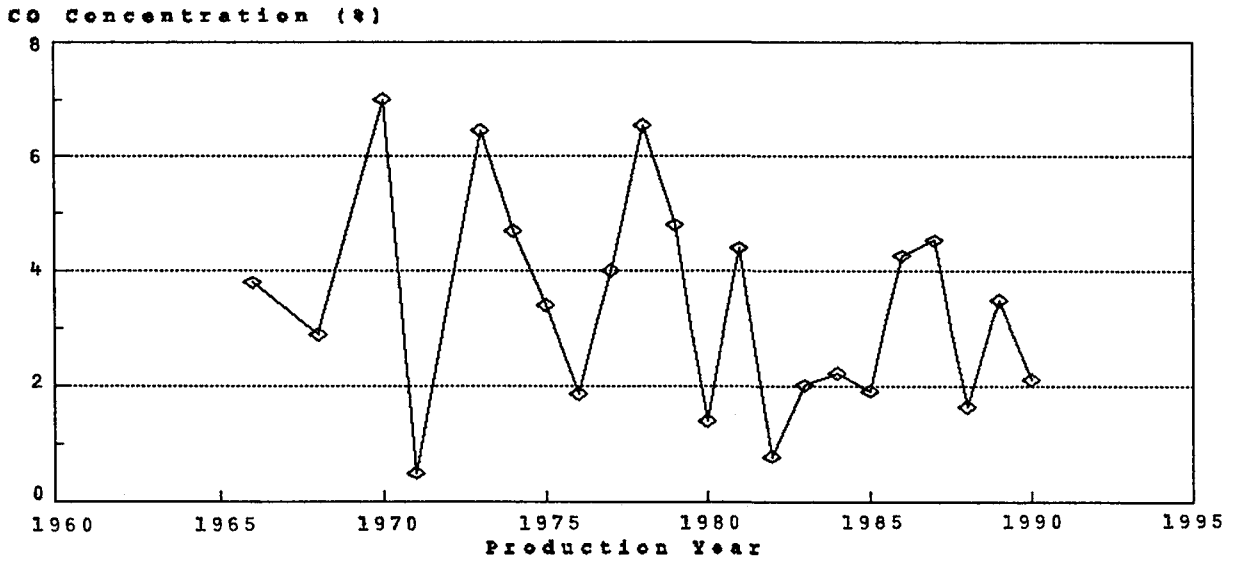
TABLE 6.13 Averages of concentrations for each day.

NO OF DAYS	AVERAGES OF DAYS FOR HC (ppm)	AVERAGES OF DAYS FOR CO (%)
1	620	3.571875
2	459	2.545
3	564.3	2.5785
4	663.25	3.53375
TOTAL AVERAGE	576.6375	3.057281
STANDARD DEVIATION	76.4409	0.496

TABLE 6.14 Production year of the car versus CO and HC Concentrations

YEAR	HC CONC. (ppm)	CO CONC. (%)
1966	720	3.8
1968	775	2.9
1970	780	7
1971	500	0.5
1973	780	6.45
1974	2000	4.7
1975	410	3.4
1976	575	1.875
1977	466.6666	4
1978	1430	6.55
1979	785	4.8
1980	165	1.4
1981	700	4.4
1982	210.3333	0.786666
1983	550	2.016666
1984	475	2.225
1985	393.3333	1.925
1986	791.25	4.2625
1987	905	4.533333
1988	325	1.65
1989	485	3.5
1990	337.8125	2.113125

**FIGURE 6.5** Graphic of CO concentration with respect to model year of the car.



**FIGURE 6.6** Graphic of HC concentration with respect to model year of the car.

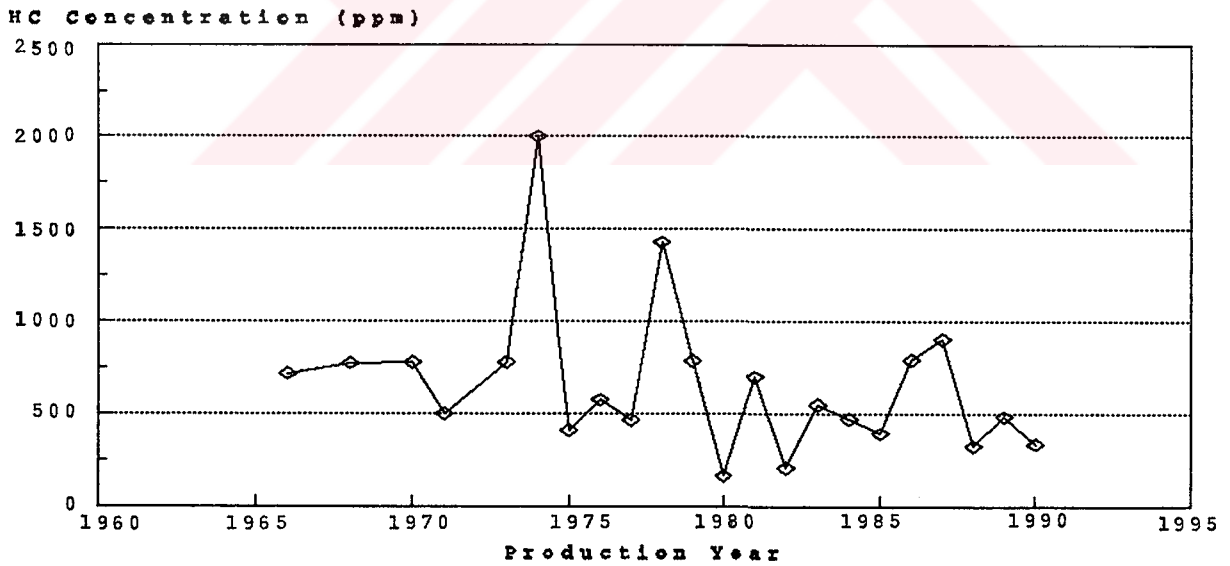
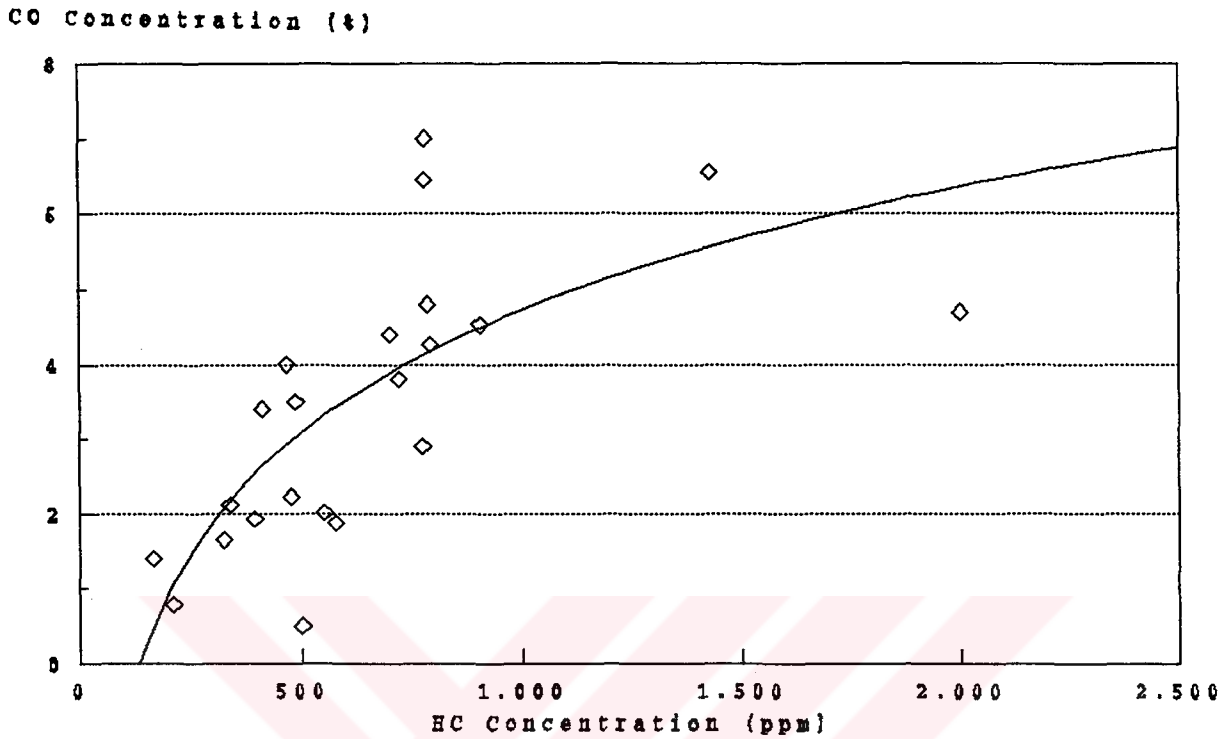


FIGURE 6.7 Graphic of HC concentration versus CO concentration.



The correlation coefficient for CO and HC concentrations was found as 0.52. There was a logarithmic correlation between these two concentrations.

On the other hand there was no correlation between CO concentration and HC concentration with respect to production year. However a decreasing trend in emissions with respect to age was observed in the graphics.

## CHAPTER 7

### 7. RESULTS AND DISCUSSIONS

Experimental results: During the sampling period average smoke concentration in the air was found as 3.9  $\mu\text{g}/\text{m}^3$ . While average lead concentration was about 412.3  $\text{ng}/\text{m}^3$ . At the same time average particulate concentration on the filter papers was found as 0.269  $\text{mg}/\text{m}^3$ . According to the experimental results that obtained with the Beckman 590 hydrocarbon and carbon monoxide analyzer, the average HC concentration was only 576.64 ppm as hexane, while CO concentration was about 3.06%. But standard exhaust concentrations of CO is about 1-2% (62) with an air to fuel ratio of 1-0.9, so by comparing with the experimental CO value the air to fuel ratio of Turkish cars might be 0.8-0.7. Standard exhaust HC concentration is around 3000 ppm (62) as methane or 571.43 ppm as hexane, this is almost equal to the experimental value.

TABLE 7.1 Experimental Results;

Pollutant	Smoke	CO	HC	Pb	Particle
Unit	$\mu\text{g}/\text{m}^3$	%	ppm	$\text{ng}/\text{m}^3$	$\text{mg}/\text{m}^3$
Value	3.9	3.06	576.64	412.3	0.269

Theoretical Results: For the theoretical part of this study two computer models are used, their results are in the form of concentration and distance matrices. Especially the concentration at the location of High Volume Sampler was calculated in the models, so that we could compare experimental and theoretical results.

ISCST model gave particulate concentrations at the location of high volume sampler (HVS) under the data and assumptions given in chapter 5 as; 0.0141  $\mu\text{g}/\text{m}^3$ . The maximum value occurring in that run at any other location as 0.0881  $\mu\text{g}/\text{m}^3$ . The results for CO at

HVS location was 2.763  $\mu\text{g}/\text{m}^3$  while the maximum value was 17.3  $\mu\text{g}/\text{m}^3$ . For HC's at HVS location it was 0.386  $\mu\text{g}/\text{m}^3$  with a maximum of 2.41  $\mu\text{g}/\text{m}^3$ . For Pb the concentration at the location of HVS was 0.00176  $\mu\text{g}/\text{m}^3$  while the maximum value was 0.011  $\mu\text{g}/\text{m}^3$ .

CALINE-3 model; The results of this model gave the result for CO concentration as 0 to 0.5 ppm (980  $\mu\text{g}/\text{m}^3$ ). But the maximum value was 0.9 ppm (1764  $\mu\text{g}/\text{m}^3$ ). For particulates concentration values were not obtainable. For HC's and Lead no values were obtainable either. Results are given in tabular form in appendix E.

**TABLE 7.2 Theoretical Results;**

Pollutant	CO	HC	Pb	Particles	Location
ISCST	2.763	0.386	0.00176	0.0141	At HVS
$\mu\text{g}/\text{m}^3$	17.3	2.412	0.011	0.0881	Maximum
CALINE 3	0.25	0	0	0	At HVS
ppm	0.9	0	0	0	Maximum

Discussion of Theoretical and Experimental Results: Since CO and HC concentrations were measured from a limited number of individual cars, it was not possible to generalize results as if they are representing the exhaust emissions in the area. We may only conclude that they are the spot checks of random sampling values from each individual car. Results for comparison is given in **Table 7.3**. Experimental CO and HC emissions in the exhaust of 75 cars showed that there were no correlation between concentration and the age of the car, but it can be said that there was a decreasing trend in concentration with the production year of the car (see **Figure 6.5 and 6.6**). Also HC and CO concentrations were correlated logarithmically. Correlation coefficient was found as 0.52. This means there was a slight correlation between HC and CO concentrations and as CO concentration increase CO concentration increase at the same time.

Table 7.3 shows that experimental results for particulates and lead are higher than theoretical values. The reason is that in experimental values the influence of concentrations coming from the highways outside of METU can be effective; but in theoretical calculations only the vehicles entering to METU were considered. Another point is that particulate matter concentrations were very much higher than the theoretical results. The experimental results of lead concentrations were also higher than the theoretical ones. The reason may be that Pb particles form the heavy fraction of exhaust particles which may settle down easily rather than other particles that might be transported away. These transported particles might come from exhausts and as well as from some other sources. The differences between experimental and theoretical Pb values might be related to the same reasoning. That is lead particles may settle out and form lead accumulations in the soil and road dust, as in the study of Sturges and Barrie (19).

TABLE 7.3 Results of The Models And Experimental Findings

Pollutant	Pb ( $\mu\text{g}/\text{m}^3$ )	Particulates ( $\mu\text{g}/\text{m}^3$ )
Experimental	0.3866	271
ISCST (at HVS)	0.00176	0.0141
ISCST (Maximum)	0.011	0.0881
CALINE 3 (at HVS)	0	0
CALINE 3 (Maximum)	0	0

ISCST and CALINE-3 was tested to see its applicability to limited road traffic. The results show that CALINE-3 model makes an underestimation compared to ISCST model. It is not the appropriate model to use for such a case. This might be because of firstly poor meteorological data used in this study; secondly it was designed for a large traffic (that could also be understood from the units of concentrations which are ppm). Also results of ISCST might not be reliable because like most of the



dispersion models ISCST requires hourly meteorological inputs. And wind directions is assumed to be parallel to the street centreline, this would make the concentrations to reach higher values.

**Table 7.4** shows the interpretation of results according to air quality standards of Turkey. Carbonmonoxide and hydrocarbon values for comparison were taken from the runs of these models, as maximum values.

**TABLE 7.4** Comparison of The Result of ISCST With Standards

Pollutant	CO µg/m <sup>3</sup>	HC µg/m <sup>3</sup>	Pb µg/m <sup>3</sup>	Particles µg/m <sup>3</sup>
Experiment	-	-	0.3866	271
ISCST	17.3	2.412	-	-
Standards	30000	140	1.5	300

According to the same table the measured levels of particulates, lead, HC and CO are not exceeding the standards. For carbonmonoxide and hydrocarbons only theoretically estimated values were compared since facilities were not available to measure their concentrations. The concentrations obtained from the models were very much smaller than the allowable limits. Obviously the actual concentrations may be higher, however the possibilities of actual concentrations to be smaller than the standards is high in the study site. Only for particulates we may say that we are near to limits specified for health hazard. Since the values given in **Table 7.4** are average concentrations. The particulate concentrations for 30 days are checked to see how many days the concentrations are bigger than the specified standards. It could be seen from **Table 6.3** of particulate concentrations exceeded the limits for seven days.

According to the same table experimental lead concentrations are smaller than air quality standards of US Federal Primary and

Secondary Ambient Air Quality. This standard states normal lead level in ordinary streets, to be between 0.5 to 1  $\mu\text{g}/\text{m}^3$ . For this study the concentration were less than the values stated.

If US, WHO and EEC particulate standards are compared for particulate matter. The monthly average concentration of 270  $\mu\text{g}/\text{m}^3$  is fairly high according to WHO standards. But according to US and EEC standards the concentrations are acceptable. (see **Table 2.9**) The estimated carbonmonoxide concentrations are not higher than the values given in US and Turkish standards.

For the statistical part of results, the correlation coefficients show that there is no relationship between smoke, particulate and lead concentrations. These pollutant concentrations are independent from each other as it can be seen in Appendix D. Histogram of frequency of occurrence of particle concentrations show that approximately 43% of the measurements occur within the interval of 0.1 to 0.2  $\text{mg}/\text{m}^3$  with a arithmetic average of 0.27  $\text{mg}/\text{m}^3$ . However 27% of the lead measurements occur in the range of 300-400  $\text{ng}/\text{m}^3$  while the arithmetic average value is 412  $\text{ng}/\text{m}^3$ . Completely reliable statistical analysis can be done only by taking into account the frequency distribution of values, that's why frequency distribution was used in this study.

Recommendation for Further Study This study was designed as a pilot study to see how mobile source effects on air quality could be locally investigated. It is recommended in future under a large monitoring system, including hourly data of emissions and micro-meteorological measurements to be included. So that theoretical modelling estimates and in situ measurements may be more reliable and trend, control strategy and allowable limits for mobile pollution could be judged.

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APPENDIX A

A. Pb, CARBON MONOXIDE and TOTAL HYDROCARBON SAMPLING and MEASUREMENT

A.1 Pb Sampling (63)

For lead sampling a high volume sampler with cellulose filter papers may be used.

Air is drawn in to a covered housing and through a filter by means of a high flow rate blower at a flow rate (1.1 to 1.7 m<sup>3</sup>/min) that allows suspended particles having diameter of less than 100 μm to pass to the filter surface. Particles within the size range of 100 to 0.1 μm in diameter are ordinarily collected on glass fibre filters. The mass concentration of suspended particulates in the ambient air (μg/m<sup>3</sup>) is computed by measuring the mass of collected particulates and the volume of air sampled. If particulate levels are unusually high, a satisfactory sample may be obtained in 6 to 8 hours or less. For determination of average concentrations of suspended particulates in ambient air, a standard sampling period of 24 hours is recommended.

The standard air volume measured could be calculated by the following formula;

$$V_a = \frac{P_a - P_m}{P_a} V_m \quad \dots\dots\dots A1$$

The air flow rate Qs;

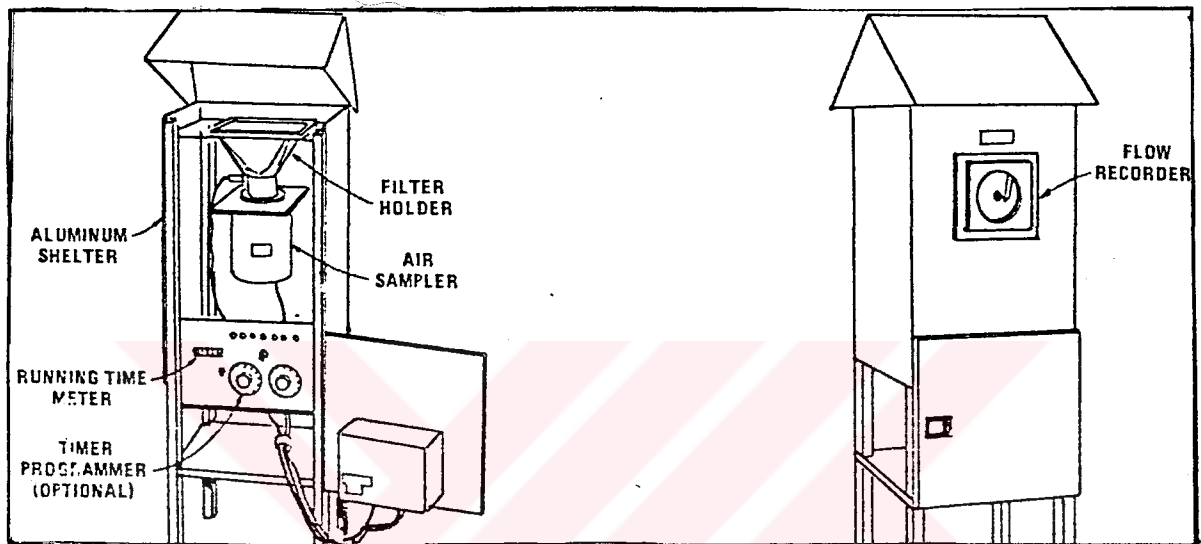
$$Q = \frac{V_a}{t} \quad \dots\dots\dots A2$$

The volume of air sampled Vt;

$$V_t = ((Q_i + Q_f)/2) t \quad \dots\dots\dots A3$$

$$SP = \frac{(W_f - W_i) * 10^6}{V} \dots\dots\dots A4$$

**FIGURE A.1** Configuration of High Volume Sampler (HVS) (63).



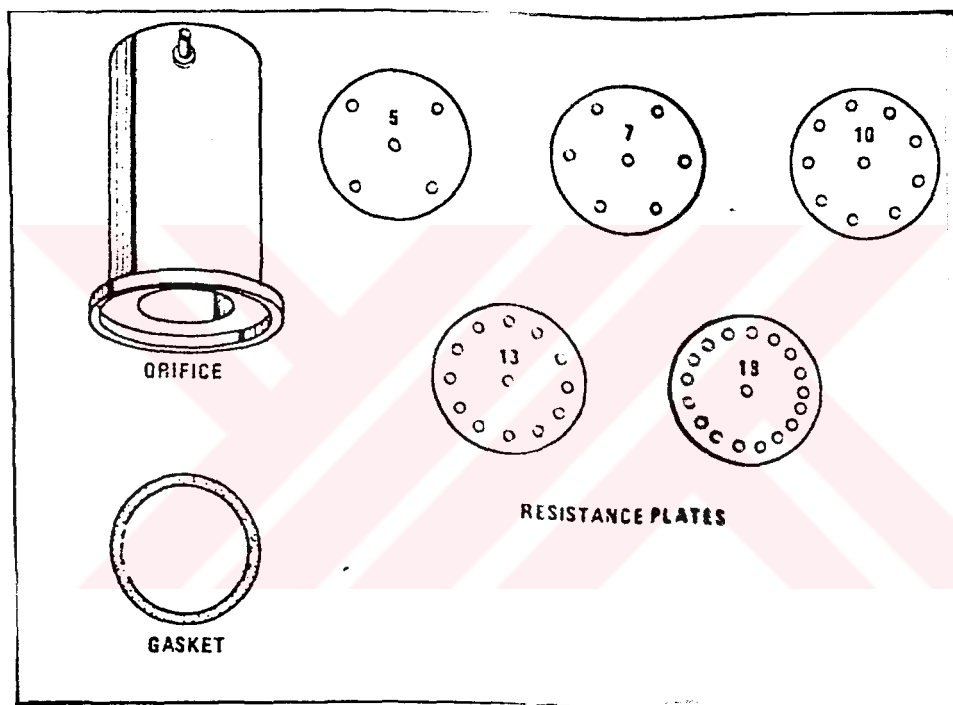
Where;

- Va = true air volume at atmospheric pressure, m<sup>3</sup>
- Vm = volume measured by primary standard, m<sup>3</sup>
- Pa = barometric pressure, mmHg
- Pm = pressure drop at inlet of primary standard, m<sup>3</sup>
- Q = flow rate, m<sup>3</sup>/minute
- t = time of flow, minute
- SP = mass concentration of suspended particulates, μg/m<sup>3</sup>
- Wf = final weight of filter, g
- Wi = initial weight of filter, g
- V = air volume sampled, m<sup>3</sup>

### A.1.1 Calibration of the Instrument

In order to calibrate the instrument we might use orifice calibration unit and a differential manometer (manometer capable of measuring to at least 40 cm. of water). Orifice calibration unit has 5 different resistance plates (figure A.2) having 5, 7, 10, 13 and 18 openings. The pressures in terms of inches of water is measured for each resistance plate.

FIGURE A.2 Calibration of the High Volume Sampler (63).



### A.2 Carbon Monoxide and Hydrocarbon Measurements

For CO and hydrocarbon measurements Beckman 590 could be used which is an infrared vehicle exhaust analyzer. The model 590 is a dual channel, non-dispersive infrared analyzer.

The sample handling system, utilizes a double headed pump. Both heads are coated with teflon fluorocarbon resin. There are two filters a 40  $\mu$  and a 25  $\mu$  filter.

### A.2.1 Calibration of the Instrument

For calibration, one point that should be noted that hydrocarbon meter reads in terms of hexane level of the gas that is analyzed. But if calibration is done for example with propane the value should be converted with necessary conversion factors.

Instrument has a flow indicator switch, it is in green colour originally but if the filters are clogged due to particulates than cleaning of filters with pressurized air should be done.

### A.2.3 Pb Measurement

Atmospheric lead concentrations from a HVS filter paper can be measured by atomic adsorption spectroscopy (AAS) or a wet chemical method.

This chemical method (64) can measure Pb from plants and animals also. The plants are dried in oven and then heated to ash in silica crucible. Then certain amount of plant or soil is digested with hydrochloric and nitric acid, the filtrate is evaporated and diluted to 100 ml. The lead concentration was determined. It was found that chloroform is the most suitable solvent for extraction of lead.

The presence of  $\text{Cu}^{+2}$ ,  $\text{Fe}^{+3}$  and  $\text{Ce}^{+4}$  are interfere with the determination of lead. However the presence of  $\text{Cu}^{+2}$  and  $\text{Fe}^{+3}$  could be eliminated by masking them with ascorbic acid.

## APPENDIX B

### B. VEHICLE COUNTS FROM ANKARA URBAN TRANSPORTATION STUDY

**Table B.1** of (65) shows the seven cordon and six screenline counts that have been conducted in Ankara by various institutions since 1970. **Figure B.1** shows 1985 cordon and screenlines and count stations.

The following classification was adopted in the 1985 counts

- .Private car
- .Taxi cab
- .Minibus dolmus
- .EGO normal bus (and private bus)
- .EGO articulated bus
- .Intercity bus
- .Service bus
- .Other

**Table B.2** shows total vehicle crossings at cordon count stations. The comparison of 1979 and 1985 cordon crossings at İnönü boulevard showed a typical development bearing resemblance to that observed in Istanbul street. The number of inbound passenger crossings increased from 22000 in 1979 to as high as 66000 in 1985, on the other hand the outbound passenger crossings which were 30000 in 1979, increased to 66000 in 1985. This can be attributed to the recent expansion of the city in Konya and Eskifehir direction.

In both counts the total number of vehicles has been summed up by 30 minute intervals for each category.

The count survey conducted in 1979 converted to vehicle and passenger movements for a total of 13 hours whereas the count survey of 1985 was carried out during a total of 12.5 hours. However the difference of half an hour was regarded as negligible and therefore no modifications were made on tables.





**TABLE B.1 Traffic Counts in Ankara (1970-1985) (65).**

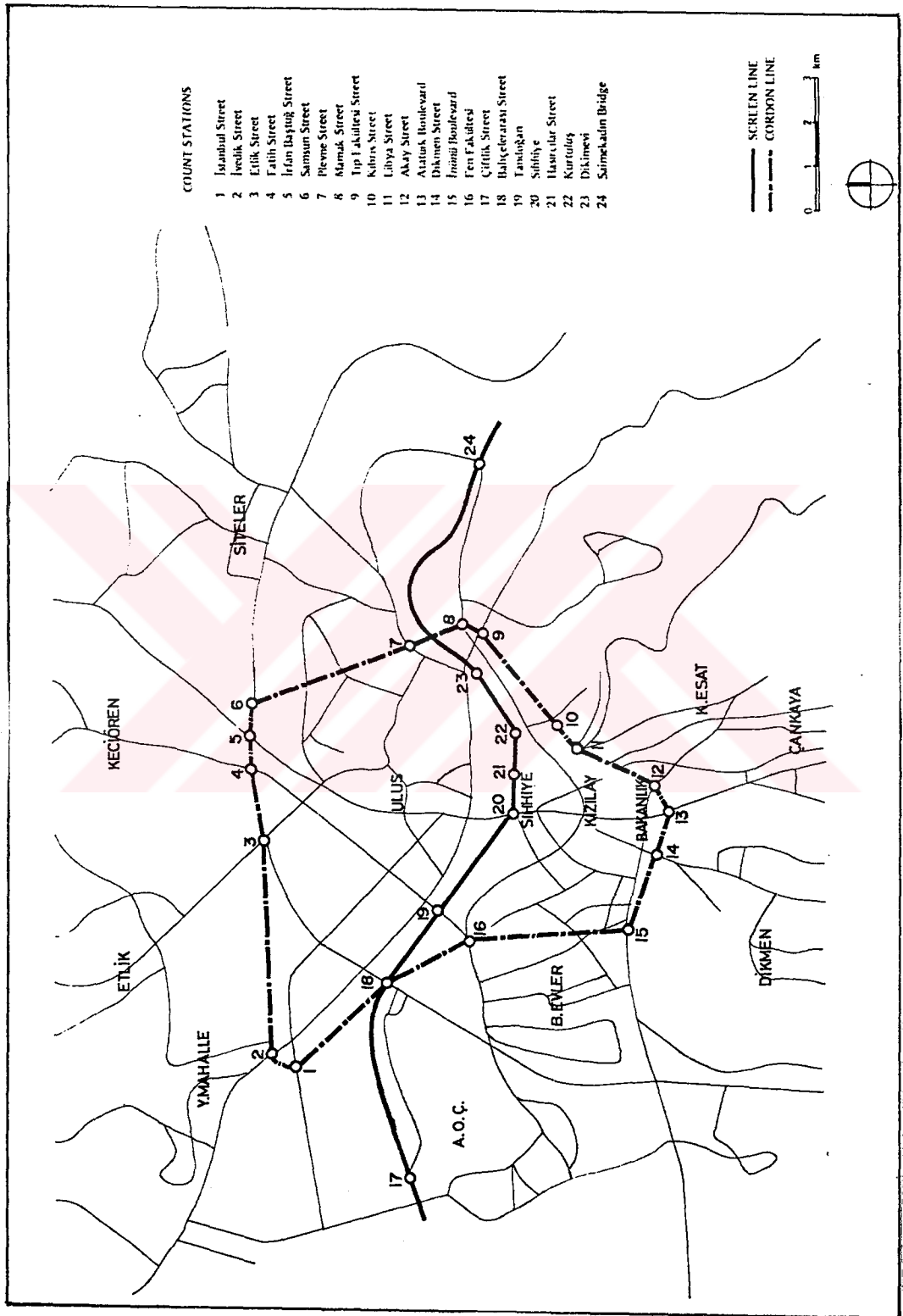
ORGANIZATION	TYPE	DATA					DATE	HOURS
		V	P	I	S			
1- SOfRETU-Municipality of Ankara	Inner Cordon	X	X				March 1970	7:45 - 8:45 a.m., 5:30 - 6:30 p.m.
2- Ankara Metropolitan Area Master Plan Bureau	External Cordon	X		X			May 1970	7:00 a.m. - 7:00 p.m.
3- Ankara Metropolitan Area Master Plan Bureau	Screen line	X					May 1970	7:00 a.m. - 8:00 p.m.
4- Transport Coordination Agency	Inner Cordon	X			X		November 1970	8:00 - 11:00 a.m., 2:00 - 6:00 p.m.
5- General Directorate of Highways	Screen line	X					April 1971	7:00 a.m. - 8:00 p.m.
6- Transport Coordination Agency	Inner Cordon	X					February 1974	8:30 - 9:30 a.m., 3:00 - 4:00 p.m.
7- EGO	Cordon	X			X		April 1979	7:00 a.m. - 8:00 p.m.
8- EGO	Screen line	X			X		April 1979	7:00 a.m. - 8:00 p.m.
9- EGO	Cordon	X			X		November 1979	7:00 a.m. - 7:30 p.m.
10- EGO	Screen line	X			X		November 1979	7:00 a.m. - 7:30 p.m.
11- ANPB-Municipality of Ankara	Screen line	X			X		November 1980	7:00 - 12:00 a.m.
12- EGO	Cordon	X			X		May 1985	7:00 a.m. - 7:30 p.m.
13- EGO	Screen line	X			X		May 1985	7:00 a.m. - 7:30 p.m.

**TABLE B.2 Total Vehicle Crossings at Cordon Count Stations**  
(1979 and 1985) (65).

DIRECTION	1979 CORDON COUNT										1985 CORDON COUNT									
	Private Car	Taxi	Minibus Dolmuş	Dolmuş	EGO Bus	Service Bus (4)	Other	Total	Private Car	Taxi	Minibus Dolmuş	Dolmuş (5)	EGO Bus Private Bus	Service Bus	Other	Total				
INBOUND	Istanbul Street	2544	671	746	181	44	4087	8273	3899	537	834	-	181	247	6083	11781				
	Ivedik Street	8027	3725	2084	75	605	3759	18275	4563	2212	2968	-	855	351	3263	13812				
	Etilik Street	4380	1731	1331	170	263	2451	10326	5214	2162	1951	-	541	757	3483	14108				
	Fatih Street	7261	3593	3633	-	337	5116	19940	4566	2031	3091	-	990	339	2640	13657				
	İrfan Baştuğ Str.	2895	1270	981	825	338	1341	7650	3543	1457	1449	-	774	278	2581	10082				
	Samsun Street	3164	1206	-	902	-	5153	10425	4124	993	-	-	147	174	4503	10712				
	Plevne Street	3427	1346	1513	52	110	2185	8633	3293	1409	1895	-	240	181	2913	9931				
	Mamak Bridge (1)	2692	1817	1571	4	112	2053	8249	1257	960	1480	-	146	132	1014	4989				
	Tip Fakültesi Str.	2028	1557	1838	-	132	1527	7082	1548	1435	2346	-	639	230	1596	7794				
	Kıbrıs Street (3)	-	-	-	-	-	-	-	1878	1157	522	-	45	130	1560	5292				
	Libya Street	5491	3678	1403	-	45	3337	13954	5768	3352	1928	-	108	165	2257	13578				
	Akay Street	3098	1424	1	686	194	913	6316	5184	3987	-	-	315	139	2244	11869				
	Atatürk Blvd.(2)	9387	5454	-	3291	393	4720	23245	14675	10047	-	-	1159	172	3046	29099				
	Dikmen Street	3597	1254	1741	145	285	2466	9488	6140	1944	2276	-	482	239	3044	14125				
İnönü Boulevard	4999	1166	17	130	86	3921	10319	5506	1609	516	-	432	794	2720	11577					
Fen Fakültesi	8039	2714	-	2244	490	1967	15454	5969	3252	318	-	601	172	1664	12039					
Bahçelerarası St.(3)	-	-	-	-	-	-	-	4804	1335	1068	-	143	640	6004	13994					
<b>Total</b>	<b>71029</b>	<b>32606</b>	<b>16857</b>	<b>8705</b>	<b>3434</b>	<b>44996</b>	<b>177629</b>	<b>81931</b>	<b>39879</b>	<b>23076</b>	<b>-</b>	<b>7798</b>	<b>5140</b>	<b>50615</b>	<b>208439</b>					
OUTBOUND	Istanbul Street	4309	1130	321	250	37	5530	11577	4438	723	886	-	268	376	6782	13473				
	Ivedik Street	5780	2756	1616	1120	624	3258	15154	3662	1759	3151	-	842	249	2945	12608				
	Etilik Street	5907	2770	1535	-	300	3241	13753	3976	1932	1723	-	500	543	3017	11691				
	Fatih Street	5358	2777	2387	-	391	3417	14330	3624	1832	3159	-	947	416	2563	12541				
	İrfan Baştuğ Str.	3068	1530	915	1263	308	3370	10454	3243	1407	1354	-	780	270	2314	9368				
	Samsun Street	5954	1785	118	1068	154	5775	14700	4433	1059	684	-	134	172	4876	11358				
	Plevne Street	4371	2834	2197	-	111	4199	13755	3099	1241	1937	-	236	162	2677	9352				
	Mamak Bridge (1)	2608	1546	1487	-	111	1091	6843	1687	1028	1449	-	488	83	910	5645				
	Tip Fakültesi Str.	2513	1744	2205	-	155	2209	8826	1490	1301	2195	-	300	214	1482	6992				
	Kıbrıs Street (3)	-	-	-	-	-	-	-	1056	714	862	-	44	73	1019	3768				
	Libya Street	5954	3437	1900	-	53	2739	14083	6720	4434	1396	-	81	125	3179	15935				
	Akay Street	3536	1688	-	946	204	911	7285	7998	5686	-	-	339	221	2936	17180				
	Atatürk Blvd.(2)	8882	5036	246	3476	422	3432	21494	9456	7442	-	-	1075	106	3029	21108				
	Dikmen Street	4253	2460	2060	-	427	1466	10666	4878	1781	2387	-	495	484	2803	12828				
İnönü Boulevard	9192	1255	11	108	87	3123	13776	6367	1805	491	-	429	758	2993	12843					
Fen Fakültesi	7147	2825	-	1106	539	2445	14062	5386	2824	383	-	591	111	2002	11297					
Bahçelerarası St.(3)	-	-	-	-	-	-	-	5502	1107	1088	-	128	499	6381	14705					
<b>Total</b>	<b>78832</b>	<b>35573</b>	<b>16998</b>	<b>9337</b>	<b>3812</b>	<b>46206</b>	<b>190758</b>	<b>77015</b>	<b>38075</b>	<b>23145</b>	<b>-</b>	<b>7677</b>	<b>4862</b>	<b>51908</b>	<b>202682</b>					

**FIGURE B.1**

**1985 Cordon and Screen Lines and Count Stations (65).**



APPENDIX C

C. THE EQUATIONS USED IN THE COMPUTER PROGRAMS

C.1 Plume Rise Formulas of ISCST

By using some complex equations the plume rise  $\Delta h$  can be calculated. The details of calculation could be seen from the reference (53).

A wind profile exponent law is used to adjust the mean wind speed  $U_1$  from the wind system measurement height  $Z_1$  (10m) to the emission height  $h$ . This law is of the form;

$$U\{h\} = U_1 (h/Z_1)^P \dots\dots\dots C1$$

Where  $p$  is the wind profile exponent. The values of  $p$  are listed in ISCST users manual (53).

C.2 Ground Level Concentration Calculations

The hourly ground level concentration at downwind distance  $X$  and crosswind distance  $y$  is given by;

$$C(x,y) = \frac{K Q}{\pi \text{SIGMAY SIGMAZ } U\{h\}} e^{[-1/2(Y/\text{SIGMAY})^2]} [\text{VT}] [\text{Decay}] \dots C2$$

Where;

- $Q$  = pollutant emission rate ( $\mu\text{g}/\text{m}^3$ )
- $K$  = a scaling coefficient to convert concentration to desired units. ( $10^{-6}$ )
- $Y$  = distance in the  $Y$  direction (meter)
- $\text{VT}$  = vertical term(meter)
- Decay = decay term

where;

$$[\text{Decay}] = \exp[-\text{func } x/U\{h\}] \dots\dots\dots C3$$

$$\text{func} = 0.693/T_{1/2} \dots\dots\dots C4$$

$$\text{SIGMAY} = 465.11628 \text{ Tan (TH)} \dots\dots\dots \text{C5}$$

$$\text{TH} = 0.017453293(\text{c-dlnx}) \dots\dots\dots \text{C6}$$

$$\text{SIGMAZ} = \text{ax}^{\text{b}} \dots\dots\dots \text{C7}$$

The coefficients a, b, c and d could be found from ISCST users manual (53).

C.3 Concentration Calculations and Main Equations Used in CALINE3 Model

$$C = \frac{A q}{2\pi \text{ SIGMAZ SIGMAY U}} \int_{y_1}^{y_2} \exp\left(\frac{-y^2}{2(\text{SIGMAY})^2}\right) \dots\dots\dots \text{C8}$$

$$A = e^{[-(z-h)^2/2(\text{SIGMAY})^2]} + e^{[-(z+h)^2/2(\text{SIGMAZ})^2]} \dots \text{C9}$$

$$\text{MIXH} = \frac{0.185 \text{ U k}}{\ln(Z/Z_0) f} \dots\dots\dots \text{C10}$$

Zo values are given in CALINE 3 users manual (54).

## APPENDIX-D

### D.1 Theoretical Calculations;

#### D.1.1 Runs of ISCST for Hydrocarbons;

1           ISCST (DATED 88166)  
          AN AIR QUALITY DISPERSION MODEL IN  
          SECTION 1. GUIDELINE MODELS  
          IN UNAMAP (VERSION 6) JAN. 88.  
          BOWMAN ENVIRONMENTAL ENGINEERING REV.6.5

#### SESSION INFORMATION

INPUT DATA FILE NAME : BDATA.DTA  
OUTPUT LIST FILE NAME : HC

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC HC CONCENTRATIONS -- \*\*\*

CALCULATE (CONCENTRATION=1,DEPOSITION=2)	ISW(1) = 1
RECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POLAR=2 OR 4)	ISW(2) = 1
DISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2)	ISW(3) = 1
TERRAIN ELEVATIONS ARE READ (YES=1,NO=0)	ISW(4) = 0
CALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0)	ISW(5) = 0
LIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2)	ISW(6) = 2

COMPUTE AVERAGE CONCENTRATION (OR TOTAL DEPOSITION) WITH THE FOLLOWING TIME PERIODS:	
HOURLY (YES=1,NO=0)	ISW(7) = 1
2-HOUR (YES=1,NO=0)	ISW(8) = 0
3-HOUR (YES=1,NO=0)	ISW(9) = 0
4-HOUR (YES=1,NO=0)	ISW(10) = 0
6-HOUR (YES=1,NO=0)	ISW(11) = 0
8-HOUR (YES=1,NO=0)	ISW(12) = 0
12-HOUR (YES=1,NO=0)	ISW(13) = 0
24-HOUR (YES=1,NO=0)	ISW(14) = 1
PRINT 'N'-DAY TABLE(S) (YES=1,NO=0)	ISW(15) = 1

PRINT THE FOLLOWING TYPES OF TABLES WHOSE TIME PERIODS ARE SPECIFIED BY ISW(7) THROUGH ISW(14):	
DAILY TABLES (YES=1,NO=0)	ISW(16) = 0
HIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0)	ISW(17) = 0
MAXIMUM 50 TABLES (YES=1,NO=0)	ISW(18) = 0
METEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2)	ISW(19) = 2
RURAL-URBAN OPTION (RU.=0,UR. MODE 1=1,UR. MODE 2=2,UR. MODE 3=3)	ISW(20) = 0
WIND PROFILE EXPONENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(21) = 1
VERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(22) = 1
SCALE EMISSION RATES FOR ALL SOURCES (NO=0,YES>0)	ISW(23) = 0
PROGRAM CALCULATES FINAL PLUME RISE ONLY (YES=1,NO=2)	ISW(24) = 2
PROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1)	ISW(25) = 1
PROGRAM USES BUOYANCY INDUCED DISPERSION (YES=1,NO=2)	ISW(26) = 0
CONCENTRATIONS DURING CALM PERIODS SET = 0 (YES=1,NO=2)	ISW(27) = 2
REG. DEFAULT OPTION CHOSEN (YES=1,NO=2)	ISW(28) = 0
TYPE OF POLLUTANT TO BE MODELLED (1=SO2,2=OTHER)	ISW(29) = 0
DEBUG OPTION CHOSEN (YES=1,NO=2)	ISW(30) = 0
ABOVE GROUND (FLAGPOLE) RECEPTORS USED (YES=1,NO=0)	ISW(31) = 0

NUMBER OF INPUT SOURCES	NSOURC = 1
NUMBER OF SOURCE GROUPS (=0,ALL SOURCES)	NGROUP = 0
TIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS)	IPERD = 1
NUMBER OF X (RANGE) GRID VALUES	NXPNTS = 10
NUMBER OF Y (THETA) GRID VALUES	NYPNTS = 11
NUMBER OF DISCRETE RECEPTORS	NXWYPT = 0
NUMBER OF HOURS PER DAY IN METEOROLOGICAL DATA	NHOURS = 1
NUMBER OF DAYS OF METEOROLOGICAL DATA	NDAYS = 1
SOURCE EMISSION RATE UNITS CONVERSION FACTOR	TK = .10000E+07
HEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED	ZR = 10.00 METERS

LOGICAL UNIT NUMBER OF METEOROLOGICAL DATA  
 ALLOCATED DATA STORAGE  
 REQUIRED DATA STORAGE FOR THIS PROBLEM RUN

IMET = 5  
 LIMIT = 43500 WORDS  
 MIMIT = 858 WORDS

1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC HC CONCENTRATIONS -- \*\*\*

\*\*\* UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES \*\*\*  
 (METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

\*\*\* X-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
 (METERS)

.0, 5.0, 10.0, 20.0, 50.0, 100.0, 200.0, 500.0, 1000.0, 2000.0,

\*\*\* Y-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
 (METERS)

-500.0, -300.0, -100.0, -50.0, -10.0, .0, 10.0, 50.0, 100.0, 300.0, 500.0,

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC HC CONCENTRATIONS -- \*\*\*

\*\*\* SOURCE DATA \*\*\*

BLDG.	T W	EMISSION RATE		X	Y	BASE	VERT.DIM	HORZ.DIM	DIAMETER	HEIGHT	LENGTH
		TYPE=0,1 (GRAMS/SEC)	TYPE=2 (GRAMS/SEC)								
1	1 0 0	.91200E-01	.0	.0	.0	.00	930.23	3.28	.00	.00	.00

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC HC CONCENTRATIONS -- \*\*\*

\* SOURCE-RECEPTOR COMBINATIONS LESS THAN 001 METERS OR THREE BUILDING HEIGHTS IN DISTANCE. NO AVERAGE CONCENTRATION IS CALCULATED \*

SOURCE NUMBER	RECEPTOR LOCATION		DISTANCE BETWEEN (METERS)
	X OR RANGE (METERS)	Y (METERS) OR DIRECTION (DEGREES)	
1	.0	.0	-7.06
1	5.0	.0	-2.06

1

MET. DATA

DAY 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC HC CONCENTRATIONS -- \*\*\*

\* METEOROLOGICAL DATA FOR DAY 1 \*

FLOW VECTOR HOUR	WIND SPEED (DEGREES)	MIXING HEIGHT (MPS)	TEMP. (METERS)	GRADIENT (DEG. K) (DEG. K) PER METER	POT. TEMP. WIND STABILITY PROFILE CATEGORY	DECAY COEFFICIENT EXPONENT (PER SEC)
------------------	----------------------	---------------------	----------------	--------------------------------------	--	--------------------------------------

1 90.0 2.47 1911.0 290.5 .0000 2 .0700 .000000E+00

'N'-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC HC CONCENTRATIONS -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*  
 \* FROM ALL SOURCES \*  
 \* FOR THE RECEPTOR GRID \*

\* MAXIMUM VALUE EQUALS 2.41230 AND OCCURRED AT ( 10.0, .0) \*

Y-AXIS / X-AXIS (METERS) (METERS)/	0.	5.0	10.0	20.0	50.0	100.0	200.0	500.0	1000.0
500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00041
300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00027	.01105
100.0 /	.00000	.00000	.00000	.00000	.00000	.00001	.01082	.06894	.05711
50.0 /	.00000	.00000	.00000	.00000	.00049	.04032	.13669	.11609	.06662
10.0 /	.00000	.00000	.38593	.66510	.72052	.51491	.30776	.13715	.06999
.0 /	.00000	.00000	2.41230	1.74990	.97658	.57257	.31835	.13811	.07013
-10.0 /	.00000	.00000	.38593	.66510	.72052	.51491	.30776	.13715	.06999
-50.0 /	.00000	.00000	.00000	.00000	.00049	.04032	.13669	.11609	.06662
-100.0 /	.00000	.00000	.00000	.00000	.00000	.00001	.01082	.06894	.05711
-300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00027	.01105
-500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00041

'N'-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC HC CONCENTRATIONS -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*  
 \* FROM ALL SOURCES \*  
 \* FOR THE RECEPTOR GRID \*

\* MAXIMUM VALUE EQUALS 2.41230 AND OCCURRED AT (10.0, .0) \*

Y-AXIS / X-AXIS (METERS) (METERS) /	2000.0
500.0 /	.00747
300.0 /	.01964
100.0 /	.03186
50.0 /	.03334
10.0 /	.03383
.0 /	.03385
-10.0 /	.03383
-50.0 /	.03334
-100.0 /	.03186
-300.0 /	.01964
-500.0 /	.00747



AN AIR QUALITY DISPERSION MODEL IN  
SECTION 1. GUIDELINE MODELS  
IN UNAMAP (VERSION 6) JAN. 88.  
BOWMAN ENVIRONMENTAL ENGINEERING REV.6.5

## SESSION INFORMATION

INPUT DATA FILE NAME : bdata.dta  
OUTPUT LIST FILE NAME : co

1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC CO CONCENTRATIONS -- \*\*\*

CALCULATE (CONCENTRATION=1,DEPOSITION=2)	ISW(1) = 1
RECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POLAR=2 OR 4)	ISW(2) = 1
DISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2)	ISW(3) = 1
TERRAIN ELEVATIONS ARE READ (YES=1,NO=0)	ISW(4) = 0
CALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0)	ISW(5) = 0
LIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2)	ISW(6) = 2
COMPUTE AVERAGE CONCENTRATION (OR TOTAL DEPOSITION) WITH THE FOLLOWING TIME PERIODS:	
HOURLY (YES=1,NO=0)	ISW(7) = 1
2-HOUR (YES=1,NO=0)	ISW(8) = 0
3-HOUR (YES=1,NO=0)	ISW(9) = 0
4-HOUR (YES=1,NO=0)	ISW(10) = 0
6-HOUR (YES=1,NO=0)	ISW(11) = 0
8-HOUR (YES=1,NO=0)	ISW(12) = 0
12-HOUR (YES=1,NO=0)	ISW(13) = 0
24-HOUR (YES=1,NO=0)	ISW(14) = 1
PRINT 'N'-DAY TABLE(S) (YES=1,NO=0)	ISW(15) = 1
PRINT THE FOLLOWING TYPES OF TABLES WHOSE TIME PERIODS ARE SPECIFIED BY ISW(7) THROUGH ISW(14):	
DAILY TABLES (YES=1,NO=0)	ISW(16) = 0
HIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0)	ISW(17) = 0
MAXIMUM 50 TABLES (YES=1,NO=0)	ISW(18) = 0
METEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2)	ISW(19) = 2
RURAL-URBAN OPTION (RU.=0,UR. MODE 1=1,UR. MODE 2=2,UR. MODE 3=3)	ISW(20) = 0
WIND PROFILE EXPONENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(21) = 1
VERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(22) = 1
SCALE EMISSION RATES FOR ALL SOURCES (NO=0,YES>0)	ISW(23) = 0
PROGRAM CALCULATES FINAL PLUME RISE ONLY (YES=1,NO=2)	ISW(24) = 2
PROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1)	ISW(25) = 1
PROGRAM USES BUOYANCY INDUCED DISPERSION (YES=1,NO=2)	ISW(26) = 0
CONCENTRATIONS DURING CALM PERIODS SET = 0 (YES=1,NO=2)	ISW(27) = 2
REG. DEFAULT OPTION CHOSEN (YES=1,NO=2)	ISW(28) = 0
TYPE OF POLLUTANT TO BE MODELLED (1=SO2,2=OTHER)	ISW(29) = 0
DEBUG OPTION CHOSEN (YES=1,NO=2)	ISW(30) = 0
ABOVE GROUND (FLAGPOLE) RECEPTORS USED (YES=1,NO=0)	ISW(31) = 0
NUMBER OF INPUT SOURCES	NSOURC = 1
NUMBER OF SOURCE GROUPS (=0,ALL SOURCES)	NGROUP = 0
TIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS)	IPERD = 1
NUMBER OF X (RANGE) GRID VALUES	NXPNTS = 10
NUMBER OF Y (THETA) GRID VALUES	NYPNTS = 11
NUMBER OF DISCRETE RECEPTORS	NXWYPT = 0
NUMBER OF HOURS PER DAY IN METEOROLOGICAL DATA	NHOURS = 1
NUMBER OF DAYS OF METEOROLOGICAL DATA	NDAYS = 1
SOURCE EMISSION RATE UNITS CONVERSION FACTOR	TK = .10000E+07
HEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED	ZR = 10.00 METERS
LOGICAL UNIT NUMBER OF METEOROLOGICAL DATA	IMET = 5
ALLOCATED DATA STORAGE	LIMIT = 43500 WORDS
REQUIRED DATA STORAGE FOR THIS PROBLEM RUN	MIMIT = 858 WORDS

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC CO CONCENTRATIONS -- \*\*\*

\*\*\* UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES \*\*\*  
(METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

\*\*\* X-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
(METERS)

.0, 5.0, 10.0, 20.0, 50.0, 100.0, 200.0, 500.0, 1000.0, 2000.0,

\*\*\* Y-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
(METERS)

-500.0, -300.0, -100.0, -50.0, -10.0, .0, 10.0, 50.0, 100.0, 300.0, 500.0,

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC CO CONCENTRATIONS -- \*\*\*

\*\*\* SOURCE DATA \*\*\*

BLDG.	T W	EMISSION RATE		X	Y	ELEV.	HEIGHT	TEMP.	EXIT VEL.	BLDG.	BLDG.
		TYPE=0,1	TYPE=2					(DEG.K);	(M/SEC);		
WIDTH	Y A NUMBER	TYPE=0	TYPE=2	BASE	VERT.DIM	HORZ.DIM	DIAMETER	HEIGHT	LENGTH		
SOURCE P K PART.	(GRAMS/SEC)	(GRAMS/SEC)	(GRAMS/SEC)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)
NUMBER E E CATS.	*PER METER**2	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)
TYPE=0	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)
1 1 0 0	.65300E+00	.0	.0	.0	.00	930.23	3.28	.00	.00	.00	.00

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC CO CONCENTRATIONS -- \*\*\*

\* SOURCE-RECEPTOR COMBINATIONS LESS THAN 001 METERS OR THREE BUILDING HEIGHTS IN DISTANCE. NO AVERAGE CONCENTRATION IS CALCULATED \*

SOURCE NUMBER	- - RECEPTOR LOCATION - -		DISTANCE BETWEEN (METERS)
	X OR RANGE (METERS)	Y (METERS) OR DIRECTION (DEGREES)	
1	.0	.0	-7.06
1	5.0	.0	-2.06

MET. DATA

DAY 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC CO CONCENTRATIONS -- \*\*\*

\* METEOROLOGICAL DATA FOR DAY 1 \*

FLOW VECTOR	WIND SPEED	MIXING HEIGHT	TEMP.	GRADIENT (DEG. K)	STABILITY	POT. TEMP. WIND PROFILE	DECAY COEFFICIENT
-------------	------------	---------------	-------	-------------------	-----------	-------------------------	-------------------

HOURL	(DEGREES)	(MPS)	(METERS)	(DEG. K)	PER METER)	CATEGORY	EXPONENT	(PER SEC)
1	90.0	2.47	1911.0	290.5	.0000	2	.0700	.000000E+00

'N'-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC CO CONCENTRATIONS -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*

\* FROM ALL SOURCES \*  
\* FOR THE RECEPTOR GRID \*

\* MAXIMUM VALUE EQUALS 17.27225 AND OCCURRED AT ( 10.0, .0) \*

Y-AXIS / (METERS) / .0	5.0	10.0	20.0	50.0	100.0	X-AXIS (METERS)			
						200.0	500.0	1000.0	
500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00296	
300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00190	.07911	
100.0 /	.00000	.00000	.00000	.00000	.00010	.07748	.49363	.40893	
50.0 /	.00000	.00000	.00000	.00000	.00349	.28866	.97872	.83119	.47702
10.0 /	.00000	.00000	2.76326	4.76218	5.15899	3.68679	2.20361	.98201	.50111
.0 /	.00000	.00000	17.27225	12.52947	6.99241	4.09962	2.27940	.98885	.50214
-10.0 /	.00000	.00000	2.76326	4.76218	5.15899	3.68679	2.20361	.98201	.50111
-50.0 /	.00000	.00000	.00000	.00000	.00349	.28866	.97872	.83119	.47702
-100.0 /	.00000	.00000	.00000	.00000	.00010	.07748	.49363	.40893	
-300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00190	.07911	
-500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00296	

'N'-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC CO CONCENTRATIONS -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*

\* FROM ALL SOURCES \*  
\* FOR THE RECEPTOR GRID \*

\* MAXIMUM VALUE EQUALS 17.27225 AND OCCURRED AT (10.0,.0) \*

Y-AXIS / X-AXIS (METERS)	(METERS) / 2000.0
500.0 /	.05346
300.0 /	.14066
100.0 /	.22815
50.0 /	.23873
10.0 /	.24222
.0 /	.24237
-10.0 /	.24222
-50.0 /	.23873
-100.0 /	.22815
-300.0 /	.14066
-500.0 /	.05346

D.1.3 Runs of ISCST for Particulates:

1

ISCST (DATED 88166)  
AN AIR QUALITY DISPERSION MODEL IN

SECTION 1. GUIDELINE MODELS  
 IN UNAMAP (VERSION 6) JAN. 88.  
 BOWMAN ENVIRONMENTAL ENGINEERING REV.6.5

SESSION INFORMATION

INPUT DATA FILE NAME : BDATA.DTA  
 OUTPUT LIST FILE NAME : PARTI

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC PARTICLE CONCENT. -- \*\*\*

CALCULATE (CONCENTRATION=1,DEPOSITION=2)	ISW(1) = 1
RECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POLAR=2 OR 4)	ISW(2) = 1
DISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2)	ISW(3) = 1
TERRAIN ELEVATIONS ARE READ (YES=1,NO=0)	ISW(4) = 0
CALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0)	ISW(5) = 0
LIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2)	ISW(6) = 2

COMPUTE AVERAGE CONCENTRATION (OR TOTAL DEPOSITION) WITH THE FOLLOWING TIME PERIODS:	
HOURLY (YES=1,NO=0)	ISW(7) = 1
2-HOUR (YES=1,NO=0)	ISW(8) = 0
3-HOUR (YES=1,NO=0)	ISW(9) = 0
4-HOUR (YES=1,NO=0)	ISW(10) = 0
6-HOUR (YES=1,NO=0)	ISW(11) = 0
8-HOUR (YES=1,NO=0)	ISW(12) = 0
12-HOUR (YES=1,NO=0)	ISW(13) = 0
24-HOUR (YES=1,NO=0)	ISW(14) = 1
PRINT 'N'-DAY TABLE(S) (YES=1,NO=0)	ISW(15) = 1

PRINT THE FOLLOWING TYPES OF TABLES WHOSE TIME PERIODS ARE SPECIFIED BY ISW(7) THROUGH ISW(14):	
DAILY TABLES (YES=1,NO=0)	ISW(16) = 0
HIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0)	ISW(17) = 0
MAXIMUM 50 TABLES (YES=1,NO=0)	ISW(18) = 0
METEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2)	ISW(19) = 2
RURAL-URBAN OPTION (RU.=0,UR. MODE 1=1,UR. MODE 2=2,UR. MODE 3=3)	ISW(20) = 0
WIND PROFILE EXPONENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(21) = 1
VERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(22) = 1
SCALE EMISSION RATES FOR ALL SOURCES (NO=0,YES>0)	ISW(23) = 0
PROGRAM CALCULATES FINAL PLUME RISE ONLY (YES=1,NO=2)	ISW(24) = 2
PROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1)	ISW(25) = 1
PROGRAM USES BUOYANCY INDUCED DISPERSION (YES=1,NO=2)	ISW(26) = 0
CONCENTRATIONS DURING CALM PERIODS SET = 0 (YES=1,NO=2)	ISW(27) = 2
REG. DEFAULT OPTION CHOSEN (YES=1,NO=2)	ISW(28) = 0
TYPE OF POLLUTANT TO BE MODELLED (1=SO2,2=OTHER)	ISW(29) = 0
DEBUG OPTION CHOSEN (YES=1,NO=2)	ISW(30) = 0
ABOVE GROUND (FLAGPOLE) RECEPTORS USED (YES=1,NO=0)	ISW(31) = 0

NUMBER OF INPUT SOURCES	NSOURC = 1
NUMBER OF SOURCE GROUPS (=0,ALL SOURCES)	NGROUP = 0
TIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS)	IPERD = 1
NUMBER OF X (RANGE) GRID VALUES	NXPNTS = 10
NUMBER OF Y (THETA) GRID VALUES	NYPNTS = 11
NUMBER OF DISCRETE RECEPTORS	NXWYPT = 0
NUMBER OF HOURS PER DAY IN METEOROLOGICAL DATA	NHOURS = 1
NUMBER OF DAYS OF METEOROLOGICAL DATA	NDAYS = 1
SOURCE EMISSION RATE UNITS CONVERSION FACTOR	TK = .10000E+07
HEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED	ZR = 10.00 METERS
LOGICAL UNIT NUMBER OF METEOROLOGICAL DATA	IMET = 5
ALLOCATED DATA STORAGE	LIMIT = 43500 WORDS
REQUIRED DATA STORAGE FOR THIS PROBLEM RUN	MIMIT = 858 WORDS

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC PARTICLE CONCENT. -- \*\*\*

\*\*\* UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES \*\*\*  
 (METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

\*\*\* X-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
(METERS)

.0, 5.0, 10.0, 20.0, 50.0, 100.0, 200.0, 500.0, 1000.0, 2000.0,

\*\*\* Y-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
(METERS)

-500.0, -300.0, -100.0, -50.0, -10.0, .0, 10.0, 50.0, 100.0, 300.0, 500.0,

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC PARTICLE CONCENT. -- \*\*\*

\*\*\* SOURCE DATA \*\*\*

BLDG.	T	W	EMISSION RATE		X	Y	ELEV.	HEIGHT	TEMP.	EXIT VEL.	BLDG.	BLDG.
			TYPE=0,1	TYPE=2					TYPE=0	TYPE=0		
WIDTH	Y	A	NUMBER	TYPE=2	BASE	VERT.DIM	HORZ.DIM	DIAMETER	HEIGHT	LENGTH		
TYPE=0	SOURCE	P	K	PART.	(GRAMS/SEC)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)
NUMBER	E	E	CATS.	*PER METER**2	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)
(METERS)	(METERS)											

1 1 0 0 .33300E-02 .0 .0 .0 .00 930.23 3.28 .00 .00 .00 .00

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC PARTICLE CONCENT. -- \*\*\*

\* SOURCE-RECEPTOR COMBINATIONS LESS THAN 001 METERS OR THREE BUILDING HEIGHTS IN DISTANCE. NO AVERAGE CONCENTRATION IS CALCULATED \*

SOURCE NUMBER	- - RECEPTOR LOCATION - -		DISTANCE BETWEEN (METERS)
	X OR RANGE (METERS)	Y (METERS) OR DIRECTION (DEGREES)	
1	.0	.0	-7.06
1	5.0	.0	-2.06

MET. DATA

DAY 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC PARTICLE CONCENT. -- \*\*\*

\* METEOROLOGICAL DATA FOR DAY 1 \*

FLOW VECTOR HOUR	WIND SPEED (DEGREES)	MIXING HEIGHT (MPS)	TEMP. (METERS)	GRADIENT (DEG. K) (DEG. K)	STABILITY PER METER	POT. TEMP.	DECAY
						WIND PROFILE CATEGORY	COEFFICIENT (PER SEC)
1	90.0	2.47	1911.0	290.5	.0000	2	.0700 .000000E+00

'N'-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC PARTICLE CONCENT. -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*

\* FROM ALL SOURCES \*  
\* FOR THE RECEPTOR GRID \*

Y AXIS / X AXIS (METERS) (METERS) /	* MAXIMUM VALUE EQUALS .08808 AND OCCURRED AT ( 10.0, .0) *									
	.0	5.0	10.0	20.0	50.0	100.0	200.0	500.0	1000.0	
500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00002	
300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00040	
100.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00040	.00252	.00209	
50.0 /	.00000	.00000	.00000	.00000	.00002	.00147	.00499	.00424	.00243	
10.0 /	.00000	.00000	.01409	.02428	.02631	.01880	.01124	.00501	.00256	
.0 /	.00000	.00000	.08808	.06389	.03566	.02091	.01162	.00504	.00256	
-10.0 /	.00000	.00000	.01409	.02428	.02631	.01880	.01124	.00501	.00256	
-50.0 /	.00000	.00000	.00000	.00000	.00002	.00147	.00499	.00424	.00243	
-100.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00040	.00252	.00209	
-300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00040	
-500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00002	

1-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC PARTICLE CONCENT. -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*

\* FROM ALL SOURCES \*  
\* FOR THE RECEPTOR GRID \*

\* MAXIMUM VALUE EQUALS .08808 AND OCCURRED AT (10.0,.0) \*

Y-AXIS / X-AXIS (METERS) (METERS) /	2000.0
500.0 /	.00027
300.0 /	.00072
100.0 /	.00116
50.0 /	.00122
10.0 /	.00124
.0 /	.00124
-10.0 /	.00124
-50.0 /	.00122
-100.0 /	.00116
-300.0 /	.00072
-500.0 /	.00027

D.1.4 Runs of ISCST for Lead:

ISCST (DATED 88166)  
AN AIR QUALITY DISPERSION MODEL IN  
SECTION 1. GUIDELINE MODELS  
IN UNAMAP (VERSION 6) JAN. 88.  
BOWMAN ENVIRONMENTAL ENGINEERING REV.6.5

SESSION INFORMATION

INPUT DATA FILE NAME : BDATA.DTA  
OUTPUT LIST FILE NAME : Pb

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC Pb CONCENTRATIONS -- \*\*\*

CALCULATE (CONCENTRATION=1,DEPOSITION=2)	ISW(1) = 1
RECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POLAR=2 OR 4)	ISW(2) = 1
DISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2)	ISW(3) = 1
TERRAIN ELEVATIONS ARE READ (YES=1,NO=0)	ISW(4) = 0
CALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0)	ISW(5) = 0
LIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2)	ISW(6) = 2
COMPUTE AVERAGE CONCENTRATION (OR TOTAL DEPOSITION) WITH THE FOLLOWING TIME PERIODS:	
HOURLY (YES=1,NO=0)	ISW(7) = 1
2-HOUR (YES=1,NO=0)	ISW(8) = 0
3-HOUR (YES=1,NO=0)	ISW(9) = 0
4-HOUR (YES=1,NO=0)	ISW(10) = 0
6-HOUR (YES=1,NO=0)	ISW(11) = 0
8-HOUR (YES=1,NO=0)	ISW(12) = 0
12-HOUR (YES=1,NO=0)	ISW(13) = 0
24-HOUR (YES=1,NO=0)	ISW(14) = 1
PRINT 'N'-DAY TABLE(S) (YES=1,NO=0)	ISW(15) = 1
PRINT THE FOLLOWING TYPES OF TABLES WHOSE TIME PERIODS ARE SPECIFIED BY ISW(7) THROUGH ISW(14):	
DAILY TABLES (YES=1,NO=0)	ISW(16) = 0
HIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0)	ISW(17) = 0
MAXIMUM 50 TABLES (YES=1,NO=0)	ISW(18) = 0
METEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2)	ISW(19) = 2
RURAL-URBAN OPTION (RU.=0,UR. MODE 1=1,UR. MODE 2=2,UR. MODE 3=3)	ISW(20) = 0
WIND PROFILE EXPONENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(21) = 1
VERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(22) = 1
SCALE EMISSION RATES FOR ALL SOURCES (NO=0,YES>0)	ISW(23) = 0
PROGRAM CALCULATES FINAL PLUME RISE ONLY (YES=1,NO=2)	ISW(24) = 2
PROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1)	ISW(25) = 1
PROGRAM USES BUOYANCY INDUCED DISPERSION (YES=1,NO=2)	ISW(26) = 0
CONCENTRATIONS DURING CALM PERIODS SET = 0 (YES=1,NO=2)	ISW(27) = 2
REG. DEFAULT OPTION CHOSEN (YES=1,NO=2)	ISW(28) = 0
TYPE OF POLLUTANT TO BE MODELLED (1=SO2,2=OTHER)	ISW(29) = 0
DEBUG OPTION CHOSEN (YES=1,NO=2)	ISW(30) = 0
ABOVE GROUND (FLAGPOLE) RECEPTORS USED (YES=1,NO=0)	ISW(31) = 0
NUMBER OF INPUT SOURCES	NSOURC = 1
NUMBER OF SOURCE GROUPS (=0,ALL SOURCES)	NGROUP = 0
TIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS)	IPERD = 1
NUMBER OF X (RANGE) GRID VALUES	NXPNTS = 10
NUMBER OF Y (THETA) GRID VALUES	NYPNTS = 11
NUMBER OF DISCRETE RECEPTORS	NXWYPT = 0
NUMBER OF HOURS PER DAY IN METEOROLOGICAL DATA	NHOURS = 1
NUMBER OF DAYS OF METEOROLOGICAL DATA	NDAYS = 1
SOURCE EMISSION RATE UNITS CONVERSION FACTOR	TK = .10000E+07
HEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED	ZR = 10.00 METERS
LOGICAL UNIT NUMBER OF METEOROLOGICAL DATA	IMET = 5
ALLOCATED DATA STORAGE	LIMIT = 43500 WORDS

REQUIRED DATA STORAGE FOR THIS PROBLEM RUN

MIMIT = 858 WORDS

1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC Pb CONCENTRATIONS -- \*\*\*

\*\*\* UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES \*\*\*

(METERS/SEC)  
1.54, 3.09, 5.14, 8.23, 10.80,

\*\*\* X-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
(METERS)

.0, 5.0, 10.0, 20.0, 50.0, 100.0, 200.0, 500.0, 1000.0, 2000.0,

\*\*\* Y-COORDINATES OF RECTANGULAR GRID SYSTEM \*\*\*  
(METERS)

-500.0, -300.0, -100.0, -50.0, -10.0, .0, 10.0, 50.0, 100.0, 300.0, 500.0,

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC Pb CONCENTRATIONS -- \*\*\*

\*\*\* SOURCE DATA \*\*\*

BLDG.	T W	EMISSION RATE		X	Y	BASE	VERT.DIM	TEMP.	EXIT VEL.	BLDG.	BLDG.	
		TYPE=0,1	TYPE=2					(DEG.K);	(M/SEC);			
WIDTH	Y A NUMBER	TYPE=2	BASE	VERT.DIM	HORZ.DIM	DIAMETER	HEIGHT	LENGTH	TYPE=0	TYPE=0	TYPE=0	
SOURCE P K	PART.	(GRAMS/SEC)	ELEV.	HEIGHT	TYPE=1	TYPE=1,2	TYPE=0	TYPE=0	TYPE=0	TYPE=0	TYPE=0	
NUMBER E E	CATS.	*PER METER**2	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	(METERS)	
(METERS)	(METERS)											
1 1 0	0	.41700E-03	.0	.0	.0	.00	930.23	3.28	.00	.00	.00	.00

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC Pb CONCENTRATIONS -- \*\*\*

\* SOURCE-RECEPTOR COMBINATIONS LESS THAN 001 METERS OR THREE BUILDING HEIGHTS IN DISTANCE. NO AVERAGE CONCENTRATION IS CALCULATED \*

- - RECEPTOR LOCATION - -			
SOURCE NUMBER	X OR RANGE (METERS)	Y (METERS) OR DIRECTION (DEGREES)	DISTANCE BETWEEN (METERS)
1	.0	.0	-7.06
1	5.0	.0	-2.06

MET. DATA

DAY 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC Pb CONCENTRATIONS -- \*\*\*



\* METEOROLOGICAL DATA FOR DAY 1 \*

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	90.0	2.47	1911.0	290.5	.0000	2	.0700	.000000E+00

'N'-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC Pb CONCENTRATIONS -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*

\* FROM ALL SOURCES \*  
\* FOR THE RECEPTOR GRID \*

\* MAXIMUM VALUE EQUALS .01103 AND OCCURRED AT (10.0,.0) \*

Y-AXIS (METERS)	X-AXIS (METERS)	.0	5.0	10.0	20.0	50.0	100.0	200.0	500.0	1000.0
500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00005
100.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00005	.00032	.00026
50.0 /	.00000	.00000	.00000	.00000	.00000	.00018	.00063	.00053	.00030	.00030
10.0 /	.00000	.00000	.00176	.00304	.00329	.00235	.00141	.00063	.00032	.00032
.0 /	.00000	.00000	.01103	.00800	.00447	.00262	.00146	.00063	.00032	.00032
-10.0 /	.00000	.00000	.00176	.00304	.00329	.00235	.00141	.00063	.00032	.00032
-50.0 /	.00000	.00000	.00000	.00000	.00000	.00018	.00063	.00053	.00030	.00030
-100.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00005	.00032	.00026	.00026
-300.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00005	.00005
-500.0 /	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000

'N'-DAY

1 DAYS

SGROUP# 1

\*\*\* -- EFFECT OF LINE SOURCE ON ATMOSPHERIC Pb CONCENTRATIONS -- \*\*\*

\* 1-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) \*

\* FROM ALL SOURCES \*  
\* FOR THE RECEPTOR GRID \*

\* MAXIMUM VALUE EQUALS .01103 AND OCCURRED AT (10.0,.0) \*

Y-AXIS (METERS)	X-AXIS (METERS)
500.0 /	.00003
300.0 /	.00009
100.0 /	.00015
50.0 /	.00015
10.0 /	.00015

.0 / .00015  
 -10.0 / .00015  
 -50.0 / .00015  
 -100.0 / .00015  
 -300.0 / .00009  
 -500.0 / .00003

D.1.5 Runs of CALINE-3 For Carbonmonoxide:

1 CALINE-3 (VERSION 86100)  
 AN AIR QUALITY DISPERSION MODELS IN  
 SECTION 1. GUIDELINE MODELS  
 IN UNAMAP (VERSION 6) JULY 86.  
 BOWMAN ENVIRONMENTAL ENGINEERING Ver 6.2  
 0 CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL - SEPTEMBER, 1979 VERSION  
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JOB: CO CONCENTRATION IN METU

RUN: CASE ONE

I. SITE VARIABLES

U = 2.5 M/S                      CLAS = 2 (B)                      VS = .0 CM/S                      ATIM = 30. MINUTES  
 MIXH = 1911. M  
 BRG = 90. DEGREES                      ZO = 283. CM                      VD = .0 CM/S                      AMB = .0 PPM

II. LINK VARIABLES

LINK DESCRIPTION	* LINK COORDINATES (M)	* LINK LENGTH	LINK BRG	TYPE	VPH	EF	H
(M)	* X1    Y1    X2    Y2	* (M)	(DEG)			(G/MI)	(M)
A. 2 Kms. ROAD SECTION	* 0.    10.    0.    2000.	* 1990.	360.	AG	850.	50.0	.010.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	* COORDINATES (M)	* CO
	* X    Y    Z	* (PPM)
1. RECP. 1 ENTRANCE A	* 15.    10.    1.0	* .0
2. RECP. 2	* 0.    10.    .0	* .5
3. RECP. 3	* 0.    20.    .0	* .9
4. RECP. 4	* 0.    50.    .0	* .9
5. RECP. 5	* 0.    100.    .0	* .9
6. RECP. 6	* 0.    200.    .0	* .9
7. RECP. 7	* 0.    500.    .0	* .9
8. RECP. 8	* 0.    1000.    .0	* .9
9. RECP. 9 SECTION END	* 0.    2000.    .0	* .5
10. RECP. 10	* 1000.    2000.    .0	* .0

D.1.6 Runs of CALINE-3 For Hydrocarbon Concentration:

1 CALINE-3 (VERSION 86100)

AN AIR QUALITY DISPERSION MODELS IN  
SECTION 1. GUIDELINE MODELS  
IN UNAMAP (VERSION 6) JULY 86.  
BOWMAN ENVIRONMENTAL ENGINEERING Ver 6.2  
CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL - SEPTEMBER, 1979 VERSION

0

PAGE 1

JOB: HC CONCENTRATION IN METU

RUN: CASE ONE

I. SITE VARIABLES

U = 2.5 M/S                      CLAS = 2 (B)                      VS = .0 CM/S                      ATIM = 30. MINUTES  
MIXH = 1911. M  
BRG = 90. DEGREES                      ZO = 283. CM                      VD = .0 CM/S                      AMB = .0 PPM

II. LINK VARIABLES

LINK DESCRIPTION W (M)	* LINK COORDINATES (M)				* LINK LENGTH	LINK BRG	TYPE	VPH	EF	H
	* X1	Y1	X2	Y2	* (M)	(DEG)			(G/MI)	(M)
A. 2 Kms. ROAD SECTION	* 0.	10.	0.	2000.	* 1990.	360.	AG	850.	4.9	.010.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	* COORDINATES (M)			* CO
	* X	Y	Z	* (PPM)
1. RECP. 1 ENTRANCE A	* 15.	10.	1.0	* .0
2. RECP. 2	* 0.	10.	.0	* .0
3. RECP. 3	* 0.	20.	.0	* .0
4. RECP. 4	* 0.	50.	.0	* .0
5. RECP. 5	* 0.	100.	.0	* .0
6. RECP. 6	* 0.	200.	.0	* .0
7. RECP. 7	* 0.	500.	.0	* .0
8. RECP. 8	* 0.	1000.	.0	* .0
9. RECP. 9 SECTION END	* 0.	2000.	.0	* .0
10. RECP.10	* 1000.	2000.	.0	* .0

D.1.7 Runs of CALINE-3 For Lead Concentration:

1 CALINE-3 (VERSION 86100)  
AN AIR QUALITY DISPERSION MODELS IN  
SECTION 1. GUIDELINE MODELS  
IN UNAMAP (VERSION 6) JULY 86.  
BOWMAN ENVIRONMENTAL ENGINEERING Ver 6.2  
0 CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL - SEPTEMBER, 1979 VERSION

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JOB: Pb CONCENTRATION IN METU

RUN: CASE ONE

I. SITE VARIABLES

U = 2.5 M/S                    CLAS = 2 (B)                    VS = .0 CM/S                    ATIM = 30. MINUTES  
MIXH = 1911. M                    Z0 = 283. CM                    VD = .0 CM/S                    AMB = .0 PPM  
BRG = 90. DEGREES

II. LINK VARIABLES

W	LINK DESCRIPTION	*	LINK COORDINATES (M)				*	LINK LENGTH (M)	LINK BRG (DEG)	TYPE	VPH	EF (G/MI)	H (M)
			X1	Y1	X2	Y2							
(M)		*				*							
-----*													
	A. 2 Kms. ROAD SECTION	*	0.	10.	0.	2000.	*	1990.	360.	AG	850.	.0 .010	

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	*	COORDINATES (M)			*	CO (PPM)
		X	Y	Z		
1. RECP. 1 ENTRANCE A	*	15.	10.	1.0	* .0	
2. RECP. 2	*	0.	10.	.0	* .0	
3. RECP. 3	*	0.	20.	.0	* .0	
4. RECP. 4	*	0.	50.	.0	* .0	
5. RECP. 5	*	0.	100.	.0	* .0	
6. RECP. 6	*	0.	200.	.0	* .0	
7. RECP. 7	*	0.	500.	.0	* .0	
8. RECP. 8	*	0.	1000.	.0	* .0	
9. RECP. 9 SECTION END	*	0.	2000.	.0	* .0	
10. RECP.10	*	1000.	2000.	.0	* .0	

D.1.8 Runs of CALINE-3 For Particulate Concentration:

1 CALINE-3 (VERSION 86100)  
AN AIR QUALITY DISPERSION MODELS IN  
SECTION 1. GUIDELINE MODELS  
IN UNAMAP (VERSION 6) JULY 86.  
0 BOWMAN ENVIRONMENTAL ENGINEERING Ver 6.2  
CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL - SEPTEMBER, 1979 VERSION  
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JOB: PARTICLE CONCENTRATION IN METU

RUN: CASE ONE

I. SITE VARIABLES

U = 2.5 M/S                    CLAS = 2 (B)                    VS = .0 CM/S                    ATIM = 30. MINUTES  
MIXH = 1911. M                    Z0 = 283. CM                    VD = .0 CM/S                    AMB = .0 PPM  
BRG = 90. DEGREES

II. LINK VARIABLES

W	LINK DESCRIPTION	*	LINK COORDINATES (M)				*	LINK LENGTH (M)	LINK BRG (DEG)	TYPE	VPH	EF (G/MI)	H (M)
			X1	Y1	X2	Y2							
		*				*							

(M)

-----\*-----\*-----  
A. 2 Kms. ROAD SECTION \* 0. 10. 0. 2000. \* 1990. 360. AG 850. .4 .010

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	*	COORDINATES (M)			*	CO * (PPM)
		X	Y	Z		
1. RECP. 1 ENTRANCE A	*	15.	10.	1.0	*	.0
2. RECP. 2	*	0.	10.	.0	*	.0
3. RECP. 3	*	0.	20.	.0	*	.0
4. RECP. 4	*	0.	50.	.0	*	.0
5. RECP. 5	*	0.	100.	.0	*	.0
6. RECP. 6	*	0.	200.	.0	*	.0
7. RECP. 7	*	0.	500.	.0	*	.0
8. RECP. 8	*	0.	1000.	.0	*	.0
9. RECP. 9 SECTION END	*	0.	2000.	.0	*	.0
10. RECP.10	*	1000.	2000.	.0	*	.0

APPENDIX E

TABLE E.1 Regression Analysis Table for Particulate and Lead Concentrations.

Regression Analysis - Linear Model : $Y = a + bX$					
Dependent Variable : Particulate Conc.			Independent Variable : Lead Conc.		
Parameter	Estimate	Standard Error	T Value	Probability Level	
Intercept	2.28239	0.903032	2.52748	0.01741	
Slope	0.00301	0.001476	2.04120	0.05076	
Analysis of Variance (ANOVA)					
Source	Sum of Squares	Df	Mean Square	F-Ratio	Probability Level
Model	20.157928	1	20.157928	4.16651	0.05076
Error	135.466460	28	4.838090		
Total (corr.)	155.624390	29			
Correlation Coefficient = 0.359902					
Standard Error of Estimation = 2.199570					
R-Squared = 12.95 %					

**TABLE E.2 Regression Analysis Table for Particulate and Smoke Concentrations.**

Regression Analysis - Linear Model : $1/Y = a + bX$					
Dependent Variable : Particulate Conc.			Independent Variable : Smoke Conc.		
Parameter	Estimate	Standard Error	T Value	Probability Level	
Intercept	0.271066	0.0842111	3.21888	0.00325	
Slope	0.405383	0.2572930	1.57557	0.12636	
Analysis of Variance (ANOVA)					
Source	Sum of Squares	Df	Mean Square	F-Ratio	Probability Level
Model	0.1707402	1	0.1707402	2.432409	0.12636
Error	1.9258420	28	0.0687800		
Total (corr.)	2.096582	29			
Correlation Coefficient = 0.285372				R-Squared = 8.14 %	
Standard Error of Estimation = 0.262260					

TABLE E.3 Regression Analysis Table for Lead and Smoke Concentrations.

Regression Analysis - Linear Model : $Y = a + X^b$			
Dependent Variable : Lead Conc.		Independent Variable : Smoke Conc.	
Parameter	Estimate	Standard Error	T Value
Intercept*	6.486050	0.260097	24.93700
Slope	0.196606	0.167286	1.17527
* NOTE: The intercept is equal to Log a.			
Analysis of Variance (ANOVA)			
Source	Sum of Squares	Df	Mean Square
Model	0.3064438	1	0.3064438
Error	6.2119890	28	0.2218570
Total (corr.)	6.518433	29	
Correlation Coefficient = 0.216822			R-Squared = 4.70 %
Standard Error of Estimation = 0.471017			