POLLUTION DISPERSION MATRIX OF TRANSPORT: A CASE STUDY OF MEGHALAYA

ABSTRACT

By

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THESIS
SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY IN ECONOMICS

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To

DEPARTMENT OF ECONOMICS
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ABSTRACT

1. Introduction

In recent times, people are showing keen interest in the quality of the ambient air. The air is not free from pollutants. The pollutants are caused mainly by the smokes that are emitted due to the burning of wood, coal and fuel. Automobiles are responsible for most of the air pollutants. The automobiles emit particulate matter, Sulphur dioxide, Oxides of Nitrogen, Lead, Hydrocarbons and Carbon monoxide in the atmosphere, thus polluting the air. The pollutants are responsible for a number of respiratory illness, skin diseases, eye irritation etc. Hence, pollutants have a direct impact on health.

2. Objectives

The objectives of our study are as under :

1) Our main aim is to find the amount of pollution caused by emission due to road transportation.

2) A mathematical model of the transport sector of the economy has been considered to assess the amount of pollution due to transportation with special reference to road transportation both for goods and passengers derived from the demand for transportation of the same.

3) We have tried to find out a relationship between the pollutants and the different pollution-related diseases, which are later related to economic loss in terms of loss of man-days and the cost of medicines and medical care. We have also tried to find out the cleaning cost due to pollution by using primary data.

3. Chapter Plan

Chapter-I deals with the introduction.

In Chapter-II, we have reviewed the literature concentrating mainly on the global scenario. The literature covers the study of pollution scenario of many countries of the world. With the increasing growth of vehicular population, the world is facing a critical situation. In this chapter, we have studied the factors responsible for air pollution, the effects of air pollution on agriculture, vegetation and human health. The literature also covers the study of economic loss, deterioration of exposed materials, etc. This chapter also deals with the rules and regulations adopted by different countries and the measures to control air pollution.

In Chapter-III, we have studied the pollution scenario of some cities of India. They include Delhi, Bombay, Bangalore, Calcutta, Ahmedabad, Hyderabad, Madras, Pune, Jaipur, Kanpur, Lucknow, Nagpur and Chandigarh. This chapter also covers the study of the factors responsible for air pollution from India's point of view. This chapter also deals with the Pollution Control Rules and Regulations in India and the measures taken by the Government to control pollution.

In Chapter-IV, we have studied the pollution scenario of Meghalaya, the state of our interest. In this chapter, we have studied the ambient air quality of some of the localities of the state. This chapter also includes the standards for vehicular emission set up by the Government of Meghalaya with the collaboration of the State Pollution Control Board.

Chapter-V deals with the methodology, data-base and analysis.

The objective of our study is to find the effect of pollution not only on the habitat as such but also on the human population. In this particular thesis, we want to look into two different directions :

1) loss of health, medical treatment, loss of working days.

2) cleaning expenditure, the devaluation of roadside dwellings, etc.

Since the objective of our study is to find the effects of pollution on human health, we need to find the amount of pollutants. For this we have estimated

a) the demand for passenger-km.

b) the demand for vehicle-km.

c) the demand for different types of fuel for transportation and finally

d) we have estimated the different types of pollutants.

The data collection was made at various places. The data on transport was collected from the Ministry of Transport, New Delhi, the Commissioner of Transport, Shillong, the District Transport Office, Shillong, and the Directorate of Economics and Statistics, Government of Meghalaya, Shillong.

The data on patients was collected from various government and private hospitals of the state, and from the Directorate of Health Services, Shillong.

In the next phase we have made an attempt to analyse the causes of different types of diseases that are influenced by pollution. For this purpose, we have used a regression equation model taking pollutants as independent variables and diseases as dependent variable.

From the analysis, we have seen that in some equations, the co-efficient of determination, i.e. R^2 is much less than 0.4, yet the estimates of the parameters are significant at desired level of significance, say, at 0.05 level of significance whereas some empirical equations demonstrate that the factor R^2 is as high or higher than 0.60 and yet the estimates of parameters are not significant. Thus we have given more weightage to reliability of estimates rather than for the best fit.

In Chapter-VI, we have given a brief conclusion of our study.

4. Conclusion

From the overall analysis we have seen that Oxides of Nitrogen is the most harmful pollutant causing all the pollution-related diseases. The next harmful being particulate matter.

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SUPERVISOR'S CERTIFICATE

Certified that the thesis entitled ***POLLUTION DISPERSION MATRIX OF TRANSPORT - A CASE STUDY OF MEGHALAYA*** submitted by **Ms. Jaya Gupta Choudhury** for the **Degree of Doctor of Philosophy in Economics** of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by her under my supervision.

She has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D degree. This work has not been submitted for any degree of any other University.

Dated December 5, 1995.

(K. BEZ)
Supervisor

DEDICATED

TO

MY PARENTS

CONTENTS

Page No.:

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December 11 , 1995

(JAYA GUPTA CHOUDHURY)

INDEX

b pkm	=	billion passenger kilometre
bt km	=	billion ton kilometre
BDL	=	Below Detection Limit
CO_2	=	Carbon dioxide
CO	=	Carbon monoxide
DHS	=	Directorate of Health Services
DTC	=	Delhi Transport Office
DW	=	Darbin-Watson
EC	=	European Community
EEC	=	European Economic Community
EEA	=	European Economic Area
EC-EFTA	=	European Community - European Free Trade Association
g/l	=	gram per litre
H_2S	=	Hydrogen Sulphide
kwh	=	Kilowatt hour
LCV	=	Light Commercial Vehicle
LTV	=	Light Transport Vehicle
µg	=	microgram
MTC	=	Meghalaya Transport Corporation
Meg	=	Meghalaya

MIDC	=	Meghalaya Industrial Development Corporation
NMHC	=	Non-Methane Hydro Carbon
NO_x	=	Oxides of Nitrogen
ON	=	Octane Number
PAN	=	Peroxyacetyl Nitrate
PM	=	Particulate Matter
ppm	=	parts per million
Pb	=	lead
SO_2	=	Sulphur Dioxide
SPM	=	Suspended Particulate Matter
TEL	=	Tetra Ethyl Lead
UP	=	Uttar Pradesh
USEPA	=	United State Environmental Protection
VOC	=	Volatile Organic Compounds
WHO	=	World Health Organization

Chapter-I

INTRODUCTION

The quality of the atmosphere on which existing terrestrial forms of life are dependent has been recognized as an important variable in the environment only during the past few decades. Throughout the earlier periods of history, wood was the prime source of energy. The dependence on wood was replaced by the discovery of coal as a source of energy.

From the beginning of the fourteenth century to the early part of the twentieth, air pollution by coal smoke and gases occupied the centre of the stage almost exclusively, and in many industrialized areas of the world, it is still the dominant concern. The necessary action to control air pollutants was taken only after their killing or irritating potentials have been realized on a large scale.

No rigorous identification of the constituents of coal smoke responsible for the respiratory illness with which it has been associated has been produced, although the effects have been generally attributed to sulphur dioxide and trioxide. Smoke and gases from the burning of coal have been the chief atmospheric pollutants in all parts of the industrialized world for more than 400 years. Inspite of the recent rapid shift to petroleum and natural gas, coal smoke still is a major contributor to poor air quality in most urbanized areas.

The contribution of automobile engine exhausts to the atmosphere was pointed out as a potential hazard as early as 1915 and the objectionable fumes from diesel power plant have been a matter of concern until about 1945, when the first acute air pollution problem definitely attributable to petroleum products and their use forced itself into public and official recognition which lead to series of enactments.

In recent years, there has been great interest in the environment and many 'new' words have become part of our vocabulary -- words such as ecology, environment, photochemical smog and green house effects. Simultaneously, we have been made aware of environmental problems caused by the high technology created to achieve the material comforts we demand and to provide us with the military protection we think we need. Among these problems are the effects of air pollution. Now the question is why at this time should we be concerned about air pollution ? After all man has lived centuries in atmosphere permeated by dust, methane, from decomposing materials in bogs and swamps and other hydrocarbon compounds emitted by trees in the forests. Society's concern exists now because urbanization and industrialization have brought together larger concentrations of people in small areas. Much of our industrialization is the result of a standard of living which requires a car or two for every family.

Transport is now one of the main causes of environmental damage. The predominant factor being road traffic. Automobile emission factors are highly variable depending on the attitude of the city and the local driving patterns, that is, free way driving versus stop-and-go city driving. Motor vehicles are a major source of several of air pollutants. We should consider why pollution from cars is a problem in 1970 when it was not so in 1940. Though engine design has improved to reduce pollutants, why does pollution increase? Briefly, the number of motor cars is increasing at a rate which is even more rapid than the population rise. We see that recent vehicle population problems result not merely from a rising population but more so from the increase in vehicle per person.

Increase in transportation is seen both in developed and developing countries, though there are distinct differences between the two. For instance, in a developing country, pedestrians, animal power, bicycles, two wheeler vehicles (mopeds, scooters, etc.) are increasingly rising, while in a developed country, it is automobile growth that is most significant. Along with the benefits occurring from increasing transportation, i.e. accessibility, distribution of goods and services, trade and commerce, there is the potential danger of causing undesirable and harmful effects on quality of environment. It is this facet of transportation that has to be looked into from environmental point of view. The phenomenal growth of automobile traffic all over the world has elicited considerable solicitude about the associated negative effects. Limited success has been obtained by some governments in controlling such effects. Governments are concerned about the cost of private motoring, energy consumption, pollution, congestion and noise. Though global air pollution from motor vehicle emissions is growing at an alarming rate because of rapid urbanization and increasing use of motor transport in Third World Countries, yet very few countries have taken up measures to control air pollution due to transportation.

In India, the acuteness of the problem was realized in mid-eighties. From that time, some action was initiated. The vehicle population in India has risen considerably during the Seventh Five Year Plan. The air pollution due to transport has reached an alarming height. The effect of pollutants on human health has become the greatest concerns.

Meghalaya, a small state of the Indian Territory is situated at the North-East corner of the country. Shillong, the capital city of the State, accounts for the highest number of vehicles in India in terms of population-car ratio. It is a well-known fact that the pollutants are responsible for a number of diseases viz. respiratory illness, skin diseases, eye irritation, lung carcinoma, etc. In our present study, we have tried to highlight some of these problems.

Objectives

1) In our study, we have tried to find out the amount of pollution caused by emissions due to vehicular transport.

2) A mathematical model of the transport sector of economy has been considered to assess the amount of pollution due to transportation with special reference to road transportation both for goods and passengers derived from the demand for transportation of the same.

3) We have tried to find a relationship between the pollutants and the different pollution related diseases, which are later related to economic loss in terms of loss of man-days and the cost of medicines and medical care. We have also tried to find out the cleaning cost by using primary data.

Chapter Plan

Chapter-I : Chapter-I deals with the introduction.

Chapter-II : In Chapter-II, we have given the review of literature. In this chapter, we have reviewed the international scenario. Here we have studied the causes of air pollution due to transport, the international laws to control it and the effect of pollution on biosphere. The remedies to control air pollution due to transport are also given in this chapter.

Chapter-III : In this chapter we have dealt with the pollution scenario in India. We have considered some Metropolitan cities of the country and studied the ambient air quality of those cities. Also we have studied the causes of pollution from India's point of view. In this chapter, we have given the rules and regulations of pollution control as set up by the Government of India.

Chapter-IV : In Chapter-IV, we have studied the pollution scenario of Meghalaya, the state of our interest. In this chapter, we have studied the ambient air quality of some of the localities of the state. This chapter also deals with the standards for vehicular emission set up by the Government of Meghalaya with the collaboration of the State Pollution Control Board.

Chapter-V : Chapter-V deals with methodology, data-base and analysis of our study. To assess the effect of pollutants on health, regression equation model has been used with pollutants as independent variables and diseases as dependent variables. In this chapter, we have given a detailed analysis of the regression equations. In the same chapter, we have also dealt with economic loss in terms of medical cost, man-days cost, and cleaning cost due to pollution.

Chapter-VI : This chapter deals with the general conclusion emerging out of this study.

Chapter-II

REVIEW OF LITERATURE

2.1. Introduction[1]

Transport is one of the main causes of environmental damage within the community, the predominant factor being road traffic. The transport sector accounts for almost 30 per cent of the final energy consumption in the community. Of that total 84.4 per cent is ascribable to road traffic, 11.1 per cent to aircraft, 2.5 per cent to railways and 2.01 per cent to inland waterway traffic. In 1986, 577 million tons of carbon dioxide (CO_2), which is 22.5 per cent of the EC total, were emitted from transport vehicles. Road traffic was again the chief offender, accounting for 79.7 per cent of the CO_2 emissions from transportation. Of this sub-total, passenger cars were answerable to 55.4 per cent, trucks 22.7 per cent, aircraft 10.9 per cent and rail traffic 3.9 per cent.

Road transport is a major source of other air pollutants too – contributing 54 per cent of the EC emissions of Oxides of Nitrogen (NO_x), 27 per cent of those volatile organic compounds and 74 per cent of the carbon monoxide (CO). Road carrying, which increased its share of the

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1. The issue of a *Green Paper* by the European Commission on February 19, 1992, marked the first serious attempt to integrade environmental protection into EC transport policy.

freight market from 56 per cent in 1970 to 73 per cent in 1988, is expected to have grown by 42 per cent by the year 2010. Between 1987 and 2010 the stock of passenger cars is projected to increase from 115 to 167 million and total the car mileage by 25 per cent (as from 1990). A rise of 74 per cent is predicted for air travel.[1]

2.2. "Automotive Air Pollution : Issues and Options for Developing Countries" says that by the year 2000, motor vehicle pollution will be more than double in some of the large cities in developing countries. It says that the projected increase of the world population from 4,800 million in 1985 to over 6,000 million in 2000 will be largely felt in developing countries. This growth will be concentrated in urban centres where motor transportation will also increase proportionately. The study notes that in 1985, eight of the world's 12 urban centres with a population of 10 million or more were located in developing countries. This number is expected to be more than double by the year 2000. There will be 17 out of 23 urban centres with population of 10 million or more. In addition, the study says, 18 metropolitan areas in developing countries will have population between 5 and 10 million. The study also warns that unless effective measures

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1. For sustainable mobility - "Acid News", May 1992.

are taken to curb air pollution, almost 400 million city population in the Third World will be exposed to unhealthy and dangerous levels of air contamination by the turn of the century. The study also says that the atmospheric pollutants associated with motor vehicles -- Carbon monoxide (CO), Oxides of Nitrogen (NO_x), Sulphur dioxide (SO_2), particulate matter (PM) and lead (Pb) -- often exceed World Health Organization (WHO) guidelines in many large cities of the Third World such as Mexico City, Sao Paulo and Santiago in Latin America, Ibadan and Lagos in Africa, nearly all the mega cities in Asia (notably Bangkok, Bombay, Jakarta, Manila and Seoul) and some secondary urban centres like Medan in Indonesia, Klang in Malaysia, Ankara, Cairo and Tehran in the Middle East and most major urban centres in Eastern Europe, for example, Belgrade, Budapest, Istanbul and Sarajevo. Mexico city, with the population of 20 million, is the most polluted city in the world. Reflecting the fact that automobile ownership is less widespread in Third World than in industrialized countries, ownership in the former has been rising much faster than in the latter in percentage terms. Between 1984 and 1988, the annual growth of motor vehicles in Korea was 30 per cent, in Kenya 26 per cent, in China 14 per cent, in Brazil 11 per cent and in Pakistan and Thailand 9 per cent compared to about 2 per cent in the United States and 3 per cent in the United Kingdom.

Higher levels of pollution are foreseen for the mega cities of the Third World because these motor vehicle growth trends of the 1980's reflect what might be expected in the year 2000 and because of expected continued heavy reliance on poorly maintained buses for public transportation. Compounding the problem of mere numbers, many of the vehicles driven have no emission control equipment, such as catalytic converters, and many use low-quality fuel which generates larger amount of lead and sulphur dioxide.

The study also notes that the urban centres in the Third World — unlike those in the industrialized world — have denser concentrations of people who follow life-style that expose them to higher levels of pollution. For example, street-space is often limited and polluted air gets trapped between buildings.

Potentially significant pollutants discharged directly by petrol-powered motor vehicles are CO, Pb, NO_x, aldehydes, ethylene and perhaps aromatic hydro-carbons. Emissions of aliphatic hydrocarbons other than ethylene are not considered of importance, except in the causation of photochemical pollution.

Exhaust gases from diesel engines contain negligible amount of CO, no lead and somewhat lower amount of the lighter hydro-carbons per unit of fuel consumed than are emitted by petrol-powered vehicles.

The major sources of potential air pollution throughout the world can be grouped into :

a) industrial processes, which are slowly decreasing in importance, especially near major cities, because of the application of control.

b) industrial and domestic combustion of fossil fuels which produces smoke, dust and sulphur dioxide.

c) motor vehicles, which besides emitting pollutants like CO, Pb, NO_x and particulate matter also give rise to photochemical oxidant pollutants; diesel powered vehicles emit irritating and malodorous fumes and smokes.[1]

Vehicle emissions which contain CO, unburnt HC, NO_x, SO_2 and smoke are creating stress to environment, thereby disturbing our ecology. Vehicle population which consumes more amount of oxygen than men are depleting the oxygen of the atmosphere. As a result, we are exposed to highly poisonous air.

Due to incomplete combustion of petrol in the carburetor, the exhaust gas from petrol powered engine contains CO and HC. These toxic gases are mainly formed by our negligence and improper maintenance of the engine, because if the engine is properly tuned, the product of

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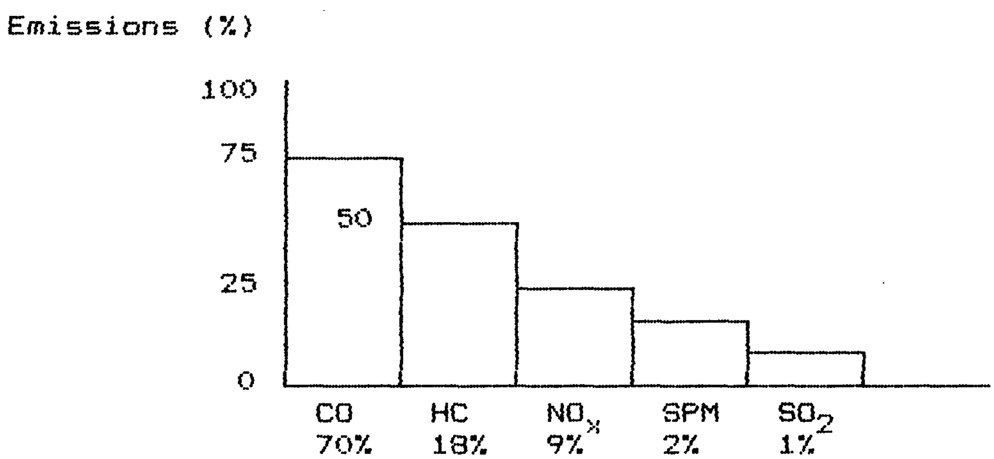
1. "Urban Air Pollution with Particular Reference to Motor Vehicles" - Report of a WHO Expert Committee, Geneva, 1969.

combustion, which depends mainly on the air-fuel ratio in the cylinder, will be only CO_2 which is harmless. A significant portion of the HC in the air comes from evaporation alone. According to one study, an average Indian car looses about 15 kg. of petrol per year by evaporation.[1]

According to survey, if we maintain air-fuel ratio of 15, we get higher generation of NO_x (4000 ppm) with HC (of about 100 ppm) and CO (of about 2 ppm). The ideal carburetor setting is done at a ratio of 13-16. The figure given below depicts a clear picture of the pollutants dispersed due to transportation.[2].



Transportation

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1. Automobile : A Source of Environmental Pollution", Arup Laskar's, The Sentinel, 7th January, 1992.

2. S.M. Khopkar, Environmental Pollution Analysis, 1993.

In most part of the world, the traditional problems associated with industrial production and the consumption of fuels are still of more importance than those due to pollution by motor vehicles. By contrast, in the U.S.A., the motor vehicles are considered to be the main source of pollution. Some 60 per cent of the total weight of pollutants discharged into the atmosphere of the U.S.A. originate from this source. As the number of vehicles continues to increase it is expected that oxidant pollution may become a problem in other cities if control measures are not introduced.

The emission of CO_2 which gas-scientists believe to be the biggest contributor to climate change, fell in 1990, according to Worldwatch Institute, an environmental organization. The Washington-based concern has predicted a continuing decline in 1991. Worldwatch attributed most of the drop in 1990 to the collapse of the economies of Soviet Union and countries in Eastern Europe. Those economies are heavily based on coal, which produces more CO_2 per quantity of energy than other fuels. In addition, these countries use more energy per unit of production than western countries, so any economic decline means a sharp drop in fuel use.

However, the overall decline in 1990 was small, less than two-tenths of a percent. Basing its estimates on data obtained from the Oak Ridge National Laboratory and British

Petroleum, Worldwatch calculated total global emissions in 1990 were 5,803 billion tonnes, down from 5,813 billion in 1989. Since 1950, the trend has been up steadily, except for the periods immediately after the oil price drops of 1973 and 1979. Emissions in 1990 were up by 12.8 per cent from 1980 and 44.6 per cent since 1970. Since 1950, emissions have nearly quadrupled.

Christopher Flavin, a Vice-President of Worldwatch, said, "while the new CO_2 figures do not represent the fundamental turn around in energy trends needed to stabilize the climate, they suggest that lowering global CO_2 emissions will be easier than most national and international agencies have yet recognized." He pointed out that when communist economics modernized formally, they would be far more energy efficient. The oil well fires in Kuwait in March 1991, not completely extinguished until November, 1991, added only about 100 million tonnes of CO_2, worldwide estimated or about 1.8 per cent of global emissions. With that factor removed in 1992, the group said, Worldwatch mentioned emissions from the Soviet Union were down by four per cent in 1990 and were likely to be down by another 5 per cent in the year 1991, while emissions from Eastern Europe fell by 28 per cent from 1987 to 1990. By the mid-1990's, emissions from the Soviet

Union and Eastern Europe could be down by 30 per cent cumulatively, according to Worldwatch.[1]

2.3. Factors Responsible for Automobile Pollution

There are many factors responsible for air pollution due to transportation. Here we have discussed some of them in brief.

1) As compared to petrol-powered engines, diesel engines emit much smaller amount of carbon monoxide and no lead. Petroleum fueled vehicles discharge through their tail pipes a significant amount of pollutants like carbon monoxide (CO) unburnt hydrocarbon (HC), lead compounds, oxides of

Table-2.1

Pollutants	Emission factor kg/1000 gallons	
	Petrol Engine	Diesel Engine
1. Carbon Monoxide	1000	27
2. Hydrocarbons	90	60
3. Oxides of nitrogen	60	100
4. Oxides of sulphur	4	18
5. Particulates	5	50
6. Organic acid	2	14
7. Aldehydes	2	5

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1. The Sentinel, 11th December, 1991.

nitrogen (NO_x) etc. Table-2.1 compares the level of various pollutants given out by four stroke petrol and diesel engine.

This table shows that the concentration of unburnt/partially burnt hydrocarbons in diesel effluent is much lower than that found in petrol engine exhaust effluent. CO concentration in diesel exhaust is very less as compared to petrol engine exhaust. No_x is slightly higher in diesel exhaust than in petrol exhaust. On the other hand, aldehydes and particulate concentrations are always high in diesel exhaust.

During idling and deceleration, the weight of particulates per cubic metre of exhaust gases is 25 to 50 times higher in case of diesel engine. During acceleration this figure increases to 500-800 per cent above the average value for petrol fueled vehicular engines. This makes the diesel exhaust more smoky to the man in the street who can see and smell the black smoke that comes out of the diesel exhaust.

Diesel engine powered vehicular exhaust, however, contains lower concentration of harmful gaseous pollutants as HC, CO etc. and to that extent, therefore, it is relatively less hazardous as compared to the invisible exhaust effluent coming out of the tail pipe of the petrol fueled vehicles. Petroleum fueled automobile engine is a source of high environmental pollution because combustion of petrol and diesel are usually incomplete. Even new vehicles are not free from emission but are within permissible limits. With increase in age and poor maintenance, the pollution emission will further increase. The age of the car does not always increase the pollution load. The pollution emission is caused due to incomplete combustion. Incomplete combustion can be due to faulty fuel system, improper oxidation, checked air and fuel filters, poor engine condition and poorly maintained exhaust system. The performance and efficiency of any vehicle get reduced with the age, if the vehicle is not properly maintained. But if any vehicle is well maintained, the pollution emission can be controlled within permissible limit irrespective of its age. Thus age is only partly responsible for increase in the pollution emission.

As mentioned earlier, diesel engine emits much less pollutants as compared to petrol engine. According to various analytical studies, the composition of diesel engine exhaust is as follows :

<u>Pollutants</u>	<u>Concentration</u>
Carbon monoxide	Less than 1000 ppm
Hydrocarbons	100-600 ppm
Oxides of nitrogen	10-1000 ppm
Formaldehydes	5-20 ppm

It has been reported that the concentration of particulate matter in diesel engine emissions is 50 $\mu g/m^3$ or 10 million particles per m^3. Other reports indicate emissions of 0.11 lb of particulate matter per gallon of fuel used, or about ten times the amount discharged by petrol engines. Many other contaminants may be emitted by both petrol and diesel engines. Diesel fuels usually contain more sulphur than petrol does and hence diesel engines may emit sulphur dioxide. In the particulate phase from both types of engine, a variety of polycyclic aromatic hydrocarbons have also been identified. In most cities, petrol and diesel-powered vehicles make a much smaller contribution to pollution by these compounds than do other fuel-burning sources. Fuel activities other than alkyl lead, such as boron, nickel, barium and manganese compounds may give rise to decomposition products that are emitted into the atmosphere in very small concentration.

According to reports from several countries, concentrations of CO in normal heavy traffic vary widely according to the local conditions. Concentrations of the gas in the range of 250-500 $\mu g/m^3$ (200-400 ppm) can sometimes be detected for brief periods, but normal maxima are more likely to be in the range of 25-125 $\mu g/m^3$ (20-100 ppm). Average values in urban air are much lower, ranging from barely detectable concentrations to perhaps 15-20 $\mu g/m^3$ (12-16 ppm).

Most of the fixed nitrogen in motor vehicle exhaust occurs as the monoxide, but this is converted to the oxide at rates depending upon atmospheric conditions. Except when mixed with hydrocarbons and exposed to sunlight, the rate of conversion is slow. In general the levels found have been low -- less than 0.2 $\mu g/m^3$ (0.1 ppm) (expressed as Nitrogen dioxides) except in heavy traffic, where values upto about 2 $\mu g/m^3$ (1 ppm) or slightly higher have been reported.[1]

2) Another major factor in automobile pollution is lead (Pb). An organic lead compound, Tetra Ethyl Lead (TEL), is added to the petrol as an antiknock agent. TEL is by far the most accepted and widely used octane number booster imparting antiknock property. The antiknock quality of petrol used in spark ignition engines allows the engines to operate smoothly at high compression ratios.

Lead antiknocks were first introduced in gasoline in 1920's to prevent engine knock. Use of TEL in gasoline practically revolutionized spark ignition engine as it provided a simple and cheap route of augmenting the octane level of motor gasoline. Consequent to the availability of high octane gasolines, the compression ratio (CR) of engines increased from 4:1 of 1920's to 11:1 in 1950's and 1960's,

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1. "Urban Air Pollution with Particular Reference to Motor Vehicles" - Report of a WHO Expert Committee, Geneva, 1969.

resulting in highly efficient, high specific output engines for automobiles. Octane number of premium gasoline in developed countries, reached 100 ON and more, the final 8-9 ON being given by the use of TEL. The motor fuel octane scale was extended beyond 100 to evaluate fuels having greater than 100 octane number, in order to meet the needs of engines with compression ratios of 10:1 and higher as compared to the earlier base compression ratio of 7:1.

One unit increase in compression ratio increases the fuel economy of about 5.2 per cent. On the other hand, engines need, a gasoline of 5-6 units higher octane number for every one unit increase of the compression ratio. On the average, it may be assumed that a one per cent improvement in fuel economy results for each octane number increase.

Worldwide, the usage of lead antiknocks increased rapidly with the growth of the automobiles and this spiraling growth of gasoline consumption continued till early eighties, when with the increase in prices of petroleum products, the growth rate of petroleum products decreased somewhat. Around the same period, the increasing awareness of the harmful effect of automobile emissions, in the high automobile population countries of North America, Western Europe and Japan, brought into focus the need of controlling the usage of TEL in the motor gasoline. Worldwide, a stage had reached when typical premium gasoline contained between 2 to 4 grams of lead per gallon with an average of 2.8 grams and regular grade gasoline averaged about 2.3 gms per gallon.

During the engine operation, on an average, 70 per cent to 80 per cent of the lead in gasoline is exhausted out of the tail pipe as particulates. The amount exhausted is less at low-speed-driving and substantially increases under highway driving conditions. Most of the lead particules from automobile are less than 2 μ in diameter and thus do not settle out of air rapidly.[1]

In order to reduce the lead emission into the urban environment many countries have reduced the limit to 0.15 gm of TEL per litre of petrol in a time bound manner. In India also the oil industry has been asked to follow the standard of 0.12 gm/lit. from September 1992 onwards. Indian Oil, the biggest oil refining and marketing corporation in India, carried out a study to choose the best alternative available for achieving this new stringent standard. The study indicated that among the Indian oil refineries catalytic reforming units will have to be installed at Barauni and Digboi to produce petrol within the specified limit for lead. The three refineries namely Mathura, Gujarat and Haldia will

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1. Programme Objective Series; PROBES/46/1992, Central Pollution Control Board, Delhi.

be able to meet this standard without addition of any new units.[1]

Several studies have been carried out in metropolitan areas of US, Canada, the then West Germany, France, Japan and other countries with high car population density and per capita gasoline consumption to assess the lead particulate levels in the ambient air of high exhaust emission areas. extensive work done by environmental agencies, clearly brought out that there is an increase in the lead level concentration of the ambient air in regions where there is high usage of leaded motor gasoline. Concentration of inorganic lead of about 1 to 3 μg/m^3 with maximum value of 7 to 9 μg/m^3 have observed in areas of heavy traffic. On highways, even a greater concentration has been found.

Lead contamination of the atmosphere by motor vehicles is attributable to the alkyl lead compounds added to gasoline to prevent knocking. In each litre of gasoline, there may be upto about one gram of these compounds (various combinations of tetra methyl and tetra ethyl lead). Their composition products are discharged mainly as particulate matter, but about 1/3rd remains in the engine and exhaust pipe or are emitted as coarser particles. Compounds that have been identified include lead chloride, lead oxide and lead

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1. Shri M. Kannan, Manager (Pollution Control), Indian Oil Corporation, New Delhi.

phosphate. In certain cities of the USSR, lead compounds are not permitted as additives of fuels for vehicles. Other countries are also examining the question of lead additives and may place restrictions upon their use.

Concentration of lead in the atmosphere adjacent to and away from traffic have been investigated widely in many parts of the world. In the detailed study carried out in the USA, the following results were reported which are of historical importance :

a) The annual average concentration of lead in the atmosphere of three cities ranged from about 3 $\mu g/m^3$ of air in the downtown and industrial areas to about 1 $\mu g/m^3$ in the outlying areas.

b) The average concentration of lead in all samples obtained ranged from 1.4 to 2.5 $\mu g/m^3$.

c) The highest concentration of lead in any sample except in heavy traffic was 11.4 $\mu g/m^3$.

d) The concentration of lead found in heavy traffic ranged from about 14 $\mu g/m^3$ in a city street to approximately 25 $\mu g/m^3$ on a major highway.

3) Poor maintenance of vehicles also aggravates the pollution load as it increases smoke density.

4) Poor upkeep of roads results in poor condition of vehicles, leading to high rate of pollutant emission. There

are four more recognized sources of pollution from ordinary automobile namely, the exhaust pipe, the crank case, the carburetor and the fuel tank. Tyre and road dust and asbestos particles from brake linings are also responsible for air pollution. Some pollution from these sources will certainly continue even if all other emissions can be eliminated as most of the researchers are ignoring this fact.

The distribution of pollutants according to source within the vehicle are :

a) Evaporation losses, tank and carburetor : 20 per cent of the HC

b) Crank case blowby : 25 per cent of the HC.

c) Exhaust : 55 per cent HC and almost all of the lead, CO and NO_x.

The nature of HC and consequently their reactivity vary according to the source. Evaporation losses are gasoline constituents comprising mainly the more volatile components. HC from crank case contain a small proportion of partial decomposition products, and those in the exhaust consist mainly of decomposition products. Considerable work has been done on determining the proportion of the major pollutants emitted by the vehicle exhausts, but various workers have obtained quite reasonable agreement. Clearly, the design and condition of an engine have considerable influence on the nature of the emissions. Exhaust emissions from uncontrolled petrol-powered vehicles have approximately the following composition :

HC – 900 ppm (measured as hexane by non-dispersive infrared analysis)

CO – 3.5 per cent

NO_x – 1500 ppm.

The chemical composition of the HC has been extensively investigated and many compounds have been separated and identified. This is not of purely theoretical interest, as the rate of photochemical reaction in the atmosphere is linked closely to hydrocarbon structure. Olefins and substituted aromatics are the most reactive species. The common constituents identified in automobile exhaust include paraffins, olefins, aromatics and acetylenes.

On the basis of total emissions given above, it has been estimated that an uncontrolled vehicle in the USA covering 12,000 miles a year emits the following pollutants.

Exhaust :	HC	3000 lbs
	CO	1700 lbs
	NO_x	90 lbs
Crank Case :	HC	130 lbs
Evaporation :	HC	90 lbs

The concentrations and ratios of HC, CO and NO_x change substantially under different operating conditions. Tests have been reported from various countries including Germany, Japan, the United Kingdom and the USA and within reasonable limits, the results reported are essentially the same. Typical values in ppm under different engine operating modes are as follows.[1]

Constituents		Idling	Cruising	Accelerating	Decelerating
CO	:	64000	24000	24000	45000
HC	:	1400	620	810	5700
NO_x	:	0	1400	1700	0

Variations in the concentrations of pollutants under different operating conditions do not provide a true indication of the quantities emitted as the volume of exhaust gases also varies.

The weight emitted by unit of time or distance travelled is a more satisfactory index. On this basis, it has been found that both the composition and the quantity of the exhaust emission is a function of average vehicle speed over a designated route. Consequently, the driving conditions in any specific city may affect the general air pollution situation of the location.

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1. "Urban Air Pollution with Particular Reference to Motor Vehicles" - WHO Expert Committee, Geneva, 1969.

2.4. Effects of Air Pollution on Biosphere

2.4.1. General Effects of Air Pollution

Air pollution is a condition which is likely to cause adverse effects in man or his possessions. The untoward consequences of atmospheric pollution cover a very wide spectrum ranging from material damage to personal discomfort and illness.

One of the difficulties in coping with air pollution lies in the variety of its effects on people. A farmer is most interested in its effect on his crops, a housewife will complain that dirt and soot soiled clothing and furniture, a traveller may get inconvenienced by low atmospheric visibility, a large segment of the general public is concerned with the possible effects of polluted air.

The gaseous and particulate materials added to the atmosphere by the activities of man are regarded to be pollutant when their concentrations have been sufficient to produce harmful effects. The majority of man-made emissions to the atmosphere also have natural sources and in many cases these are larger than the pollutant ones. The world as we know it developed in the presence of these chemicals which cannot, therefore, be regarded to be harmful but only if they produce unacceptable effects at concentrations above the natural background level. The effects that are of concern are those that do, or may in the future, influence man's health and well-being and his enjoyment of the world as we know it without undue alternation of biological or physical systems.

In reality, the association between effects and pollutant concentrations -- air pollution criteria -- has been not clear cut because of the immense number of variables involved. This lack of adequate criteria adds to the problems of decision-making on the concentration levels of pollutants acceptable in air.

After formation, air pollutants get emitted to the atmosphere and dispersed. Once mixed with the air, some air pollutants, like the inert fluorinated hydrocarbons used in aerosol sprays, persist unaltered and become mixed throughout the atmosphere where they potentially have a global influence. More reactive pollutants are having a shorter life-time in the atmosphere and could be removed either by conversion to normal atmospheric constituents or by deposition on the surface of the earth. In the process, they may combine with other atmospheric constituents to form secondary pollutants, which are removed by the same process. Both the primary emission and the secondary pollutant can bring about alteration to the chemical composition of soils and waters, and direct damages to biological systems and property. The mix of pollutants in the air is never a constant or a simple one and the damage observed in a particular situation has been often the result of more than one pollutant acting together. In certain cases, a synergistic interaction takes place where the total effect gets enhanced over and above the sum of the effects of the individual pollutants present. Because our interest in pollutants has been man-centred, effects on human health will predominate our observation.

2.4.2. <u>Economic Loss</u>

Many adverse consequences of air pollution may be directly or indirectly measured in terms of monetary loss.

i) <u>Soiling</u> - High levels of smoke, soot and other particulates tend to increase the rate of soiling of clothes, house furnishings, displayed merchandise, and interior surfaces like walls and ceilings. The added expense of frequent cleaning and repainting represents the increased cost of living in a polluted area.

ii) <u>Damage to Vegetation</u>

It is recognized that plants are among the most sensitive receptors of air pollution. The type and severity of damage has been found to depend on a number of factors including species sensitivity, type of contaminant involved, concentration and time of exposure and the other environmental and horticultural factors. It may be interesting to note that certain types of plants can serve as sensitive indicators of air pollution.

The cost of damage to vegetation in the world has been measured in terms of hundreds of millions of dollars annually and appears to be rising every year.

iii) Damage to Livestock

Animals who graze in the vicinity of certain pollution sources can suffer severe injury and death. Cattle are getting ingested sufficient quantities of flurine from contaminated vegetation surrounding copper smelters or phosphate fertilizer plants to develop flourosis.

Sheep grazing in the vicinity of copper smelters are having ingested fatal quantities of arsenic. The loss of productivity or death of the livestock has been a serious economic loss to the farmers.

2.5. Deterioration of Exposed Materials

i) The corrosion of certain metals from exposure to combinations of natural and man-made air pollutants, especially SO_2 and acidic gases and mists, can get greatly accelerated. More frequent scaling and painting of bridges and other exposed structures represents an additional cost of living or operating in areas of high air pollution.

ii) Weathering of stone in buildings and monuments likewise is accelerated by man-made pollution. This trend poses a serious threat to the survival of historical monuments and other architectural and art forms exposed to modern urban atmosphere.

iii) The darkening of lead-based white paints by sudden exposure to hydrogen sulphide has been a well-known phenomenon. Certain acidic pollutants--gaseous and particu-ates -- like sulphuric acid or incinerator flyash can severely blister paints of automobiles, opening the way to metal corrosion.

iv) Ozone can bring about accelerated cracking of rubber. Because of the high oxidant content of photochemical air pollution, rubber products like tires and radiator hoses tend to deteriorate more rapidly in Los Angeles. Oxidants attack the carbon-to-carbon bonds in the rubber which under tension fails, producing minute cracks. Frequent replacement of rubber components and insulators in regions afflicted by photo-chemical air pollution represents substantial economic loss.

v) Fabric likewise can be deteriorated by air pollution. For instance, nylon has been subjected to attack from sulphur dioxide. Years ago, there were several reports of nylon stockings suddenly disappearing from the legs of women living in certain cities. The strength and life of fabrics can be appreciably reduced by certain pollutants. In addition, dyes tend to fade more quickly in regions of high air pollution.

In general it can be said that real estate property in areas with excessive atmospheric pollution becomes devaluated more rapidly than normal. The sum total of the adverse effects on individuals and property in high pollution zones makes these areas less desirable and, therefore, less valuable.

2.6. Personal Discomforts

One of the most manifest effects of Los Angeles smog has been eye irritation. During periods of moderate to heavy smog, large percentages of the population have been affected by lachrymation and eye irritation. These periods may occur as often as 150 days per year. Many persons also complain of irritation of the nose and upper respiratory system. Discomforts from air pollution is not confined to Los Angeles. During periods of heavy pollution which occurs in metropolitan cities, a feeling of tightening of the chest is experienced by many persons, presumably from exposure to sulphur oxides in air.

Individual with pre-existing conditions of asthma, bronchitis and sinusitis appears to be more greatly affected than others.

2.7. Effects on Vegetation

The most obvious damage caused by air pollutants to vegetation occurs in the leaf structure. The surface of a leaf is covered by a waxy layer known as cuticle. In between the waxy layer is the epidermis, a single layer of cells forming the surface skin of the leaf. Its chief functions are the protection of the inner tissues from excessive moisture loss and the admission of CO_2 and oxygen to those internal tissues. The leaf surface is penetrated by a large number of openings called stomata. Each stomata is protected by a pair of guard cells, which control the opening and closing of stomata. The internal tissues of the leaf are the palisade, the spongy mesophyl and the conducting tissues or veins, which carry water, minerals and foods. Of particular interest with regard to air pollution are the stomata through which gases diffuse to the surface of the cells within the leaf.

The damage caused by air pollutants is of several types like necrosis, chlorosis and epinasty. The dead areas of a leaf structure are referred to as necrosis. Chlorosis is the loss or reduction of chlorophyll and leads to the yellowing of the leaf. Epinasty is a downward curvature of the leaf due to higher rate of growth on the upper surface and the

Table-2.2

Pollutant	Level (ppm) and Exposure	Effects
SO_2	0.3 to 0.5 for several days	Bleached spots, chlorosis, chronic injury to spinach and other leafy vegetables
NO_2	0.25 for 8 months	Increased abscission and reduced yield in citrus plants
	0.5 for 10-12 days	Suppressed growth of tomatoes
	3.5 for 21 hours	Spots of mild necrosis on cotton and bean plants
	25 for 1 hour	Acute leaf injury.
Ozone	0.3 for 8 hours, time effect reduced if low level of SO_2 is also present	Fleck on upper surface; Necrosis and bleaching; damage to tobacco leaves at O_3 = 0.027 ppm and SO_3 = 0.24 ppm after 2 hrs of exposure.
Peroxy-acetyl nitrate (PAN)	0.01 to 0.05 for a few hours	Glazing or bronzing of underside of leaf; damage to sensitive plants; young leaves more susceptible to damage.

dropping of leaves is called abscission. Few species of plant are spared from damage on the exposure to one or more of the principal air pollutants. In general, the pollutants enter tissues through the stomata, where they destroy the chlorophyll and disrupts photosynthesis. The adverse effects range from reduction in growth rate to death of the plant.

The effects of the specific pollutants on vegetation are summarised in Table-2.2.

2.7.1. Effects on Agriculture

A large number of food, forage and ornamental crops have been shown to be damaged by air pollutants. Curtailed value results from various types of leaf damage, stunting of growth, decreased size and yield of fruits, and destruction of flowers. Some plant species are so sensitive to specific pollutants as to be useful in monitoring air quality. Annual blue grass, the pinto bean, spinach and certain other forms have been so employed.

Substances thus far identified as responsible for the damage include ethylene, SO_2, PAN (Peroxyacetylnitrate), acid mists, fluorides, ozone and a number of oxidants.

2.8. Effect on Human Health

Human beings are the worst victims of air pollution. There are many acute and chronic diseases which are caused by vehicular pollution. The effects of air pollution on human health could be divided into three general categories :

(i) Short-term Effects

These consist of interference with normal bodily functions. Exposure to carbon monixide may impair lung ventilation by reducing the oxygen transport capacity of blood. The carbon is deposited in the lung and can cause respiratory diseases. Air pollution by industry, for example, asbestos industries can lead to a condition called asbestosis. The cement industry can affect the respiratory system causing silicosis. These diseases in the long term can lead to cancer of the thorax. Sulphur dioxide on the other hand can cause increased airway resistance and partial ciliary paralysis. These reactions to CO and SO_2 are regarded to be reversible and permanent damage may not occur. Lead causes blood abnormalities and can affect the nerves also. Most health authorities and organized international bodies like the WHO have brought out studies pointing the harmful effects of increased lead levels in human blood. Inorganic lead acts as an agent to cause a variety of ill effects on human including liver and kidney damage, gastro-intestinal damage, mental health effects in children and abnormalities in fertility and pregnancy. Out of the daily lead intake via food and water, perhaps only 10 per cent is absorbed and rest is discarded. Of the atmospheric intake through inhalation, some 25 to 50 per cent is retained in the lungs. According to various studies, intake from atmosphere in urban areas, in the developed western countries, is considered to be of the order of 40 to 55 μg/day and of this 12 to 25 μg is retained in the lungs.

Lead has long been known to inhibit major enzymatic processes, to have adverse effects on the central nervous system and to lower the intelligence and affect the behaviour of children. In a US EPA report, "Costs and Benefits of Reducing Lead in Gasoline", March, 1984, seven independent studies are presented which consistently found lower IQ in children with high blood lead levels. The high lead groups in the studies have less than 30 microgramme of lead per decilitre of blood (µg/dl). Previously, 25 to 30 µg/dl of lead was thought by many experts to be a safe level.

Equally disturbing are the studies published in the last five years which demonstrate that blood lead level as low as 10 µg/dl and possibly lower can lead to reduced infant birth weight, effects on mental development of the foetus during pregnancy and high blood pressure and hypertension in adults. A European Community survey conducted in the late 1970's found a median blood level of 13 µg/dl with some countries as high as 17 µg/dl. This suggests that in the neighbourhood of 50 per cent of the European Economic Community (EEC) population at the time was at risk to lead exposure. In high traffic urban areas, levels can be higher, for example, a median level of 19 µg/dl was measured in Bangalore (in India) and 26 µg/dl in Turin (in Italy).

On reviewing the most recent medical evidence on lead, a Canadian Government report concludes : "From all of these findings, it is reasonable to assume that blood lead levels should not be allowed to exceed 10 µg/dl and that, in fact, even this limit allows little or no margin of safety" (Lead in Gasoline - Why we should take another lock, Minister Environment, Canada, December 1987).

Citing the "well known and undesirable" health effects of lead, a group of distinguished French medical and pollution experts recommended to the Ministry of Environment in 1983 to reduce the amount of lead in gasoline to 0.15 g/l ("Revue Pollution Atmospherique", July-September, 1983).

The human nervous system may be the most sensitive target of environmental pollutants. A number of pollutants that are ubiquitous in the environment, home or work place including lead, have the potential to injure the nervous system.

Lead is one of the best studied neurotoxins. The more closely researchers have looked at the mental's toxicity, the more concerned they have grown about its effects at very low levels. Between 1972 and 1991, the amount of lead concentration in blood that U.S. federal agencies deemed "safe" dropped by 75 per cent. In 1991, the Centres for Disease Control announced that subtle effects on the central nervous system of children began at blood-lead concentrations above 10 µg/dl. The previous guideline had established blood-lead levels over 25 µg/dl of blood as cause for concern.

The burning leaded automobile fuel is an important source of children's exposure to lead in many countries. A second source is lead-paint, which still lives in millions of American homes as well as those elsewhere. When the US began removing lead from gasoline (which is scheduled to be completed by 1996) concentration of lead in blood also dropped. Many countries in Europe, Latin America and Asia still rely heavily on leaded automobile fuel.

(ii) <u>Acute Illness and Death</u>

A number of dramatic episodes have occurred in which deaths resulted in man and animals during periods of intense air pollution. These are known as killer smogs.

(iii) <u>Long-Term or Chronic Effects</u>

Several chronic respiratory diseases have been thought to be caused by or aggravated by air pollution. They include chronic bronchitis, emphysema and lung cancer. While a clear cut cause and effect relationship, between air pollution and health has not yet been established, there has been a growing body of medical opinion which claims that air pollution together with cigarette smoking, contributes to excesses in death, increased morbidity and earlier onset of respiratory diseases. Respiratory diseases, like chronic bronchitis, emphysema, if not treated for a long time can affect the heart and can even cause death. People having these diseases have a higher fatality rate.

The best evidence for a link between broad environmental pollution and immune dysfunction may be the effect of air pollution on asthma and respiratory illness. Deaths as a result of asthma are rising in a number of industrial countries, including Australia, Canada, Denmark, New Zealand, Sweden, the UK and the US. In the last two decades, the prevalence of asthma rose to 56 per cent in Americans under the age of 18, compared with 36 per cent in the general population. Between 1979 and 1987, Americans under the age of four were the fastest growing group of people entering the hospital because of asthma attacks.

Carbon monoxide and lead are examples of substances which may be absorbed in the blood and cause adverse effects on any of the body's organs; so-called "system toxic effects". High levels of carbon monoxide are often a problem along roads with heavy traffic and poorly ventilated streets. Better treatment of exhaust gases compounds from petrol-driven vehicles have long been a problem, but the future exclusive use of unleaded petrol will cause this problem to disappear. The all-pervading global problem is that of the growing emissions of carbon dioxide which threaten to change the conditions under which all plants and animals live everywhere on earth. It has been agreed internationally that global emissions need to be reduced by at least 20 per cent by 2005 (as compared with 1988 levels) and by at least 50 per cent over the next 40-50 years. Industrial countries emitting large quantities per inhabitants must probably reduce their emissions still further. Emissions from stationary and mobile sources must be sharply reduced.

Many scientists consider that deposition and thus also the emissions must be reduced by between 50 and 90 per cent in order to reach the level which nature can tolerate.[1]

2.9. Reported Level of Lead in Blood

The WHO environmental health criteria on lead had considered 200 µg/litre as the level at which bio-chemical changes in the blood start occurring (increase of free erythrocyte protoporphyrins). Changes in enzyme activities may occur at even lower levels. Effects on the nervous system (peripheral neuropathy in adults or minimal brain dysfunction in children) start occurring at 400-500 µg/lit. (Ref: Global Pollution and Health, WHO and UNEP 1987 copyright).

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1. "Traffic - A Communication Problem", Swedish Environmental Protection Agency.

The USSR has recommended an extremely low level of ambient air quality standard for lead of 0.7 $\mu g/m^3$. Ambient air quality standard of California for lead is 1.5 $\mu g/m^3$.

Although many factors undoubtedly influence the lead exposure levels, it is found from a report that the lowest blood lead levels were found in Tokyo, a city in which all petrol has been virtually lead free since 1976. In contrast, as per the report, petrol in Mexico city contained the highest lead content of all the cities studied and people of the city have the highest levels of lead in blood.

Another finding emanating from the study is that on average, the exposure levels to lead in males are about 30 per cent higher than in females. For Peru and Sweden, blood lead levels were about the same in 1967 and 1981, while for Israel, Japan, the United States and Yugoslavia, there was a substantial decrease in the same period. The most striking case was of Japan, where decrease in level was from 210 µg/litre in 1967 to 60 µg/litre in 1981. On the other hand, in a few locations, the blood lead levels were found to be in excess of the no effect level. For example, in Bangalore and in Mexico city, 10 per cent of the population sampled, had levels higher than 300 µg/lit.[1]

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1. Report on Tetraethyl lead (TEL) in Petrol and Lead in Exhausts from Automobiles - Central Pollution Control Board, Delhi, 1992.

2.10. The Costs of Air Pollution

What are the total costs in damages due to air pollution? What will be the cost in investment and operation for adequate controls? Neither of these questions can be answered very accurately but there have been some pioneering studies carried out to provide estimates.

Amounts were unknown for replacement and protection of precision instruments, maintenance of cleanliness in production of foods and beverages, soiling of homes and their furnishings, medical costs, the cost of absenteeism from work due to illness, and the cost of fuels wasted in incomplete combustion. Lave and Seskin have tried to determine the medical costs and they estimated that a 50 per cent reduction in air pollution levels in major urban areas would save $2.08 billion annually in terms of decreased mortality and morbidity -- or 4.5 per cent of all economic costs associated with mortality and morbidity. They also say that the total annual cost of these health effects might run as high as $29 billion.

Most of the effects of air pollution on plants, animals, property and human health result in a direct cost to individuals and to society. Attempts have been made to assess some of these, although some factors such as discomfort in illness or the loss of works of art, cannot be assessed in simple economic terms.

The cost of air pollution to individuals living in a highly polluted community in comparison with an average, less polluted one, is illustrated by a study some 15 years ago in two cities of similar size in the United States — Steubenville, Ohio (a steel manufacturing town), and Uniontown, Pennsylvania, where there was no major large pollution producing industry. In Steubenville, the average spent on external house cleaning, laundry, dry cleaning, hair and facial care was $84 per family more than in Uniontown. However, the higher income groups in Steubenville spent relatively more than the lower income groups in that city. A similar study in Newcastle, Australia, gave analogous results, but it was pointed out that the extra costs in cleaning incurred by living in a more polluted suburb closer to the places of employment were counter-balanced by the higher travelling costs for those who lived in a cleaner suburb further away.

The cost of additional health services, lost working time and other health-connected factors, has been almost impossible to estimate but some attempts indicate staggering amounts. Similarly, the costs of repairs to buildings, losses of works of art and related aesthetics losses are not really assessable.[1]

2.11. Measures to Control Pollution

Environmental pollution is the most burning problem requiring immediate attention by the society. A survey of basic needs of man in America revealed that people wanted consideration of issues such as vandalism, odour, busfare, parks, employment, noise, medical care, schools, roads, garden and house. However, they gave top priority to the stoppage of degradation of their environment in preference to other important issues. In England, there was greater awareness since 1952. With the enforcement of clear air act (1968), air was cleaned, while in the USA, Environmental Protection Agency (USEPA) was established. In India, since 1962 Maharashtra was the first state to enact Water Pollution Act, followed by preparation of the draft proposal for Air Pollution Control in 1980. Fortunately, the Central Government is aware of the problems. It passed comprehensive environmental protection bill in 1986 to include legislation on abatement of noise pollution. Bombay city was the first to introduce a bill for transportation of hazardous chemicals (1988) in India.

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1. Encyclopaedia of Ecology, Environment and Pollution Control, Vol.17, Environmental Air and Water Analysis, 1992.

With regard to the vehicular emissions, most countries, with the exception of USA, have been mainly concerned with visible or odorous emissions from exhausts. For this reasons, diesel vehicles have received greater attention and some European countries have adopted legislation setting limits of emissions of smoke density. Belgium, for example, introduced regulations providing that from 1st January 1966, no diesel vehicle should emit smoke in excess of 50 units on the Hartridge metre. Additive to facilitate achieving this density is permitted. Italy is now preparing similar legislation for the setting of exhaust standards.

Six countries have established ambient air quality standards [CSSR; Federal Republic of Germany; Poland; Romania; USSR; USA (California State and Los Angeles City, Colorado and New York States)] and four of them have standards in respect of motor exhaust pollutants or products of photochemical reactions. Recently, India has also joined these countries in establishing standards for vehicular exhaust emission.

In the United Kingdom, motor vehicles are subjected to be controlled by regulations empowered by the Road Traffic Act 1930 and the Road Safety Act 1967. The Motor Vehicles (construction and use) Regulations 1966 are those in effect at present. Under these regulations, every motor vehicle is required to be so constructed that no visible smoke or vapour is emitted. A further regulation states that vehicles must not be used in such a manner as to emit smoke, fumes, cinders, oily substances etc. if such are likely to cause damage to property or to cause injury or endanger any person. Provisions also exist to prohibit the use of devices to supply excess fuel to compression ignition engines while vehicles are in motion. The Road Safety Act 1967 also provides powers of inspection in relation to faults, including excess smoke emissions in vehicles and for systems of approval of specifications, such as power-to-weight ratio and performance standards on engine.

In relation to carbon monoxide, Japan introduced regulations in April 1966, under Ministry of Transport legislations, requiring a maximum concentration of 3 per cent for all vehicles produced after September 1966. New draft legislation in West Germany will limit the concentration of carbon monoxide emitting from idling motor vehicles to 4.5 per cent. Certain countries have passed legislation defining air quality standards in relation to contaminants from motor vehicle exhausts.

The First Federal air pollution legislation in the USA was the Air Pollution Research and Technical Assistance Law of 1955. This was superseded in 1963 by the Clear Air Act. In 1966, this Act was amended to provide for the establishment of national emission standards for the control of motor vehicle pollution. Regulations were promulgated requiring vehicle manufacturers to provide means of eliminating crank case emissions and to meet the national exhaust standards for carbon monoxide and hydrocarbons, starting with the production of the 1968 model. The standards for exhaust gases were similar, but not identical, to the standards of 275 parts per million (ppm) for hydrocarbons and 1.5 per cent for carbon monoxide which had already become law for 1966 model-year vehicles in California. In that state, which had pioneered activities associated with the control of motor vehicle pollution, crank case control equipment had already become mandatory.

Federal standards promulgated in June 1968 are as follows :

a) Exhaust standards for new vehicles under 6000 lbs gross vehicle weight, starting with 1970 model-year production, are required not to exceed the following :

Hydrocarbons - 2.2 g per vehicle mile

Carbon monoxide - 23 g per vehicle mile

These requirements will have the effect of reducing emissions to conform with existing standards.

b) For the year 1971 model-year production, fuel evaporative emissions from light-duty vehicles are not to exceed 6 g per test according to a standard test procedure.

c) On or after 1st January, 1970, exhaust emissions from new heavy-duty gasoline (petrol) vehicles are not to exceed :

Hydrocarbons	–	275 ppm
Carbon Monoxide	–	1.5 per cent

d) On or after the 1st January, 1970, exhaust standards for the heavy-duty diesel vehicles are to be as follows :

Opacity of smoke emissions from new vehicles not to exceed 20 per cent during engine lugging mode (i.e., when the engine is running at the speed of maximum torque or at least 60 per cent of the rated speed, whichever is higher, and 40 per cent during engine accelerating mode.

The existing provisions applying to all vehicles and engines except motor cycles, requiring virtually 100 per cent control of crank case emissions, will continue to apply.[1]

2.11.1. Common EC-EFTA Rules

Countries in Europe, Latin America and Asia are also trying to introduce new tougher rules on vehicle exhausts. The question is, though, whether these more stringent rules will even counter balance the rise in emissions resulting from, among other things, European Community's single market

1. "Urban Air Pollution with Particular Reference to Motor Vehicles", Report of a WHO Expert Committee, Geneva, 1969.

and economic growth in Eastern Europe and some of the wealthier developing countries.

In this terms of vehicle emissions, completion of the single EC market in 1993 will pose a special problem for the other countries of Europe, some of which have more rigorous requirements than the community and completely different rules on such matters as the car manufacturer's responsibility for the long-term performance of catalytic converters. The agreement reached between the EC and the EFTA countries on a European Economic Area (EEA) means that, as from 1st January 1995, EC rules in this field, as in others, will apply throughout the EC-EFTA area.

According to Jan Karlsson, head of the Swedish Environmental Protection Agency's Transport Section, "different test methods and emission standards and an absence of long-term performance requirements and after-scale monitoring systems, however, mean that the 1993 EC rules will be between 30 and 90 per cent less stringent than existing Swedish Standards".

As far as Sweden is concerned, it also remains to be seen whether the environmental classification system for both cars and heavy vehicles recently divided on by Parliament will be able to be retained in its present form after 1995. The system is based on three environmental classes, and will be introduced as from 1993 "year models" of both light and heavy vehicles (i.e., new vehicles sold from the autumn of 1992).

i) <u>Light Vehicles</u>

Class-3 will consist of cars meeting existing compulsory Swedish standards, Class-2 of those conforming to requirements already partially introduced in California and Class-1 of cars meeting the standards for 'low emission vehicles' due to become mandatory in California in the year 2000.

Class-3 vehicles will be Skr 2000 ($330) more expansive than at present while the tax on cars in the Class-1 will be cut by Skr 4000.

The difference between EC Emission standards for cars and the Swedish standards for Class-1 light vehicles is considerable. New cars sold in the EC from 1993 will be permitted to emit a maximum of 1.13 grams per kilometre (gm/km) of nitrogen oxides and hydro-carbons (NO_x plus HC), 3.16 g/km of carbon monoxide and 0.18 g/km of particulates.

The Swedish limit values for environmental Class-1 are 0.25 g/km NO_x, 0.25 g/km HC, 2.1 g/km CO and 0.124 g/km of particulates. What is more, their limits are coupled with a rule requiring manufacturers to make sure exhaust clearing equipment can keep emissions below these levels for 5 years or 80,000 km. For the remainder of a vehicle's entire life, which is estimated at 10 years or 16,000 km, somewhat higher levels will be permitted.

In addition, Sweden has introduced a separate requirement that Class-1 cars must not emit more than 6.2 g/km of CO when started from cold.

ii) Heavy Vehicles

As for emission standards for heavy vehicles, the differences between Sweden and the EC are fairly small. EC proposals, intended to be introduced in 1996, will permit emissions of 7.0 grams per kilowatt-hour (g/kwh) of NO_x, 1.1 g/kwh of HC, 4.0 g/kwh of CO and 0.15-0.30 g/kwh of particulates. Sweden's Environmental Protection Agency judges these limit values to be at a level comparable to both the US standards due to be introduced in 1994 and the Swedish proposals for future, stricter standards.

The Swedish standards that will apply to new heavy vehicles sold from Autumn 1992 include a stipulation requiring engine manufacturers to ensure that heavy diesel engines are able to meet emission limits for 8 years or for a distance ranging from 2,00,000 to 5,00,000 km. depending on the class they are associated to.

The European Community, on the one hand, and the United States and EFTA countries, on the other, use different methods to test pollutant emissions from cars. The limit values quoted are, therefore, not entirely comparable.

The EC uses an artificial test cycle in which engines are accelerated at a constant rate upto three different speed levels. The US method which is also used in the EFTA member states, stimulates with varied acceleration and breaking.

Although the Swedish are concerned that the more rigorous requirements which they place on car manufacturers in terms of responsibility for long-term performance and after-sale monitoring of emission control equipment may prove incompatible with EC rules, some community countries, like Germany are already using tax subsidies to speed the introduction of cleaner cars.

In most parts of the world, vehicle exhausts are, of course, causing growing problems. In many of the chaotic big cities of the developing world, particles from dirty-diesel-engined vehicles represent an especially serious health hazards. More than a billion people -- one in five of the world's population -- are exposed to air with excessive particulate levels.

Several of the industrialized countries outside North America and Europe are now beginning to introduce stringent emission standards. Japan has for many years applied exhaust standards for cars comparable to forthcoming US rules, and countries such as Australia, Brazil, South Korea, Taiwan and Mexico have set successively lower limit values. California is the only state in the US with the right to set environmental standards. However, other states can adopt California's standards, or alternatively federal US rules. Several states have in fact decided to introduce California standards.

In 1990, California adopted a low-emission plan for light vehicles. The law will take effect in 1994, by which time car manufacturers will have to make sure that average emissions of non-methane hydro carbons (NMHC) from new cars are below a given level. Vehicles will be divided into four categories, with the toughest requirements imposed on ZEV's (Zero Emission Vehicles), which will not emit any pollution at all. The intention is over the period upto 2003, an increasingly large proportion of the car fleet will be made up of vehicles with increasingly low emission devices. By 2003, 75 per cent of the fleet is expected to consist of cars emitting upto 0.045 g/km NMHC, while the rest meet even better standards.

California also has the strictest rules on emissions from heavy vehicles. From 1994, trucks will not be allowed to emit more than 5.0 gm of NO_x 1.3 g of HC, 15.5 g of CO and 0.10 g of particulates per brake horse-power-hour. The rest of the United States is expected to follow suit here as it is doing on cars.

The problem in the United States is that the country is extremely dependent on cars and that is very difficult to deal with vehicle emissions in any way than through technical movements, which can only achieve so much.

"The whole of the Los Angeles needs to come up with new transport systems, not primarily for the state of the environment, but for economic reasons", Jan Karlsson pointed out.

Throughout the world, cities and entire countries are now facing impossible traffic situations, in both economic and environmental terms. And everywhere, authorities are thinking about how they can get to grip with their traffic problems without having to make too many unpopular decisions. Stricter exhaust standards have consequently become the commonest approach, although they do not seem to be achieving the large-scale cuts in emissions that are necessary for both health and long-term environmental reasons.[1]

The EC commission emphasizes that the existing community programme for technical standard-setting must be kept up and expanded. The reduction of pollution will require "stricter gaseous emission standards for all fuel types, for mother vehicles (cars, commercial vehicles, buses and coaches), motorcycles, aircraft, ships and barges, stricter noise emission standards for motor vehicles,

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1. "Vehicle Exhausts - Problematic Search for Tougher Standards", Enviro, May 1992.

motorcycles, trains and aircraft, stricter standards for fuel quality and bio-fuels, stricter energy efficiency requirements for motor engines, aircraft engines, motor-cycle engines, ship and barge engines, as well as noise design requirements for roads, railways and runways.[1]

In a draft for a fifth EC Environment Action Programme, the European Commission has proposed emission targets for sulphur and nitrogen oxides. These would apply to all emissions sources :

NO_x : A stabilization of emissions at 1990 levels by 1994, followed by a 30 per cent reduction by 2000.

SO_2 : A 35 per cent reduction in emissions by 2000, taking the figures for 1985 as baseline. According to a directive adopted in 1988, the emissions of sulphur and a nitrogen oxides from such plants were to be reduced by 42 and 30 per cent respectively by 1998, as from 1980. A further reduction of 58 per cent by 2003 was required for sulphur. The proposed targets for green houses gases would be stabilization of carbon dioxide emissions at 1990 levels by the year 2000, reducing them by 10 per cent by 2005, and by 20

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1. "For Sustainable Mobility", Acid News, May 1992.

per cent by 2010. Halon gas is destined to disappear by the year 2000.[1]

A means to reduce the problem has recently been announced by the Ford Motor Company. Styled exhaust gas ignition, it involves feeding the engine at the moment of starting with an extra rich fuel mixture, followed by after burning of the hydrocarbon-rich exhaust gas with an addition of oxygen just before the catalyzer. The latter then gets warmed up in a matter of seconds, thus reducing the emissions of CO and VOCs by 80 per cent during the first few minutes of driving.

For its part the Saab Company is developing an accumulator that utilizes heat from the engine. The device contains salt crystals which melt when heated, thus storing a considerable amount of energy. The next time the car is started, the cooling water and engine oil, as well as the interior, are warmed up by means of a heat exchanger. The accumulator is said to retain full effect for three days even when the car is standing still. The method is claimed to result in a reduction of emissions by 50 to 80 percent during the first few minutes of driving.[2]

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1. "Targets to Apply to all Sources", Acid News, May 1992.
2. "Avoiding Cold Starts", Acid News, May, 1992.

Public transport buses in Rouen and Grenoble, France, are now running on a mixture of regular diesel fuel and something called diester, in equal proportions. Diester is a new type of fuel derived from rapeseed oil. To produce it, rapeseed oil is allowed to react with methanol. Unlike untreated rapeseed oil, diester can be used in ordinary diesel engines. This means that imported diesel oil can be replaced by a domestic fuel with better environmental characteristics. Diester contributes less than diesel oil to the greenhouse effect, it gives no emissions of sulphur and 40 per cent less particulate matter than diesel.[1]

Apart from these, there are various other technical measures by which the vehicular emissions could be controlled. As seen earlier, formation of hydrocarbons in case of petroleum fuelled vehicle engine is unavoidable because of the flame quenching phenomenon. As long as the emission is within permissible limit and not health hazard, no technical measures are required. But once excessive pollution emission is caused, steps have to be taken to contain the emission. The main cause of this excessive pollution emission is due to incomplete combustion and incomplete combustion can be due to one or more of the following reasons :

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1. "New Fuel Replaces Diesel", Acid News, October, 1992.

A) <u>Reasons which are common to both petrol and diesel engine and their corrective measures to be taken</u> :

1) <u>Clogged air filters</u> : Because of clogged air filter, the required amount of air cannot enter the engine cylinders and thus complete oxidation cannot take place. The air filter dust bowl is required to be cleaned once every week or every 1000 kms. After cleaning, fill in the recommended engine oil upto the correct level in the air filter body. Check condition of rubber sleeve and replace if damaged.

2) <u>Poor engine condition</u> : If the performance of the engine is found to be poor, emission will be more and under-mentioned components have to be checked and rectified.

a) <u>Worn-out piston ring</u> : If piston rings are worn-out, they can be replaced with the next even size provided the bore are not damaged.

b) <u>Leaky gasket</u> : If the head gasket is damaged, replace with new one and tighten the cylinder head bolts to correct torque and in the proper sequence. Arrest any possible leakage of compression.

c) <u>Leaky valve</u> : Compression is lost due to leaky valves. Rectify the defect and replace with new ones.

d) <u>Incorrect Tappet Clearance</u> : This also causes loss in compression. Correct the tappet clearance.

e) Valve timing : If the valve timing is wrong, proper ignition will not take place. The timing has to be corrected. If the smoke emission still persists, engine has to be overhauled.

3) Choked silencer muffler : The blackness of smoke may be due to choked silencer muffler. This has to be cleared regularly at every 75,000 kms. or 1 year.

B) Special Measures for Diesel Engine

1) Clogged fuel filters : The clogged filters at the fuel pump are to be cleaned every 9000 kms. and they have to be replaced every 18,000 kms.

2) Faulty nozzles : The nozzle pressures and spray characteristics are to be checked and rectified every 24,000 kms. In case of incorrect pressures, they could be rectified and set at the prescribed norms. But if spray characteristics are found faulty, the nozzles are to be replaced.

3) Faulty fuel injection pump : If the Fuel Injection Pump (FIP) is faulty, the injection of fuel will be more and this will cause excess emission. The pump has to be checked at the Test Bench every 75,000 to 80,000 kms. Repair/ Calibration has to be carried out if the performance is below/above the prescribed norms.

C) Special Measures for Petrol Engine

1) Faulty Carburetor - If the carburetor is faulty, excess fuel will be injected inside the engine and proper

combustion will not take place. Hence the carburetor has to be checked and rectified every 6 months or 18,000 kms. Replacement of parts has to be done if they are worn out.

2) Faulty spark plug - If spark plug are faulty, there will be incomplete ignition and oxidation. Hence they are to be checked every 6 months, and take corrective measures.

It is found that if the maintenance schedules are carried out religiously, the vehicular pollution emission can be reduced substantially to the tune of around 30 per cent. In general, vehicular emission control techniques can be classified into two categories. They are either employed to prevent the formation of the pollutants or once formed to destroy them. Formation of hydrocarbons in case of vehicle engine is unavoidable because of the flame quenching phenomenon. These hydrocarbons find their way to exhaust causing exhaust hydrocarbon pollution. The available techniques for their control involve their destruction in the exhaust system by further oxidation. It may be necessary to supply additional oxygen or alternatively to use catalysts to achieve their destruction in a reasonable size convertor.

The formation of carbon monoxide is almost directly related to air fuel ratio. If formed, it may be deliminated by further oxidation either thermally or by use of catalysts. The formation of the oxides of nitrogen can be minimized by lowering the combustion temperature. Its catalytic destruction in the exhaust is also possible through reduction reactions.

Certain institutions have been working for quite sometime now on abatement of vehicular emissions. They have developed catalytic convertors for reducing vehicular exhaust (HC) and (CO) emissions. It is claimed that their use can reduce CO and HC concentration by about 85 and 76 per cent respectively.

The use of anti-smoke additives appears to be quite effective in reducing diesel smoke. Their use in small concentrations (around 0.3 per cent by volume) brings about substantial reduction in smoke density without requiring any addition, alterations or modifications in the engine. It has been found that use of Barium additives in diesel oil can reduce smoke by 50 per cent.

It is found that Natural Gas does not produce particulates, hydro-carbons, lead and sulphur compound. Natural gas vehicles have the advantage of less noise, less emission of nitrogen and carbon monoxide besides absence of aldehydes. Natural gas if used as fuel has many advantages such as :

i) It has high octane value.

ii) It is safer than gasoline.

iii) It burns clearly and protects the environment.

iv) It prevents carbon built-up so that engines run smoothly and need less maintenance.

Thus Compressed Natural Gas Vehicles will be more environmental friendly.

There is ample scope for improving fuel efficiency of motor vehicles by effecting changes in engine design such as change from pre-combustion to direct combustion engine, provision of engine exhaust brakes which can cut off High Speed Diesel (HSD) flow when it is driven by wheels while coming down of plains, and by designing of light-weight but strong body of vehicles made of aluminium or fibre glass to reduce dead weight of the vehicle. The chassis of vehicles could also be redesigned as an integrated unit of redistribute weight of the vehicle for better power development. Both automobile manufacturers as well as transport operators should explore such possibilities. The matter should receive urgent attention of Directorate General, Technical Development.

It has been argued on behalf of automobile industry that in the interests of fuel economy and savings in transport cost, introduction of heavier payload vehicles and savings in transport cost, introduction of heavier payload vehicles and truck or tractor semi-trailer combinations has a distinct advantage over conventional trucks. They are of the view that for road safety system and need for fuel conservation, trailerisation should be preferred to single-deck higher payload vehicles. Accordingly, this may be encouraged, keeping in view the carrying capacity of road system.

It is well known that the timely and proper maintenance of vehicles and certain operational measures contribute to fuel savings. Better fueling practices avoid spillage and leakage in vehicles. Periodic and proper check of fuel transmission equipments like feed pump, fuel filters, fuel injection pump, high pressure pipes, injectors and derating of fuel injection pumps to suit loads carried on specific routes could also affect savings. Other critical and useful maintenance jobs are tyre pressure and brake-pedal check, engine tuning and air cleaner maintenance. It considers that operational measures, such as timely replacement of over-aged vehicles, plying of relatively younger vehicles for long-distance traffic, rationalization of operations through proper routing and scheduling and minimization of dead kins of vehicles, particularly in passenger transport services, could lead to fuel savings. There is also scope for fuel economy through improved driving habits, for instance, avoiding jerky and fast racing starts, sudden acceleration and braking, frequent change of speed, over speeding and bad clutch handling.

The study reveals that the Association of State Road Transport Undertakings is pursuing the possibility of recycling used engine oil on a large scale, which is a worthwhile endeavour. However, it is reported that levy of excise duty on recycled oil is liable to make it uneconomical. In the absence of permanent exemption from excise duty on recycled engine oil, the possibility of large-scale adoption of this practice is doubtful. It recommends that recycled engine oil should be exempted from excise duty on a permanent basis with suitable safeguards against its misuse, so that the public sector undertakings are enabled to set up recycling plants and use recycled engine oil widely.[1]

2.12. Public Awareness

Public protest against increasing air pollution from road traffic and aircraft continues to grow all over Europe. Highly visible demonstrations have been taking place from the Baltic region down to the Alps, and widespread lobbying and public actions are being made ready to counteract the threat that is looming over the whole continent.

On October 25, 1991, environmentalist group including Robin Wood in Germany and children of the earth in

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1. "Report on the National Transport Policy Committee", Government of India, Planning Commission, New Delhi, May 1980.

Czechoslovakia blocked the main roads crossing the border between Germany and Czechoslovakia in protest against the increase in truck traffic. To underscore a demand for switching freight carrying from the railways, a group at Waldhaus had even managed to place a 14-metre-long locomotive on the highway. In this case, the demonstrations had been arranged to coincide with a meeting of European Transport ministers in Prague.

A Pan-European Transport Conference had been called simultaneously by NGOs (Non-Governmental Organisations) to formulate a declaration to the ministers. This demanded an environmentally inclined transport policy which, with the critical-load concept as a basis, would take in a full assessment of the social, economic, and environmental costs of future infrastructural projects.

During an international Traffic Day on November 15, 1991, environmentalist groups gathered in 65 cities in 13 European countries to protest against air pollution from traffic and the construction of new motor ways, circular routes around cities and large bridges. Under the slogan of "Not one more metre of motorway" some of the protests were also directed against the International Road Federation, which had recently presented a plan for building 20,000 kms. of new motorway in Europe before 2010. According to a fresh report from the Environmental Protection Agency, Sweden will not be able to attain the aim, set by parliament in 1985, of reducing its emissions of nitrogen oxides (NO_x) by 30 per cent (from 1980) by 1995. The main reason is greatly increased road traffic.[1]

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1. Acid News - A Newsletter from the Swedish and Norwegian NGO Secretariats on Acid Rain, March 1992.

Chapter–III

POLLUTION SCENARIO IN SOME CITIES OF INDIA

3.0. Introduction

Environmental problem is no longer an issue of a particular geographical area or confined to some political boundaries. It has become a global issue which is very much interlinked with the well being and the best existence of mankind. The world is facing acute problems like global climate change, ozone depletion, acid rain, massive deforestation, pollution of air, water and land, noise pollution, etc. which are threatening the very existence of mankind. Pollution of atmosphere due to smoke emission from automobiles has been experienced as a long-standing problem throughout the world, particularly because of wide application and use of internal combustion. Exhaust gases from the automobile engine contain unburnt fuel hydrocarbon (HC), partly burnt fuel carbon monoxide (CO) and nitrogen oxide (NO_x). These compounds pollute the air. Sixty per cent of pollution is caused by automobiles in metropolitan cities. Besides these pollutants, the lead arising out of Tetra Ethyl Lead (TEL) in petrol is an important pollutant emitted by automobiles. While the developed countries, with high density of automobile population and very large petrol consumption, started taking short and long term effective measures in phases to reduce the CO, NO_x, unburnt HC and lead in exhaust emissions. In India, the acuteness of the problem was realized in mid-eighties and some action was initiated. With the steep rise in the automobile population in the Seventh Five Year Plan, the problem has further aggravated for limiting the concentration of CO in exhaust emissions. Attention has also been given to the lead problem. The Government has felt the need to evolve suitable measures to ensure that the ambient air lead concentration in the cities and other high density traffic areas does not grow to undesirable levels with the growing automobile population.

According to the reports received in Calcutta, the overall average concentration of lead in ambient air was 6.63 $\mu g/m^3$ (due to vehicular traffic). The table-3.1 below shows the lead level in certain cities in India.[1]

Table-2.1

Overall values	Ambient lead concentration Annual mean level ($\mu g/m^3$)
Bombay	0.1 - 3.8
Patna	0.1 - 0.68
Delhi	0.185 - 0.459
Calcutta	1.03 - 6.63
Guwahati	0.14 - 0.91

1. "Report on Tetra Ethyl Lead in Petrol and Lead in Exhaust from Automobiles", Central Pollution Control Board, Delhi, 1992.

Like other countries of the world, air pollution in India is mostly due to emission of vehicles moving on roads. Unlike in developed countries, no national estimate of emission is available in India. A study was made by Indian Institute of Petroleum in January 1985 with regard to emission of pollution by road vehicles in five large cities of Delhi, Bombay, Calcutta, Madras and Bangalore. This study indicates that the absolute magnitudes of vehicle emission of diverse pollutants is lower. This finding is due to the low vehicle strength and annual oil consumption (2 million tons for India against 300 million tons for USA). This, therefore, does not give a correct picture. However, the rate of pollutant emission like carbon monoxide per vehicle in India is 33 per cent higher than in USA. This is mostly due to the increase in the number of vehicles in India.

In the surface transport system of India, both for movement of passengers and goods, road transport is of crucial importance. There is a wide variety of mechanized and non-mechanized vehicles in the country for road traffic which provide some choice to people to travel and transport goods according to their requirements and paying capacity. The vehicles include hand driven and animal drawn carts, bicycles and bi-cycle-rickshaws, horse carriages, tongas and different power-driven two and three wheelers like scooters, rickshaws, motor cycles, autorickshaws, moped, motorcars, buses and articulated vehicles. Motore transport efficiency depends on a good road system, in addition to quality vehicles, adequate repair cover and supply of fuel which is petroleum products. In view of the characteristics of easy availability and flexibility of operation, adaptability to individual needs, door-to-door service and reliability, road transport is ideally suitable for bulk movement of goods and mass transit of passengers. Motor transport is also the main mechanized means of transport in hilly and rural areas not served by railways. Further road and road transport provide one of the basic infrastructures for economic development of backward areas and serve as a feeder service to rail traffic, ports and harbours. In 1977-78, mechanized road transport handled an estimated 77 bt km. and 250 b pkm freight and passenger traffic respectively. It is envisaged that by 2000-01 A.D., this traffic would increase to 182 bt km. and 800 b pkm.

It will be useful here to study the vehicular population growth in India. According to the latest available source, the total number of registered vehicles in India upto 1990 is given in the Appendix-1. It is found that in the year 1951, the number of vehicles in the country was 3.06 lakhs. In 1961, this number increased to 6.65 lakhs and in 1971 to 18.65 lakhs. The number of vehicles in 1981 was 51.81 lakhs and in 1986 this was 104.89 lakhs and in 1990 it is estimated to be 190.70 lakhs. this is clear from these figures that the magnitude of emission from the vehicles is on the increase in this country. In order to satisfy the growing demands of the public for comfortable short distance travel, Government has contemplated running passenger bus services by themselves. The State Road Transport Corporation Act was passed in 1950 to enable Government to set up State Road Transport Corporation. The State Government has set up the corporations in various states to provide road transport service. However, not all the routes have been nationalized. The private operations still predominate in many states. The percentage of nationalization is at present about 48 in terms vehicles owned by the public sector undertakings. At the beginning of the Seventh Plan, there were 53 State Road Transport undertakings with a fleet of about 80,000 buses. Nationalization of road transport is not likely to have any positive effect on the problem of air pollution by motor vehicles.[1]

Projections made available indicate that in the five metropolitan cities of Delhi, Bombay, Calcutta, Madras and Bangalore, the rate of increase in the number of registered vehicles would decrease in the coming decades whereas in the cities of Pune, Hyderabad and Ahmedabad, the rate of increase

1. Bidhi Chand, Transport : Air Pollution and Management.

would continue at the same trend. The quantum of vehicular pollutants emitted is highest at present in Delhi followed by Bombay, Bangalore, Calcutta and Ahmedabad. Carbon monoxide, hydrocarbons and oxides of nitrogen emitted by diesel and petrol driven vehicles in the 12 metropolitan cities reported here constitute about 64, 22 and 12 per cent of the total pollutional load respectively. Transport is the prime source of mobility in urban society. It not only provides a fast, convenient and economical mode of carrier to meet multifarious activities of citizens, but also caters to the need of transportation of goods of commercial and industrial importance from stock centres to user agencies. However, it vitiates obnoxious and toxic pollutants in the surrounding atmosphere and thereby poses serious health hazards to biotic community.

In the recent past, the growth in vehicular population has assumed alarming proportions in urban India and metropolitan cities in particular, due to their development as major centres of trade, commerce and industries. The metropolitan cities constitute 35 per cent of total registered vehicles in the country while comprising just 6 per cent of human population.

Although the vehicular population in Indian metropolitan cities is much less compared to those in developed countries, yet ill-maintained vehicles, outdated engine designs, defective and deficient road network, erratic driving pattern and congested and slow moving traffic have perhaps aggravated the problems and the signs of vehicular air pollution are already apparent in metropolis. This has prompted the Central Board to undertake assessment of vehicular pollution in these cities so as to suggest possible action plan to concerned agencies to control and minimize vehicular pollution in problem areas.

In India, there are three different categories of vehicles :

i) vehicles with spark ignition engines using petrol.

ii) vehicles with compression ignition engines using diesel and

iii) vehicles with two strokes ignition using lubricating oil mixed petrol (two or three wheelers).

Considering petrol as C_7H_{13}, combustion of petrol to carbon dioxide occurs according to the following equations :

$$4C_7H_{13} + 41O_2 + 154\ N_2 \longrightarrow 28\ CO_2 + 26\ H_2O + 154\ N_2$$

On mass basis the above equation can be written as

$$44(kg)\ C_7H_{13} + 148.8(kg)O_2 + 489.9(kg)\ H_2 \longrightarrow 139.7(kg)\ CO_2 + 530.7(kg)\ H_2O + 489.9(kg)\ N_2$$

The existing road network in metropolitan cities is inadequate and deficient, and unable to accommodate the burgeoning vehicular population. The land use for road network and transport facilities, varies from 6 per cent (Calcutta) to 17 per cent (Bangalore) against the international norm of 30 per cent. Also the traffic flow follows a unidirectional or radial flow due to central business areas located in the heart of the city or concentrated in a particular area. The non-availability of space and funds for road expansion and development coupled with increasing use of personal vehicles and mixing of fast and slow moving vehicles further accentuate the problem and precipitate in the generation of immense vehicular air pollution.

The inherent tendency to opt for breakdown maintenance instead of preventive maintenance, has led to poorly maintained vehicles which emit excessive amount of pollutants. Further, the boom of two and three wheelers population has resulted in the emission of enormous quantity of unburnt hydrocarbons into the environment mainly due to inefficiency of the two stroke engines and the solution to this problem exists nowhere in the foreseeable future.

The assessment of vehicular pollution was carried out by the Central Pollution Control Board by applying emission factors laid down by the World Health Organization (WHO) based on kilogram of pollutants emitted per thousand kilometres running of different categories of vehicles within the municipal limits of metropolitan city. Stepwise activities undertaken by the Board are described as follows :

1) Sample surveys of approximately 500-1200 vehicles were carried out in 6 selected metropolitan cities, e.g., Delhi, Bombay, Calcutta, Madras, Ahmedabad and Kanpur to estimate average running of different categories of vehicles in the city. The citywise approach for a overall assessment of vehicular pollution, was necessitated since every metropolitan city is unique in its own topography, land use pattern, traffic movement and road network, socio-econometric development, trip length etc.

2) For buses and goods transport vehicles, concerned organizations were contacted to estimate average running of these vehicles in the city.

3) The collected data were processed to compute the number of vehicles running in a particular range and the number of registered vehicles of a particular type in the above said range.

4) The data of registered vehicles, total and categorywise were collected from Regional Transport Office. In order to calculate the total distance travelled in a day by a particular category of vehicles, the average distance travelled (km/day) was multiplied by the total number of registered vehicles, and the total fuel consumption (kl/day) was calculated on the basis of average consumption (km/lit.)

for that category of vehicles. Similar exercise was repeated for other categories of petrol driven vehicles as well.

5) The total fuel consumption (kl/year) calculated by this method and the data provided by the Indian Oil Corporation Delhi have been compared to arrive at a correction factor based on actual fuel consumption which may be applied in the assessment of actual running of different categories of vehicles in respective cities.

6) After correcting the total distance travelled by different categories of vehicles within the municipal boundary of the city, WHO prescribed emission factors were applied to compute total pollution load generated by vehicles in the city.

India is getting urbanized very rapidly in recent years, but the growth rate of vehicular population is much higher than that of human population in metropolitan cities where population is one million or more. According to 1981 census, there are 12 metropolitan cities in India, out of which the top five are Delhi, Bombay, Calcutta, Madras and Bangalore. Projected population figures show that by 1991 there would be as many as 23 metropolitan cities. Total population of the existing metros constitutes 6.15 per cent of total population and 26.4 per cent of the total urban population of India.[1]

The vehicles in the metropolitan cities constitute about 35 per cent of the total vehicular population in the country and the vehicular population in the top five metropolitan cities is approximately 68.6 per cent of the total vehicular population in the 12 metropolitan cities. It is expected that the metropolitan vehicular population by 1991 is likely to increase to 39.5 per cent whereas in the top five, the vehicular population is expected to come down to 65 per cent of the total vehicular population in the 12 metropolitan cities. This indicates that the top five metropolitan cities are attaining a saturation level and the growth in other seven metropolitan cities is relatively on the increasing phase. The metropolitan cities constitute about 53 per cent of four-wheelers and 38 per cent of two-wheelers of the total four and two-wheeler population of the country respectively. It is estimated that these figures in 1990-91 would touch 61 and 45 per cent respectively. Only top five metro-cities constitute about 84 per cent of the four-wheelers and 64 per cent of two-wheelers in the 12 metro cities. The trend is likely to go down in future and it is

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1. "Assessment of Vehicular Pollution in Metropolitant Cities", Part-I, Abridged Report, Central Pollution Control Board, New Delhi.

estimated that by 1990-91, these figures would be 82 and 62 per cent respectively. Out of the country's total vehicular population, approximately 64.9 per cent is the contribution of two-wheelers, and three wheelers and four-wheelers contribute only 35.1 per cent. It is estimated that by 1990-91, the two wheelers are likely to go down to 13.2 per cent of the total. In the metropolitan cities, two-wheelers contribute about 62.5 per cent of the total vehicular population; however, four-wheelers contribute only 25 per cent. It is estimated that by 1990-91 there would be an increasing trend in the contribution of two-wheelers (i.e., 72 per cent) and a decreasing trend in case of four-wheelers (i.e., 20.2 per cent).

The daily pollution load generated due to automobiles in the metropolitan cities has been estimated by the Central Board and shown in the Appendix-2. It is evident that maximum pollution load is generated in Delhi, followed by Bombay, Bangalore, Calcutta and Ahmedabad. Carbon monoxide, hydrocarbon and oxides of nitrogen constitute about 63.7, 22.4, and 12 per cents of the total load respectively. The contribution of SO_2 and particulates is relatively negligible.[1]

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1. "Assessment of Vehicular Pollution in Metropolitan Cities", Part-I, Abridged Report, C.P.C.B., New Delhi.

In the major metropolitan cities, vehicular exhaust accounts for 70 per cent of all CO, 50 per cent of all HC, 30-40 per cent of all oxides and 30 per cent of all particulate matter. In Delhi alone, there happens to be 8,50,000 vehicles which release 325 tonnes of CO, SO_2, NO_x, HC and other pollutants into atmosphere everyday. If the emissions are not controlled, then by 1991-92, they would be contributing upto 50 per cent of the CO and 80 per cent of total HC in the air. It has been estimated that a car (without cleaning device) on burning 1000 litres of fuel releases 350 kg. of CO, 0.6 kg. of SO_2, 0.1 kg. of lead and 1.5 kg. of particulate matter.

All the two and three wheelers in the country, run on two stroke engines, burn a mixture of petrol and oil. The combustion has been never complete and all of them, therefore, give out a cloud of blue smokes. Buses and trucks in India are now powered exclusively by diesel engines and, in theory at least, the exhaust from them should be far less toxic than that of petrol burning vehicles. According to Prof. J.M. Dave, Dean of the School of Environmental Sciences at Jawharlal Nehru University (JNU) and his team of researchers, 400 tones of pollutants are emitted everyday in Delhi by nearly 5,00,000 vehicles amounting to 34 per cent of the smoke and dust emitted in the city. According to a report prepared by the Institute of Petroleum, Dehradun, if vehicle pollution remains unchecked, by 1991-92, the vehicles in Bombay will release 1,07,000 tonnes of hydrocarbons per year in the atmosphere. In 2000 A.D., 1,85,000 tonnes carbon monoxide and 6,93,000 tonnes of hydrocarbon will be released in Bombay city's atmosphere.[1]

The Government of India at last has realized the severity of the problem. It has taken up various measures to check the air pollution in the country. The Central Pollution Control Board, Delhi, has taken the initiative to measure the amount of pollutants present in the air. They have collected data from some important cities of the country through the State Pollution Control Board of the respective states.

In this chapter, we have tried to study the pollution scenario of those cities. We have presented here the latest available text depicting the amount of pollutants of those cities as obtained from the Board. The tables showing the pollution load have been given in the appendix of this thesis.

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1. Encyclopaedia of Ecology, Environment and Pollution Control, Vol.17, Environmental Air and Water Analysis, 1992.

3.1. Ambient Air Quality of Some Major Cities of the Country

3.1.1. Delhi

Delhi, the capital city of the Indian territory is the most polluted city in the country. This pollution is caused mainly by the vehicular traffic. Vehicles of all classes put together emit during peak traffic hour 692 kg. of Carbon monoxide (CO), 240 kg. of Hydrocarbons (HC) and about 50 kg. of Oxides of nitrogen in South Delhi and 454 kg. of CO, 158 kg. of HC and 64 kg. of NO_x in North Delhi. Two wheelers and three wheelers contribute over 60 per cent of the total emission of CO and as high as 83 per cent of the total emission of HC. In case of the emission of NO_x, heavy vehicles contribute 55 to 80 per cent of total and the balance being from medium vehicles. The emission of particulates and SO_2 from vehicles are much low.

In terms of pollutional load intensity, the pollutants emitted per square kilometre were 582 kg. of CO, 202 kg. of HC and 82 kg. of NO_x by vehicular traffic during peak hour in North Delhi. The corresponding emission in kg. per square kilometre in South Delhi were 247 of CO, 86 of HC and 18 of NO_x during peak hour.

The Indian standard specification for the smoke intensity is limited to 65 on the Hatridge Scale. Only 10 per cent of UP Roadways, 15 per cent of Haryana and 25 per cent of Inter-State DTC buses monitored at the Inter-State Bus Terminal (ISBT) conform to that limit. However, 65 per cent of the DTC buses at the Bawda Bahadur Marg Depot (BBMD) would qualify the limit. As many as 50 per cent of UP Roadways, 35 per cent of Haryana, 25 per cent of Punjab, Himachal Pradesh and Inter-State DTC buses, 20 per cent of Rajasthan and 5 per cent of BBM Depot buses had smoke intensity of 90 or more on the Hatridge Scale which should never be permitted to travel unless rectified.

Spot surveys with aspirator tubes indicated CO concentrations as high as 20 ppm at some crossings during peak traffic hours. The 12 hour average values for CO ranged between 3 and 7 ppm showing significant impact of vehicular pollution. The 12 hour average of suspended particulate matter (SPM) at Tilak Foot Overbridge booth location ranged between 180 and 398 µg/cubic metre establishing no impact of vehicular emission. Comprising the range of exhaust concentrations with international data, it is found that the pollutants' concentration in the exhaust emissions of Indian vehicles is higher than in similar emissions in Western countries.

3.1.2. Emission Inventory for Vehicular Exhaust

The total pollutants emitted in a study area may be estimated knowing the following two basic factors :

i) emission factors expressed as kg. of pollutant per 1000 km. of vehicle travel for each type of the vehicle and

ii) the distance in kilometre of vehicle travelled within the study area during the period of investigation.

Because of limited observations made to evaluate, the emission factors using the Mechanical Engineering Laboratory of IIT (Delhi), the emission factors used in computing the emission of pollutants in the present investigation are taken from World Health Organization (WHO) Offset Publication

Table-3.2

Emission Factors in Kg. of Pollutant for Vehicle Km x 10^3

Type of Vehicle	Particulates	SO_2	NO_x	HC	CO
Light duty gasoline powered	0.33	0.08	3.2	6.0	40
Light duty diesel powered	0.45	0.39	0.99	0.28	1.1
Heavy duty diesel powered	0.75	1.5	21.0	2.1	12.7
Motor cycles	0.2	0.02	0.07	10	17*

* It was taken as 21.25 in place of 17 to accommodate higher quantity of CO emission from 3-wheelers, as the petrol consumption for the 3-wheelers is one and a half times more than of 2-wheelers (motor cycle or scooter), per km. travel. Thus 17 for 2-wheelers and 25.5 for 3-wheelers and LTV as a group ½(17+25.5) = 21.25.[1]

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1. "Vehicular Air Pollution in Delhi - A Preliminary Study", 1982. CUPS/10/1982-83, C.P.C.B., Delhi.

No.61. It should be recognized that the emission factors of vehicles made and run in India should be on the higher side. As a ready reckoner the relevant extract of the emission factors as given in the WHO publication is given in Table-3.2.

The calculated total vehicular pollution load for Delhi has clearly shown the increasing trend and it has increased from 424 tonnes per day to 865 tonnes per day during 1980-81 to 1986-87 and the overall increase was approximately 2.2 times. The petrol driven vehicles contributed more than 90 per cent CO and HC while the diesel driven vehicles emitted approximately 84 per cent of NO_x when compared with total pollution load. Among the petrol driven vehicles two and three wheelers contributed approximately 44 per cent of total CO emitted in 1980-81 which has risen to 54 per cent by 1986-87. The corresponding figures for HC were 75 to 81 per cent. The four wheelers emitted approximately 43 per cent of total CO discharged and its share has come down to 33 per cent by 1986-87. The corresponding figures for hydrocarbons has also shown a declining trend, i.e. from 20 per cent to 13.4 per cent.

Although, very little work has been done to study the impact of vehicular pollution on ambient air quality in surroundings of heavily congested traffic intersections with respect to major pollutants like CO, HC and NO_x, and the work done so far is inadequate and sketchy, yet the table in Appendix-3 reveals the amount of pollutants present in the atmosphere due to transport.

3.1.3. Bombay

The unidirectional traffic flow, narrow roads, slow moving heterogeneous traffic and frequent halts, have reduced the vehicular speed from 45 km./hr. to 15 km./hr. in Central Bombay. Although vehicular maintenance, in general, is good, yet requires periodical check up and remedial measures as the pollution generated from these vehicles, appears to be higher than the stipulated limit.

The impact of high rise buildings, slow wind, high humidity and near isothermal conditions during most part of the year may aggravate the effects of vehicular emissions at congested traffic intersections particularly during peak hours.

The survey conducted by Maharashtra State Pollution Control Board and Bombay Municipal Corporation reveals that the average concentration of carbon monoxide at 3-4 feet height and approximately 25 metres distance from the congested traffic intersections, has been in the range of 4 to 30 ppm, while touching upto 50 ppm level during peak hours at a time, while the concentration of HC has been in the range of 3 to 5 ppm.

Since, industrial areas are distributed in different parts of the city and the major pollutants emitted by vehicles namely CO, HC and NO_x, are of minor significance, so far industrial pollution is concerned. Moreover, it would be difficult to estimate the percentage contribution of vehicular pollution to total air pollution load until or unless a complete inventory of air polluting industries including fuel consumption, pollution control status, etc. could be compiled. The calculation based on fuel consumption to estimate the total air pollution load could be misleading and also while doing so, the contribution by other pollutants like NH_3, H_2S, CS_2 etc. should be taken into consideration.

The pollution load estimated by Bombay Municipal Corporation clearly shows the increasing vehicular pollution during 1973-1986 (from 398.7 tonnes/day to 1314.33 tonnes/day) based on assumed daily running of different categories of vehicles without using any correction factor which is essential to correct the imbalance precipitated due to the assumption that all registered petrol driven vehicles, are playing on the road of Bombay on an average day. The estimated vehicular pollution load, based on survey conducted by Central Board, during 1986-1987 for Greater Bombay is approximately 583.96 tonnes/day while applying correction factor of 0.34. The break-up of the pollutants is given in Appendix-4.

The detailed analysis of data reflects that the contribution of CO, HC and NO_x has been in the range of 69.5 per cent, 16.4 per cent and 12.4 per cent respectively. The four wheelers and two and three wheelers emit 71.2 per cent and 21.5 per cent of total CO emission while the corresponding figures for HC were 45.9 per cent and 48.9 per cent, respectively. The emission of NO_x was predominantly from trucks (47 per cent), four wheelers (32 per cent) and buses (19.1 per cent) when compared to total NO_x emissions from vehicles.

3.1.4. <u>Bangalore City</u>

It is estimated that the total vehicular pollution load was approximately 254 tonnes/day in Bangalore city during 1986-1987. Out of which, the share of petrol and diesel driven vehicles was 87.4 per cent and 12.6 per cent respectively. Bangalore is the third polluted city in the country. The share of two wheelers, and three wheelers comes to about 62 per cent of total vehicular pollution load while of four wheelers, it is 25.4 per cent.

The major vehicular pollutants comprised of CO, HC and NO_x and their percentage distribution is 63.7 per cent, 26 per cent and 8.7 per cent respectively.

The emission of CO and HC by two and three wheelers is estimated to be 61.4 per cent and 85.6 per cent while from four wheelers, 32 per cent and 11.7 per cent respectively when compared with total CO and HC emissions from vehicles. The diesel driven vehicles are the major source of emissions of oxides of nitrogen and the per cent contribution of which is 79.5 per cent. The break-up of the pollutants is given in the Appendix-5.

The data of ambient air quality collected by the Karnataka government from 10 places in Bangalore has indicated an increase in air pollution following a steep multiplying of the automobile population. According to the Karnataka State Council for Science and Technology, the air pollution and air quality issues had reached critical stages in Bangalore. Although no detailed study has been carried out in the city to study the impact of vehicular emissions on air quality, yet a generalized feeling does not reflect the signs of deteriorated air quality in a significant way. The well managed traffic, disciplined vehicles, extensive road network with radial pattern etc. might be the factors responsible for diluting the impact of vehicular emissions. The existence of well maintained parks and extensive greenery might have further diluted the impact of vehicular pollution.

3.1.5. Calcutta

The estimated total vehicular pollution load within the Calcutta municipal city was 310.6 tonnes/day during 1987-

1988. The major pollutants are comprised of carbon monoxide (65 per cent), hydrocarbons (15.76 per cent) and oxides of nitrogen (17.3 per cent).

Petrol driven vehicles were major contributors of CO (87 per cent) and HC (90 per cent) while diesel driven vehicles mainly emit oxides of nitrogen (79 per cent). Among the petrol driven vehicles, two and three wheelers emit approximately 52 per cent and 22 per cent of HC and CO. While four wheelers contribute 48 per cent and 78 per cent respectively.

The survey revealed the deteriorated air quality with reference to CO level which has been found in the range of 40-100 ppm at various intersections during different time intervals. The table in Appendix-6 reveals the pollution load due to vehicles in Calcutta city.

The actual pollution load would be very much high in the Calcutta city than the calculated load due to frequent traffic halt, crawling speed of the vehicle, ill maintained vehicle and erratic driving pattern coupled with presence of high rise buildings, slow wind pattern, high temperature built up in city than the outskirts and high humidity.

3.1.6. <u>Ahmedabad</u>

The total vehicular pollution load, generated within the city, was about 209.1 tonnes per day during 1987-1988.

The petrol driven vehicles contributed approximately 91 per cent of total vehicular pollution load while rest is being contributed by diesel driven vehicles. The principal vehicular pollutants included CO, HC and NO_x and their percent contribution was approximately 64, 27.7 and 4.9 per cent respectively.

The contribution of two and three wheelers and four wheelers in respect to total CO emission has been 66 per cent and 28.9 per cent while for total HC emissions, 88 per cent and 10 per cent respectively. Diesel driven vehicles emit approximately 74.8 per cent of total NO_x emissions.

The pollution load could be higher than the emitted, particularly in old city of Ahmedabad due to crawling speed of heavy concentration of incoming traffic, frequent traffic halts and poorly maintained vehicles coupled with deficient road network. The presence of high buildings, slow wind and higher temperature at the outskirts due to heat island effect, further aggravates the problem. Deficient traffic management and erratic driving pattern may precipitate the vehicular pollution in a visible form. Appendix-7 shows the break-up of pollutants.

3.1.7. Pune

The total vehicular pollution load in the metropolitan city of Pune, on an average, was estimated to be 212.88

tonnes/day during 1986-1987. The contribution of petrol vehicles was approximately 89.9 per cent while of diesel driven vehicles - 10.1 per cent of total vehicular pollution load.

The major pollutants, emitted from vehicles, were CO, HC and NO_x and their percent contribution has been estimated as 63.5 per cent, 28.60 per cent and 6.3 per cent respectively. The two and three wheelers and four wheelers emitted maximum CO - 80.5 per cent and 14.20 per cent respectively while for HC, the similar figures were 93.4 per cent and 4 per cent respectively.

Although air quality for CO and HC at congested traffic intersections has not been carried out, yet the traffic pattern and linear orientation of city along with unidirectional traffic movement clearly reflects the possibility of adverse impact on air quality particularly in CBD area and the bridge connecting the western and eastern part of the city. The respective break-up of the pollutants in the air of Pune is shown in Appendix-8.

3.1.8. Madras City

The total pollution load generated by vehicles in Madras Municipal Limit on an average day was estimated to be approximately 297 tonnes/day. The major vehicular pollutants emitted by vehicles were CO, HC and NO_x and their contribution in total pollutional load has been 70 per cent, 16.5 per cent and 11.2 per cent respectively.

Petrol driven vehicles are the main source of CO emission, contributing approximately 94 per cent of total CO emitted, out of which four wheelers and two and three wheelers discharge 74 per cent and 18.2 per cent respectively. Similarly, the quantity of HC, emanating from petrol driven vehicles was in the range of approximately 9.5 per cent of total HC emission out of which the contribution of two wheelers and four wheelers was of 47 per cent each for both these categories. The diesel driven vehicles emitted NO_x as a major pollutant; contributing approximately 62 per cent of total NO_x emissions from vehicles while the rest came from petrol driven vehicles and that too mainly from four wheelers. The break up of the pollutants is given in Appendix-9.

3.1.9. Hyderabad

The total vehicular pollution load, emitted in Hyderabad Municipality City for the year 1986-1987, was estimated to be 170 tonnes per day. The major pollutants include CO, HC and NO_x which contribute approximately 61.8 per cent, 27.6 per cent and 8.2 per cent respectively of total vehicular pollution load.

Petrol driven vehicles are the major contributors of pollution discharging approximately 85.8 per cent pollutants while remaining 14.2 per cent is being emitted by diesel driven vehicles.

Two and three wheelers are responsible for maximum emissions of CO and HC and their per cent contribution is 76 per cent and 91.6 per cent respectively, while the similar figures for four wheelers are 16.7 per cent and 5.6 per cent respectively. The diesel driven vehicles discharge approximately 88 per cent of the total NO_x emissions. The respective break-up is given in Appendix-10.

3.1.10. Jaipur

The total vehicular pollution load generated within the municipal limit of the city, on an average day during 1986-1987 was estimated to be 75 tonne/day which is mainly contributed by petrol driven vehicles (66 per cent) followed by diesel driven vehicles (34 per cent).

The major pollutants, emitted by two, three and four wheelers (petrol driven) consist of CO and HC and their percent contribution has been approximately 79 per cent and 90 per cent respectively when compared with total CO and HC emissions by vehicles. Further two and three wheelers discharge 58.8 per cent and 84 per cent of total CO and HC emissions respectively. While for four wheelers the similar figures have been observed as 24 per cent and 9 per cent respectively. The emission of NO_x has been mainly from heavy duty diesel powered vehicles, i.e. buses, and trucks which contribute approximately 93 per cent of total NO_x emissions from vehicles.

Since the construction of city has been done under a well-thought plan with proper road network and adequate green vegetation and residential areas scattered all around the city, the visible impact of vehicular pollution on air quality is yet to be observed. However, the congested old city area, which is left untouched by recent development of city, do exhibit signs of traffic congestion on certain roads and thereby needs to be given proper attention for containing its impact on vehicular pollution. Appendix-11 shows the overall break-up of the pollutants.

3.1.11. Kanpur

The total vehicular emissions in metropolitan city of Kanpur was estimated to be 75.47 tonnes/day for the year 1987-1988, out of which the contribution of petrol and diesel driven vehicles was approximately 86.5 per cent and 13.5 per cent respectively. Total Carbon monoxide and Hydrocarbons were the principal vehicular pollutants, contributing approximately 61.6 per cent and 28.27 per cent respectively.

The impact of total vehicular pollution load on air quality would be higher particularly at the congested traffic intersections due to concentration of ill maintained vehicles, improper traffic control, narrow roads and abrupt halt of vehicles because of mixing of fast and slow moving vehicles. However, a detailed investigation is yet to be taken up in this regard. The over-all break-up of pollutants due to vehicular traffic is given Appendix-12.

3.1.12. Lucknow

Total pollution load generated in the city was about 79 tonnes/day, as calculated on the basis of a rapid survey conducted by Central Pollution Control Board in August 1988 and applying WHO emission factors. Main pollutants were HC (22 tonnes) and CO (48 tonnes).

Petrol driven vehicles are major contributors of HC and CO. Two wheelers alone contribute about 20 and 34 tonnes of HC and CO respectively. Out of the total pollution load, petrol driven vehicles contribute 45.26 per cent of particulates, 16.38 per cent of SO_2, 12.24 per cent of oxides of Nitrogen, 96.51 per cent of HC and 91.16 per cent of CO.

Diesel vehicles contribute only a major share of oxides of nitrogen, i.e. 87.76 per cent of total emissions.

Petrol driven vehicles contribute about 84.11 per cent of total pollution load and rest is contributed by diesel vehicles. Appendix-13 gives the break-up of pollutants.

Even by visual observation, pollution created by vehicles is visible specially in the evening time. Some major roads and their surroundings such as Vidhan Sabha Marg, Station Road, Latus Road, Alam Bagh Marg and Faizabad Road become smoky and sooty in the evening time and morning peak hours due to exhaust emission of vehicles especially of tempos.

3.1.13. Nagpur

The total vehicular load has been estimated to be approximately 47.8 tonnes on 31st March, 1987, within the metropolitan city of Nagpur. The major pollutants emitted by vehicles included CO (61 per cent), HC (28.4 per cent) and NO_x (8.9 per cent) of total vehicular pollution load. While the major contributors of pollution are petrol driven vehicles approximately 85 per cent of total vehicular pollution load while remaining 15 per cent was emitted by diesel driven vehicles.

The two and three wheelers contributed approximately 75 per cent and 92 per cent of total CO and HC emissions respectively, while the similar figures for four wheelers correspond to 16.6 per cent and 5.3 per cent respectively. The diesel driven heavy vehicles like trucks and buses emit approximately 97.5 per cent of total NO_x emissions. Appendix-14 gives the break-up of the pollutants.

The well-developed road network surrounding green belt and low vehicular traffic help in containing the steady deterioration in air quality in the city. However, the circular development pattern, leading to traffic concentration in the heart of the city and thereby precipitating thrombosis requires to be given immediate attention so as to contain the vehicular pollution within the manageable limits, otherwise situation could be critical in near future.

3.1.14. <u>Ambient Air Quality at Chandigarh</u>

The Central Pollution Control Board recently conducted exhaust monitoring of Chandigarh covering 396 petrol driven vehicles and 76 diesel buses. The observations are as follows :

1) Almost 99 per cent of the scooters (all makes) were found conforming to the emission standards of CO, i.e., 4.5 per cent.

2) 100 per cent motor cycles including new 100 cc vehicles were found complying with CO standards.

3) 66 per cent of the 3-wheelers were found complying with emission standards.

4) 43 per cent of four wheelers were found to be within the prescribed limits. Performance of Maruti vehicles was found marginally better than ambassador and premier cars.

About 197 tonnes of CO, 94 tonnes of HC, 5 tonnes of NO_x, 2 tonnes of particulate matter and 330 kgs. of SO_2 have been estimated as being emitted everyday by all kinds of two, three and four wheelers, petrol driven passenger vehicles and CTU buses plying within the Union Territory of Chandigarh.

It is found that in Chandigarh, the CO emission level from two, three and four wheelers was reduced substantially below the prescribed level after proper adjustment of carburetor and RPM (revolution per minute) of the engine. The smoke density of more than 70 per cent of CTU buses was found exceeding the prescribed limits (Ref: CPCB Newsletter,

Table-3.3

Projected Number of Vehicles and Pollution Load in Metropolitan Cities for 1991

Sl. No.	Name of the city	No. of vehicles	Total pollution load (Tonnes/Day)
1.	Delhi	15,98,000	1319.96
2.	Bombay	5,76,400	460.80
3.	Calcutta	4,53,400	357.35
4.	Hyderabad	4,53,133	357.13
5.	Ahmedabad	4,15,500	325.48
6.	Madras	4,15,000	325.06
7.	Bangalore	3,91,500	305.30
8.	Pune	2,79,500	211.10
9.	Jaipur	2,14,270	156.25
10.	Lucknow	1,92,600	138.02
11.	Kanpur	1,60,000	110.61
12.	Nagpur	1,41,500	95.05
	Total	52,90,803	4162.11

Source : Central Pollution Control Board, Delhi.

Vol.4, No.2, April 1991). Table-3.3 shows the pollution load in the 12 cities.

3.2. Causes of Air Pollution in India

In the previous chapter, we have talked about the causes of air pollution due to transport in general. The air *pollution in India depends on many other factors which may* not be prevalent in other countries of the world. The factors responsible for high rate of air pollution in India can be described as follows :

3.2.1. <u>Poor maintenance of vehicles</u>

Proper maintenance of vehicles plays a big role in containing the rate of pollutant emissions. In the proper maintenance of vehicles, preventive maintenance plays an important role. Every organisation should formulate its own preventive maintenance schedules based on past experience and its peculiar operating conditions. It will not be possible to detain a vehicle during daily and weekly maintenance for more than 34 hours keeping in view that any detention longer than the above duration may adversely affect the availability of vehicles for operation. A good preventive maintenance system should be kept in view and be based on :

i) co-ordination between the traffic and maintenance functions;

ii) personal knowledge of routes by mechanical supervisors;

iii) adherence to bus links;

iv) providing sufficient time for preventive maintenance;

v) carrying out preventive maintenance in full;

vi) cross checks by supervisors;

vii) maintaining machinery functioning;

viii) prompt attention to drivers' complaints;

ix) having proper plan of action;

x) proper control over the staff in the garage;

xi) facility of adequate stores supplies and provision of units;

xii) adequate, managerial checks;

xiii) strengthening of night maintenance.[1]

It is essential that such type of vehicles which emit heavy black smoke, are maintained in time so that they do not emit undesirable black smoke. One reason for not giving due attention to proper vehicle maintenance could be the shortage of maintenance facilities. Due to the increase in transport demand the number of vehicles go on increasing, but no commensurate increase in maintenance facilities takes place. This again may be due to the non-availability of adequate

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1. Telco Dealers News reproduced in <u>Journal of Transport Management</u>, November, 1986.

resources to road transport sector. The plan outlays have been getting reduced for total transport from 22.1 per cent to 12.8 per cent and road sector 6.7 per cent to 2.9 per cent. Maintenance funds' allotments too have been increasingly falling short of norms. Maintenance funds norm during 1977-78 for National Highways stood at Rs.27.28 crores. The allotment was Rs.25.30 crores, which was 7 per cent short of the norm. In 1981-1982, the norm in this regard was Rs.67.98 crores. The allotment was only Rs.47.00 crores. This had a short fall of 31 per cent. The maintenance funds norm for these roads during 1985-86 was Rs.110.00 crores. The allotment of funds stood at Rs.7600 crores. The shortfall increased to 40 per cent.

3.2.2. Poor Upkeep of Roads

The poor upkeep of roads results in poor condition of vehicles, leading to high rate of pollutant emission. Road maintenance is generally of three types :

i) routine day-to-day maintenance of road width, structure, road signs, etc.

ii) periodical renewal of surface and

iii) special repairs necessitated by floods, land slides, storms and natural calamities. Members of the Committee on National Transport Policy, Government of India, 1980, during their visits to states found that roads including national highways were poorly maintained. They were told by the state representatives that the main reason for such poor maintenance was inadequate financial allocation.[1] In the opinion of the Committee, road maintenance should be accorded a higher priority than new construction and there should be a major policy shift in favour of road maintenance both in terms of financial allocation and organizational effort.

3.2.3. Large Proportion of Over-aged Vehicles, Extensive Overloading and More Frequent Traffic Jams

In the high rate of pollutant emission, large proportion of over-aged vehicles also play a great role. The vehicles are not generally replaced on their due dates and they continue to be operated. An averaged vehicle needs more maintenance and also emits more smoke. Therefore, the solution lies in the replacement of vehicles at the proper time. Over loading of vehicles also causes problems. There are frequent traffic jams in big cities and on important roads. It is because the width of roads is generally not adequate. "What has happened is that with the recent vehicle boom and without corresponding development in the quantum and quality of roads, without improvement in the quality of

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1. "Report of the Committee on National Transport Policy", Government of India, 1980.

driving, the road congestion is increasing and if the present trend continues, it is expected that the road congestion would be trebled by the turn of the century." All this is bound to increase the rate of pollutant emissions.[1]

3.4. Pollution Control Rules and Regulations in India

India is one of the very few countries of the world which has enshrined in its Constitution a commitment to environment protection and improvement. Many provisions dealing with the environment are scattered in pieces and found in the different enactments of this country. A direct reference to environmental protection and improvement was introduced with the Constitution (42nd Amendment) Act of 1976. It has been made obligatory for the Central Government, State Governments and every citizens to protect and improve the environment. Mrs. Indira Gandhi enacted the Wild Life (Protection) Act, 1972. The Water (Prevention and Control of Pollution) Act was passed in 1974. This was a major and significant act in environmental protection in India. The Forest (Conservation) Act was passed in 1980. The law concerning air pollution, i.e., the Air (Prevention and Control of Pollution) Act was passed in 1981. This Act makes provision for prevention, control and abatement of air

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1. P.G. Patankar, "Road Development must Match Vehicle Boom", Journal of Transport Management, January 1989.

pollution, for establishment of Boards for conferring powers and functions relating thereto for matters connected therewith. These Boards have been empowered to establish air laboratories, to enable them to perform their functions efficiently. In 1986, the Government enacted the Environment (Protection) Act, 1986. In the transport sector, the most important in this regard is Motor Vehicles Act, 1989. Government of India has set up standards for emission of smoke, vapour, etc. from motor vehicles :

1) On and from the 1st day of March 1990, every motor vehicle shall comply with the following standards :

a) Idling carbon monoxide emission limit for all four wheeled petrol driven vehicles shall not exceed 3 per cent by volume.

b) Idling carbon monoxide emission limit for all two and three wheeled petrol driven vehicles shall not exceed 4.5 per cent by volume.

c) Smoke density for all diesel driven vehicles shall be as follows :

Method of Test	Maximum Smoke Density: Light Absorption Co-efficient m^{-1}	Bosch Units	Hartridge Units
Full load at a speed of 60% to 70% of maximum engine rated speed declared by the manufacturer.	3.1	5.2	75
Free Acceleration	2.3	–	65

2) On and from the 1st day of April 1991, all the petrol driven vehicle shall be so manufactured that they comply with the mass emission standards as specified at Annexure-I.

3) On and from the 1st day of April 1991, all diesel driven vehicles shall be so manufactured that they comply with the mass emission standard based on exhaust gas capacity.

4) On and from the 1st day of April 1992, all diesel driven vehicles shall be so manufactured that they comply with the following levels of emissions under the Indian driving cycle :

Mass of Carbon monoxide (CO), Maximi Grams/KWH - 14

Mass of Hydrocarbons (HC), Maximi Grams/KWH - 3.5

Mass of Nitrogen oxides (NO_x), Maximi Grams/KWH - 18

5) Each motor vehicle manufactured on and after the dates specified in paragraph (1), (2), (3) and (4) shall be certified by the manufacturers to be conforming to the standards specified in the said paragraph and the manufacturers shall further certify that the components liable to affect the emission of gaseous pollutants are so designed, constructed and assembled as to enable the vehicle, in normal use, despite the vibration to which it may be subjected to, to comply with the provisions of the said paragraphs.

6) Test for smoke emission level and carbon monoxide level for motor vehicles :

a) Any officer not below the rank of Sub-Inspector of Police or an Inspector of motor vehicles, who has reason to believe that a motor vehicle is by virtue of smoke emitted from it or other pollutants like carbon monoxide emitted from it, is likely to cause environmental pollution, endangering the health or safety of any other user of environmental pollution, endangering the health or safety of any other user of the road or the public, may direct the driver or any person-in-charge of the vehicle to submit the vehicles for undergoing a test to measure the standard of black smoke or the standard of any of the other pollutants.

b) The driver or any person-in-charge of the vehicle shall upon demand by any officer referred in sub-paragraph (a), submit the vehicle for testing for the purpose of measuring the standard of smoke or the levels of other pollutants or both.

c) The measurement of standard of smoke shall be done with a smoke metre of a type approved by the State Government and the measurement of other pollutants like carbon monoxide shall be done with instruments of a type approved by the State Government. The Government of India has approved the Pollution Control Acts and Rules with Amendments as proposed by the Ministry of Law, Justice and Company Affairs, New Delhi, the 30th March 1981.

In Chapter-I, in this Act, which is called Air (Prevention and Control of Pollution) Act, 1981, unless the context otherwise requires :

a) [1]["air pollutant" means any solid, liquid or gaseous substances present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment;

b) "air pollution" means the presence in the atmosphere of any air pollutant;

c) "approved appliance" means any equipment or gadget used for the burning or any combustible material or for generating or consuming any fume, gas or particulate matter and approved by the State Board for the purpose of this Act;

d) "approved fuel" means any fuel approved by the State Board for the purpose of this Act;

e) "automobile" means any vehicle powered either by internal combustion engine or by any method of generating power to drive such vehicle by burning fuel;

f) "Board" means the Central Board or State Board.

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1. Which were later amended in 1987, said after the words "gaseous substance" the brackets and words "(including noise)" shall be inserted.

g) [1]["Central Board" means the Central Board for Prevention and Control of Water Pollution constituted under Section 3 of water (Prevention and Control of Pollution) Act, 1974.

h) "chimney" includes any structure with an opening or outlet from or through which any air pollution may be emitted;

i) "control equipment" means any apparatus, device, equipment or system to control quality and manner of emission of any air pollutant and includes any device used for securing the efficient operation of any industrial plant;

j) "emission means any solid or liquid or gaseous substance coming out of any chimney, duct or any flue or any other outlet;

k) "industrial plant" means any plant used for any industrial or trade purpose and emitting any air pollutant into the atmosphere;

l) "member" means a member of the Central Board or a State Board, as the case may be and includes the Chairman thereof;

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1. For the words "Central Board for the Prevention and Control of Water Pollution", the words "Central Pollution Control Board" shall be substituted.

m) [1]["occupier", in relation to any factory of premises, means the person who has control over the affairs of the factory or the premises and where the said affairs are entrusted to a managing agent, such agent shall be deemed to be the occupier of the factory or the promises;

n) "prescribed" means prescribed by rules made under this Act by the Central Government or as the case may be, the State Government;

o) "State Board" means -

i) [2][in relation to a state in which the Water (Prevention and Control of Pollution) Act, 1974, is in force and the State Government has constituted for that State a State Board for the Prevention and Control of Water Pollution under Section 4 of that Act, the said State Board and

ii) in relation to any other State, the State Board for the Prevention and Control of Air Pollution constituted by the State Government under section 5 of this Act.

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1. "occupier", in relation to any factory or premises means the person who has control over the affairs of the factory or the premises and includes in relation to any substances, the person in possession of the substance.

2. in sub-clause(i) for the words "State Board for the Prevention and Control of Water Pollution", the words "State Pollution Control Board" shall be substituted.

Chapter-IV, in this Act, which is named as Prevention and Control of Air Pollution, states

1) The State Government may, after consultation with the State Board, by notification in the official Gazette, declare in such manner as may be prescribed, any area or areas within the State as air pollution control area or areas for the purposes of this Act.

2) The State Government may, after consultation with the State Board, by notification in the official Gazette -

a) alter any air pollution control area whether by way of extension or reduction.

b) declare a new air pollution control area in which may be merged one or more existing air pollution control areas or any part or parts thereof.

3) If the State Government, after consultation with the State Board, is of the opinion that the use of any fuel other than an approved fuel, in any air pollution control area or part thereof, may cause or is likely to cause air pollution, it may, by notification in the official Gazette, prohibit the use of such fuel in such area or part thereof with effect from such date (being not less than three months from the date of publication of the notification) as may be specified in the notification.

4) The State Government may, after consultation with the State Board, by notification in the official Gazette, direct

that with effect from such date as may be specified therein, no appliance, other than an approved appliance, shall be used in the premises situated in an air pollution control area.

Provided that different dates may be specified for different parts of an air pollution control area or for the use of different appliances.

5) If the State Government, after consultation with the State Board, is of opinion that the burning of any material (not being fuel) in any air pollution control area or part thereof may cause or is likely to cause air pollution, it may, by notification in the official Gazette, prohibit the burning of such material in such area or part thereof.

With a view to ensuring that the standards for emission of air pollutants from automobiles laid down by the State Board, the State Government shall, in consultation with the State Board, give such instructions as may be deemed necessary to the concerned authority in-charge of registration of motor vehicles under the Motor Vehicles Act, 1989, and such authority shall, not withstanding anything contained in that Act or the rules made there under be bound to comply with such instructions.

The following Act, the Air (Prevention and Control of Pollution) Amendment Act, 1987 received the ascent of the President on the 16th December, 1987.

An Act to amend the Air (Prevention and Control of Pollution) Act, 1981.

Be it enacted by Parliament in the Thirty-eight Year of the Republic of India as follows :

1.(1) This Act may be called the Air (Prevention and Control of Pollution) Amendment Act, 1987.

(2) It shall come into force on such date as the Central Government may, by notification in the official Gazette, appoint; and different dates may be appointed for different states and different provisions of this Act.

"3(i) the Central Pollution Control Board constituted under section 3 of the Water (Prevention and Control of Pollution) Act, 1974, shall, without prejudice to the exercise and performance of its powers and functions under that Act, exercise the powers and perform the functions of the Central Pollution Control Board for the prevention and control of air pollution under this Act.

(ii) In any State in which the Water (Prevention and Control of Pollution) Act, 1974, is in force and the State Government, has constituted for that state a State Pollution Control Board shall be deemed to be the State Board for the Prevention and Control of Air Pollution constituted under section 5 of this Act, and accordingly that State Pollution Control Board shall, without prejudice to the exercise and performance of its powers and functions under that Act, exercise the powers and functions of the State Board for the Prevention and Control of air pollution under this Act."

11. "22A.(1). Where it is apprehended by a Board that emission of any air pollutant, in excess of the standards laid down by the State Board is likely to occur by reason of any person operating an industrial plant or otherwise in any air pollution control area, the Board may make an application to a court, not inferior to that of a Metropolitan Magistrate or a Judicial Magistrate of the 1st Class restraining such person from emitting such air pollutant.

(2) On receipt of the application, the court may make such order as it deems fit.

(3) Where the court makes an order restraining any person from discharging or causing or permitting to be discharged the emission of any air pollutant, it may, in that order -

(a) direct a person to desist from taking such action as is likely to cause emission

(b) authorize the Board, if the direction under Clause(a) is not complied with by the person to whom such direction is issued, to implement the direction in such manner as may be specified by the court.

(4) All expenses incurred by the Board in implementing the directions of the court under clause (b) of subsection

(3), shall be recoverable from the person concerned as areas of land revenue or of public demand."[1]

3.5. Measures to Control Pollution

The plants act as bio-indicators of air pollution as well as pollution sinks. It helps in monitoring and mitigating air pollution in urban and industrial areas. Morphology of plants, like presence or absence of trichomes, exudates, wax deposition, size and orientation of leaves etc. plays a vital role in such pollutionally relevant functions of the plants. The foliar damage, reduction in diversity of plants, prostate or distorted growth form are indicative of adverse effects of environmental pollution on plants.

In India, a few research laboratories and Institutions namely Centre of Advanced Studies in Botany, BHU; National Botanical Research Institute (NBRI), Lucknow; School of Environmental Sciences, JNU; Institute of Sciences, Bombay, Life Science Centre, Calcutta University, etc. are engaged in research to find out the biomonitoring species which could be used to monitor or control air pollution.

Currently, a research team at National Botanical Research Institute (NBRI) Lucknow, is studying the usefulness

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1. Pollution Control Acts and Rules with Amendments - Central Pollution Control Board, Delhi, 1989.

of plants for monitoring and mitigating air pollution. The team is entrusted with the responsibility to :

i) study the response of common plants to air pollution,

ii) lay down simple biological parameters for monitoring air pollution,

iii) identify pollution tolerant plants for planting in urban and industrial areas to improve air quality.

iv) identify plant species with relatively higher dust trapping potential for planting as screens or green belts in adverse urban locations to mitigate dust pollution.

The Ashok Leyland Limited, India has introduced diesel exhaust purifier (make Honey Cat). In order to convert the pollutants like the carbon monoxide, unburnt fuel and incomplete combustion products in diesel exhaust into harmless gasses, diesel exhaust purifier is introduced on ALRD 20 and HGP vehicles as an optional fitment. The diesel exhaust purifier (Honey Cat make) comprises of a specially treated ceramic honey-comb support coated with a very thin layer of catalyst, enclosed in a tough shock and vibration resistant stainless steel shell. It utilizes the principle of catalytic oxidation to convert the pollutants into harmless gases. The catalyst supported on the surface of the ceramic honeycomb structure works by reducing the temperature at which oxidation of the harmful pollutants can take place.

This temperature is somewhat lower than the outlet temperature of the exhaust gas, thus ensuring efficient conversion of the pollutants to harmless carbon dioxide and water. Although, the catalyst plays a very important part in the reaction, it remains chemically exchanged. This means it neither gets used up nor wears out. Since the outer shell is in stainless steel, the purifier lasts for the life of the vehicles.

The Government of India has decided in January 1995, to introduce unleaded petrol in the four metros and made catalytic converters mandatory for all new cars sold after April 1, 1995.

ANNEXURE-I

Mass Emission Standards for Petrol Driven Vehicles

1. Type Approval Tests:
   Two and Three Wheeler Vehicles

Reference Mass, R(Kg)	CO(g/km)	Hc(g/km)
R < 150	12	8
150 < 350	$12 + \frac{18(R-150)}{200}$	$8 + \frac{4(R-150)}{200}$
R > 350	30	12

Light Duty Vehicles

Reference Mass, MW(Kg)	CO(g/km)	Hc(g/km)
180<rw<1020	14.3	2.0
1020<rw<1250	16.5	2.1
1250<rw<1470	18.8	2.1
1470<rw<1700	20.7	2.3
1700<rw<1930	22.9	2.5
1930<rw<2150	24.9	2.7
rw>2150	27.1	2.9

2. Conformity of Production Tests:

Reference Mass, MW(Kg)	CO(g/km)	Hc(g/km)
R < 150	15	10
150 < R < 350	$15 + \frac{25(R-150)}{200}$	$10 + \frac{5(R-150)}{200}$
R > 350	40	15

Light Duty Vehicles

Reference Mass, MW(Kg)	CO(g/km)	Hc(g/km)
180<rw<1020	17.3	2.7
1020<rw<1250	19.7	2.7
1250<rw<1470	22.5	2.8
1470<rw<1700	24.9	3.0
1700<rw<1930	27.6	3.3
1930<rw<2150	29.9	3.5
rw<2150	32.6	3.7

For any of the pollutants referred to above of the three results obtained may exceed the limit specified for the vehicles by not more than 10 per cent.

Explanation
Mass emission standards refers to the gm. of the pollutants emitted per km. run of the vehicle, as determined by a chassis dynamometer test using the Indian Driving Cycle.

Chapter-IV

AIR POLLUTION IN MEGHALAYA

4.1. Introduction

Meghalaya, situated in the North-Eastern part of India, is a small state having an area of 22,429 square kilometre and a population of 17,74,778 (1991 Census). This state has no rail link with other states of the country. So road transport is the only transport of the state. Most of the State's transport is concentrated at Shillong, the capital of Meghalaya. Moreover all types of vehicles, both light and heavy, going to Silchar, Tripura and Mizoram have to pass through Shillong as there are no other roads entering these places. Though Silchar has rail link with Guwahati, still trucks carrying goods, buses, cars and taxis pass through Shillong only. According to the survey, about 9,000 trucks play through Shillong every day. This aggravates the pollution load of Shillong substantially. Compared to national average of 7.5 per cent annual rise in vehicular traffic in towns and cities, Shillong is above the normal with 11 per cent more vehicles moving into the already busy streets.

A survey conducted at Barik Point in Shillong in 1989, showed 20,149 vehicles cross the point a day. The traffic census figures for 1993 beginning are as follows :

For vehicles entering Shillong :

Buses	–	787
Trucks	–	3201
Cars	–	2352
Two-wheelers	–	185

The survey also indicates that 9 per cent cars would use bypass (if it is ever made), 10 per cent of buses and an astronomical 74 per cent of trucks would bypass the city.

The traffic census inside the city for 1989 was as follows :

Cars	–	11,609
Buses	–	2,364
Trucks	–	4,420
Two-wheelers	–	1,756

– a total of 20,149 vehicles moving through Barik Point on an average per day.[1]

Shillong, though devoid of any industry which might cause major threat to public health, is not entirely free from scourge of air pollution, with a high density of vehicle population. According to unofficial estimates, the ratio between human population and number of vehicles in Shillong is the highest in the country. The situation is compounded by the unending movement of heavy lorries along the National

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1. "Bypass only solution to city's traffic snarl-up", Rabiul Islam, The Shillong Times, dt. April, 5, 1993.

Highway No.44 passing through the heart of the town. It is an established fact that vehicles, especially those operated on petrol, account for 50 per cent of air pollutants - CO and HC. The city buses, mini-buses, not to speak of long distance vehicles, are collectively vitiating the environment. The heavy vehicles emit such thick black smoke that the National Highways passing through the State virtually remain covered by thick blanket of smokes.[1] It is reported that about 2000 vehicles from outside the State ply through Meghalaya's National Highways No.40 and 44 every day.

Since the pollution is directly proportional to the number of vehicles, therefore, it will be wise on our part to have a look at the growth of vehicles in Meghalaya (Table 4.1).

Like other states of the country, Meghalaya is also going ahead with its environmental protection programme. It has taken up some measures to check air pollution in the State. The Meghalaya State Pollution Control Board is the first of its kind to take up responsibilities in detecting the amount of pollutants present in the ambient air. They have selected some localities of the State on random basis to perform certain tests to measure the amount of pollutants present in the air. In this regard, they have mainly

1. The Shillong Times, 23rd April, 1991.

selected heavy traffic zone areas. The results of these tests are based on single day's sample. In these tests, they have checked the presence of suspended particulate matter (SPM), Sulphur dioxide (SO_2) and Oxides of Nitrogen (NO_x) only.

Table 4.1

Number of Vehicles Registered in Meghalaya

For the Year	Number of Vehicles
1980-81	9,099
1981-82	10,451
1982-83	11,838
1983-84	12,784
1984-85	14,132
1985-86	16,598
1986-87	18,962
1987-88	24,251
1988-89	27,061
1989-90	29,908
1990-91	31,797
1991-92	35,804
1992-93	37,763
1993-94	40,181

Source : Commissioner of Transport, Meghalaya

Here we are giving the results of these tests as obtained from the Meghalaya State Pollution Control Board, Shillong.

1) Nongstoin

It is the Headquarters of the West Khasi Hills District of Meghalaya. The survey was conducted on the 8th February, 1994, under clear sky weather condition. The data received from the Board reveals that the pollutants present in the air are as follows :

i) SPM = 120 $\mu g/m^3$

ii) SO_2 = 8.2 $\mu g/m^3$

iii) NO_x = 37.3 $\mu g/m^3$

2) Nongpoh

This is the Headquarters of the Ri-Bhoi District of Meghalaya. The survey was conducted on 15th January, 1994, under the clear sky weather condition. The result is :

i) SPM = 211.8 $\mu g/m^3$

ii) SO_2 = 0.44 $\mu g/m^3$

iii) NO_x = 30.0 $\mu g/m^3$

3) Jowai

It is the Headquarters of the Jaintia Hills District of Meghalaya. The survey was conducted three times in two days.

a) Jowai (1st)

The survey was conducted on 10.2.94 under cloudy weather condition. The survey reveals the following :

i) SPM = 34.6 $\mu g/m^3$

ii) SO_2 = 1.21 $\mu g/m^3$

iii) NO_x = 50.0 $\mu g/m^3$

b) Jowai (2nd)

The survey conducted on 10.2.94 under partial weather condition reveals :

i) SPM = 140.0 $\mu g/m^3$

ii) NO_x = 33.0 $\mu g/m^3$

iii) SO_2 = Nil

c) Jowai (3rd)

The survey conducted on 11.2.94 reveals :

i) SPM = 227.5 $\mu g/m^3$

ii) SO_2 = 0.7 $\mu g/m^3$

iii) NO_3 = 30.7 $\mu g/m^3$

4) Tura

Tura is the Headquarters of the West Garo Hills District of Meghalaya. The survey was conducted on 23.2.94 under clear sky weather condition. It finds the presence of :

i) SPM = 130.8 $\mu g/m^3$

ii) SO_2 = 0.5 $\mu g/m^3$

iii) NO_x = 25.0 $\mu g/m^3$

5) <u>William Nagar</u>

It is the Headquarters of the East Garo Hills District of Meghalaya. The survey conducted on 25.2.94 under clear sky reveals :

i) SPM = 162.7 $\mu g/m^3$

ii) SO_2 = Nil

iii) NO_x = 32.0 $\mu g/m^3$

6) <u>Police Bazar</u>

It is one of the busy commercial areas situated in the heart of the Shillong city. The survey was conducted on 2.3.94 under clear sky weather condition. The result is :

i) SPM = 142.0 $\mu g/m^3$

ii) SO_2 = 1.1 $\mu g/m^3$

iii) NO_x = 34.4 $\mu g/m^3$

7) <u>Residential Area</u> (M.I.D.C. Headquarters) Industrial Estate Barapani.

The survey was conducted on 11.11.94 under clear sky weather condition and West-South-West wind direction during sampling period. The result shows :

i) SPM = 185.12 $\mu g/m^3$

ii) SO_2 = B.D.L.

iii) NO_x = Nil

8) <u>Shillong Municipality Area</u>

A survey conducted by Meghalaya State Pollution Control Board, Shillong, reveals that the amount of pollutants present in two different places of Shillong is as follows :

a) Near Secretariat Building

The survey was conducted on 2.11.92 :

i) SO_2 = B.D.L.

ii) NO_x = 5.2 µg/m^3

iii) SPM = 36.2 µg/m^3

Another survey conducted on 12.11.92 observes.

i) SO_2 = B.D.L.

ii) NO_x = 6 µg/m^3

iii) SPM = 39.3 µg/m^3

b) In Motinagar

The survey conducted on 2.11.92 finds :

i) SO_2 = B.D.L.

ii) NO_x = B.D.L.

iii) SPM = 20.8 µg/m^3

Another survey on 16.11.92 reveals :

i) SO_2 = B.D.L.

ii) NO_x = 3.2 µg/m^3

iii) SPM = 25 µg/m^3

4.2. Measures to Control Pollution

Meghalaya State Pollution Control Board has also taken up measures to control the pollutants emitted by the vehicles. It has developed standards for pollution emissions. The vehicles which emit exhaust gases containing pollutants at rates more than permissible limits, i.e. CO more than 3 per cent volume for four wheelers and 4.5 per cent volume for two-wheelers in case of petrol engines and more than 65 Hatridge Smoke Unit (HSU) (by free acceleration method) in case of diesel engines, are issued a red certificate with the instruction that the vehicle's engine should be tuned or rectified within a stipulated period under intimation to Transport DTO Enforcement (Department). The following Tables-4.2 and 4.3 give the results of survey conducted by them.

To control the vehicular emission, the District Transport Department has taken up certain measures. They are inspecting the cars at regular intervals. For new cars, the emission is tested once in 1st two years, from 3rd to 10th year, it is done every year and from eleventh year onwards, test is done once in every six months. The Department has also taken up regulatory measures and it has been made mandatory. It says that any person who drives or causes or allows to be driven, in any public place a motor vehicle, which violates the standards prescribed in relation to road safety, control of noise and air pollution, shall be punishable for the first offence with a fine of one thousand rupees and for any second or subsequent offence with a fine of two thousand rupees.[1]

Table-4.2
Result of Vehicular Emission Study during January and February 1990

Sl.No.	Types of Vehicles	No. of vehicles monitored	No. of vehicles emitted CO more than permissible limit	% of vehicles emitting CO more than permissible limit
1.	Petrol Driven			
	a) Ambassador/Fiat	530	257	48.40
	b) Maruticars including Van and Gypsy	258	123	47.60
	c) Jeep	227	59	25.90
	d) Two-Wheelers	213	13	6.1

Table-4.3

Sl.No.	Types of Vehicles	No. of vehicles monitored	Vehicles complying with Emission standard		Vehicles not complying with Emission standard	
			Number	%	Number	%
1.	Diesel Driven					
	Trucks/Buses/Four-wheelers	1709	641	37.5	1068	62.5

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1. Motor Vehicles Act, 1988.

The Meghalaya State Transport Corporation has taken up a healthy policy of keeping the air clean by introducing no visible exhaust in all MTC buses. Achieving cleaner exhaust was a quick process for the MTC, as the changes needed rarely major repairs. Eliminating visible exhaust involves simple and inexpensive changes to nozzles, dirty air filters, leaky head gaskets and bad valves. So one hopes that one day all of Shillong's vehicles will be cleaner so that the people of Shillong will be able to breathe easier.[1]

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1. The Meghalaya Guardian, 11th February, 1995.

Chapter-V

METHODOLOGY, DATA BASE AND ANALYSIS

5.1. Methodology

The work undertaken by us is a very new one. No organization or individual has done any work in this line or similar to it. Though many highway models have been developed, typically of the new roadways, there has been less effort devoted to the verification of the model results. This is mainly due to the shortage of field data. One of the greatest difficulties with highway modelling involves the specification of emissions. Emission from vehicles, unlike those from most stationary sources, are from highly variable combustion processes. Changes in emissions occur due to change in operating mode. In addition, large differences in emission occur between vehicles in similar operating modes. So none of these models could considered.

Prof. K. Bez has developed a model on pollution due to transportation using utility function. For motor vehicles, emission is a function of speed of the vehicle. Plying of vehicles necessitates energy consumption and consequently pollution. Therefore, a constraint on energy consumption would automatically exert constraint upon vehicle-km. which is a function of passenger-km. Let us consider the following functions -

an energy consumption function

$$E_{ik} = E_{ik}(V_i) = \Sigma e_{ik} \; V_i \quad .... \quad (1)$$

a pollution production function

$$H_{mk} = \Sigma h_{ik} \; V_i = H_m(V_i) \quad .... \quad (2)$$

a utility function

$$U = U(V_i) \quad .... \quad (3)$$

where

$e_{ik} = E_{ik}/V_i$ = the energy co-efficient

$h_{ik} = H_{mk}/V_i$ = the pollution co-efficient

we wish to minimize $E_{ik} = e_{ik}V_i$ subject to $H_m = H_m(V_i)$ and maximize $U = U(V_i)$ subject to $E_{ik} = e_{ik}V_i$.

we set,

$$h_{ik}V_i - \beta[E_{ik}(V_i) - E_{ik}] = L \quad .... \quad (4)$$

Differentiating (4) w.r.t. β and V_i and setting the derivatives equal to zero. We have

$$\frac{\delta L}{\delta \beta} = -[E_{ik}(V_i) - E_{ik}] = 0 \quad .... \quad (5)$$

and $$\frac{\delta L}{\delta V_i} = h_{ik} - \beta\left[\frac{\delta E_{ik}(V_i)}{\delta V_i}\right] \quad .... \quad (6)$$

From (5) and (6), we have

$$E_{ik} = E_{ik}(V_i) \quad .... \quad (7)$$

$$\text{and} \quad h_{ik} = \beta \frac{\delta E_{ik}(V_i)}{\delta V_i} \quad \ldots\ldots\ldots \quad (8)$$

$$\text{or} \quad \beta = \frac{h_{ik}\,\delta V_i}{\delta E_{ik}(V_i)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

where β is the marginal pollution.

Rewriting the function (1) as

$$E = e_1V_1 + e_2V_2 + \ldots + e_iV_i + \ldots + e_nV_n \quad \ldots \quad (10)$$

With $i = 1, 2, 3, \ldots, n.$

$k = 1, 2, 3, \ldots, n.$

Now differentiating (10) with respect to e_i, and then setting to zero, we have,

$$\frac{\delta E}{\delta e_i} = e_1 \frac{\delta V_1}{\delta e_i} + e_2 \frac{\delta V_2}{\delta e_i} + \ldots + V_i + \ldots + e_n \frac{\delta V_n}{\delta e_i} = 0 \quad \ldots\ldots\ldots \quad (11)$$

$$= \Sigma e_j \frac{\delta V_j}{\delta e_i} + V_i = 0 \qquad \text{for } i=j \quad \ldots\ldots\ldots \quad (12)$$

Which finally gives

$$\Sigma e_j \frac{\delta v_j}{\delta e_i} = - V_i \quad \ldots\ldots\ldots \quad (13)$$

The respective energy-derivatives and the vehicle-km. derivatives are

$$\frac{\delta V}{\delta E} = \begin{vmatrix} \dfrac{\delta V_1}{\delta E} \\ \dfrac{\delta V_2}{\delta E} \\ \vdots \\ \dfrac{\delta V_n}{\delta E} \end{vmatrix} \qquad \ldots\ldots\ldots\ldots \qquad (14)$$

$$\frac{\delta V}{\delta e} = \begin{vmatrix} \dfrac{\delta V_1}{\delta e_1} & \dfrac{\delta V_1}{\delta e_2} & \ldots\ldots\ldots\ldots & \dfrac{\delta V_1}{\delta e_n} \\ \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots \\ \dfrac{\delta V_n}{\delta e_1} & \dfrac{\delta V_n}{\delta e_2} & \ldots\ldots\ldots\ldots & \dfrac{\delta V_n}{\delta e_n} \end{vmatrix} \qquad \ldots\ldots\ldots \qquad (15)$$

Since $E = eV$,

therefore, $V = Ee^{-1}$ .... (16)

Thus we have,

$$\delta E = \Sigma e_i \delta V_i$$

or, $dE = \Sigma e_i dV_i$ .... (17)

or, $1 = \Sigma e_i dV_i / dE$ .... (18)

We can write,

$$dV_i = (\delta V_i / \delta E) dE \qquad \ldots\ldots\ldots \qquad (19)$$

Using (19) in (18), we have,

$$1 = \Sigma e_i[(\delta V_i/\delta E).dE]/dE$$

$$= \Sigma e_i(\delta V_i/\delta E)(dE/dE) \qquad \ldots\ldots. \quad (20)$$

To maximize $U(V_i)$ subject to $E = e_i V_i$, we start with

$$L = U(V_1, V_2, \ldots, V_n) - \beta[\Sigma e_i V_i - E] \qquad \ldots\ldots. \quad (21)$$

Differentiating (21) with respect to V_i and setting the derivative equal to zero, we have,

$$\frac{\delta L}{\delta V_i} = \frac{\delta U}{\delta V_i} - \beta e_i = 0 \qquad \ldots\ldots. \quad (22)$$

$$\text{or,} \quad \frac{\delta U}{\delta V_i} = \beta e_i \qquad \ldots\ldots. \quad (23)$$

Again differentiating (22) with respect to E, we have,

$$\delta U/\delta E/\delta L/\delta V_i = \Sigma \left[\frac{\delta U}{\delta V_i} . \frac{\delta U}{\delta V_j} . \frac{\delta V_j}{\delta E} \right]$$

$$= \Sigma \delta^2 U/\delta V_i \delta E = e_i\ (\delta\beta/\delta E) \qquad \ldots\ldots\ldots \quad (24)$$

and finally differentiating with respect to e_j (for i = j)

$$\delta U/\delta e_i\ (\delta L/\delta V_i) = \Sigma\ \delta U/\delta V_j\ .\ \delta U/\delta V_j\ .\ \delta V_j/\delta e_j$$

$$= \beta + e_i\ (\delta\beta/\delta e_i) \text{ for } i = j \qquad \ldots\ldots\ldots \quad (25)$$

and for $i \neq j$

$$\delta U/\delta e_j\ (\delta L/\delta V_i) = e_i\ (\delta\beta/\delta e_j) \qquad \ldots\ldots\ldots \quad (26)$$

Expressing (24) in matrix notation, we have

$$U(\delta V/\delta E) = e.\delta\beta/\delta E \quad \ldots\ldots\ldots \quad (27)$$

Similarly, writing (25) in matrix notation, we get

$$U(\delta V/\delta e) = \beta I + e.\delta\beta/\delta e \quad \ldots\ldots\ldots \quad (28)$$

Likewise, (13) and (18) in matrix notation can be expressed as

$$e\delta V/\delta e = - V \quad \ldots\ldots\ldots \quad (29)$$

$$\text{and} \quad e\delta V/\delta E = 1 \quad \ldots\ldots\ldots \quad (30)$$

Writing compactly the relations from (27) through (30), gives

$$\begin{bmatrix} U & e \\ e & O \end{bmatrix} \begin{bmatrix} \delta V/\delta E & \delta V/\delta e \\ -\delta\beta/\delta E & -\delta\beta/\delta e \end{bmatrix} = \begin{bmatrix} 0 & \beta \\ 1 & -V \end{bmatrix} \quad \ldots\ldots\ldots \quad (31)$$

The left-hand side of which can be expressed as

$$\begin{bmatrix} U\delta V/\delta E - e\delta\beta/\delta E & U.\delta V/\delta e - e\delta\beta/\delta e \\ e\delta V/\delta E - 0 & e.\delta V/\delta e - 0 \end{bmatrix} = \begin{bmatrix} 0 & \beta \\ 1 & -V \end{bmatrix}$$

$$\ldots\ldots\ldots\ldots \quad (32)$$

The equations (32) have to satisfy for optimizing the utility function subject to the constraints. Here U is a Hessian.

This model as such can not be reduced to a single equation model because there are more parameters to be estimated than the number of equations. However, in order to use this model, we can estimate each equation separately and substitute the values when necessary to other equations to arrive at the final results, but due to the paucity of the data, with special reference to Meghalaya, this model is not used.

Since the objective of our thesis is to find the effect of pollution not only on the habitat as such but also on the human population so that we can translate this into some other form of economic activities either positive or negative. In this particular thesis, we want to look into two different directions :

1) Loss of health, medical treatment and loss of working days,

2) Cleaning expenditure, the devaluation of road side dwellings, etc.

Since our objective is only to estimate the effects of pollution, we need to know first the amount of pollutants. So we have decided

i) to estimate the demand for passenger-km. in Meghalaya.

ii) to estimate the demand for vehicle-km. for both Meghalaya and Shillong.

iii) to estimate the energy consumption by different modes of transportation both in Meghalaya and in Shillong.

iv) to estimate the different types of pollutants both for Meghalaya and Shillong, and finally,

v) to estimate the number of patients suffering from pollution-related diseases both in Meghalaya and in Shillong.

In the next phase, our problem becomes much more sensitive. It does not exactly fall on the purview of economic science, never-the-less, we have made a humble attempt to analyse the causes of different types of diseases that are normally thought to be influenced by one or combination of different types of pollutants.

To estimate the demand for passenger-km., vehicle-km. and energy consumption, we have adopted the following methods.

First we have estimated the demand for passenger transport. Then we have calculated the passenger-km. per day which was later converted to passenger-km. per year. From the passenger-km. we have found out the vehicle-km. by dividing it by the occupancy rate. Thus

$$\text{Vehicle-km.} = \frac{\text{Passenger-km}}{\text{Occupancy rate}}$$

This vehicle-km. is determined for each mode of transportation viz., the petrol driven vehicles (i.e., cars and taxis), heavy diesel driven vehicles (i.e., buses and trucks), and the two wheelers (There are a negligible number of three wheelers in Meghalaya and no three wheelers in Shillong).

The occupancy rate is determined in the following way :

Normally number of seats in a bus varies from 28 to 45 but where in Shillong or elsewhere in Meghalaya, buses are always over loaded. We are not considering the extra standing passengers. Therefore, we are taking the occupancy rate for buses to be 45. Trucks are usually used for transportation of goods but often we find, in many rural areas, where there is no access to buses or where there is no bus route at all, the villagers are compelled to use the trucks as means to transportation. Therefore, we are taking the minimum value of occupancy rate to be 4 for trucks. In case of taxis, the seating capacity is 6 including the driver. But normally, the taxis are not full always. Sometimes they run without any passenger. Moreover, the private cars normally run with 1-3 people on an average. So taking all these into consideration, we have taken the occupancy rate for petrol driven light vehicles to be 2.5. For two wheelers, the occupancy rate is taken to be 2.

From the vehicle-km., we have found out the energy consumed by each mode of transportation. Thus we have

$$\text{Energy consumed} = \frac{\text{Vehicle-km}}{\text{Mileage/litre of fuel}}$$

In Meghalaya and Shillong in particular, the mileage given by each mode of transportation is as follows :

i) For petrol driven light vehicles - 11 kms./lit.

ii) For diesel driven heavy vehicles - 3.45 kms./lit.

iii) For two wheelers - 30 kms./lit.

Again from the energy consumption, we have found out the volume of pollutants caused by each mode of transportation. To get the amount of pollutants, we have used the National Standard for emission factors per litre of fuel used, since there is no standard for emission factors available for Meghalaya and for that matter for Shillong.

5.2. Data Base

5.2.1. Transport Data

Data on transportation was collected from the District Transport Office (DTO), Shillong, Commissioner of Transport, Meghalaya; City and Mini Buses Owners' Association and from the Statistical Handbook of Meghalaya, published by Directorate of Economics and Statistics, Government of Meghalaya, Shillong. Although the transport data for the year 1980 was not available, we have estimated it graphically with the help of a trend line.

After the passenger-kms. are obtained from the above sources, we have estimated the vehicle-km. by using the occupancy rate as mentioned earlier.

Since there are two types of fuel used and we do not have the exact data for the fuel used except for Meghalaya Transport Corporation Buses which are very few in number, about only 150 buses, therefore, for the rest of the heavy vehicles, we have used the standard rate given in the National Transport Policy Committee Report. Similarly, we have used the estimated data to calculate the fuel used by other types of vehicles (11 km./lit. for petrol driven light vehicles, 3.45 km./lit. for diesel driven heavy vehicles and 30 km./lit. for two wheelers).

5.2.2. Data on Pollution

Once the energy consumption is obtained for Meghalaya and Shillong by each mode of transportation, the amount of pollutants caused by each mode of transportation is calculated by using National Standard for Emission factors per litre of fuel used (Ref: "Vehicular Air Pollution in Delhi - A Preliminary Study", Control of Urban Pollution Series : CUPS/10/1982-83, published by Central Pollution Control Board, Delhi).

5.2.3. Data on Patients

After consultation with a number of medical doctors, we have found that the following are the diseases which may be directly or indirectly caused by pollution :

i) Acute Bronchitis

ii) Chronic Bronchitis

iii) Asthma

iv) Pharyngitis

v) Respiratory Tract Infection

vi) Emphysema.

After ascertaining this, regarding the patients, we have to make a remark. We have collected data from the Shillong Civil Hospital, Jowai Civil Hospital, K.J.P. Hospital, Shillong, K.J.P. Hospital, Jowai, Nazareth Hospital, Shillong, and the Office of the Directorate of Health Services (DHS), Meghalaya. We could not include the number of patients treated in the Nursing Homes and by the private practitioners because most of these Nursing Homes and the general private practitioners do not keep any record about their patients. In this connection, we should also mention that some patients, specially the literate ones go directly to the pharmacy and get the medicines without consulting any doctor. So for many patients, there are no records available.

With the data obtained from the above mentioned sources, we have divided our calculations into two categories:

i) the effect of pollutants in Meghalaya.

ii) the effect of pollutants in Shillong.

i) In case of Meghalaya, the Government Hospitals and the Office of the D.H.S. were unable to give the statistics of the patients suffering from the pollution-related diseases in terms of sex and age. They could give us the number of patients suffering from these diseases per year. Hence, in this case we have made a general calculation for both male and female patients and of all age group put together.

ii) In case of Shillong, since the statistics of patients suffering from pollution-related diseases were available in terms of sex and age, therefore for Shillong patients we have made two groups for both male and female patients - one in the age group below 5 years and the other, 5 years and above.

5.2.4. Economic/Financial Loss

In order to calculate the economic loss, we have taken the following steps:

i) Medical cost

ii) Number of man-days lost and

iii) The Academic loss.

A) Medicine and Medical Care Cost

The statistics obtained from the doctors and hospitals suggest that the cost incurred in treating the pollution-related diseases varies from disease to disease and hospitals to hospitals. It says that in most of these diseases, the patients are required to be treated with antibiotics and at present the cost of antibiotics is extremely high. The cost of antibiotics ranges from Re.1/- per tablet/capsule to Rs.40/- per tablet/capsule approximately. Now we are giving the approximate cost of treating the pollution-related diseases one by one.

a) <u>Acute Bronchitis</u>

The patients suffering from Acute Bronchitis are to be treated with antibiotics. The prices of antibiotic range from Rs.100/- to Rs.400/- per course depending on the type of antibiotics used. Along with antibiotics, some other medicines should also be given which might cost Rs.100/- per course. So the patients suffering from Acute Bronchitis and not requiring hospitalization (i.e. outdoor patients) spend Rs.300/- to Rs.400/- per course. They may be attacked by the disease once or twice a year. So the overall expenditure per patient ranges from Rs.400/- to Rs.800/- per year approximately.

But the patients requiring hospitalization (i.e., indoor patients) spend much more. They are required to stay in the hospital for 2-3 days to 2 weeks depending on the severity of the sickness. Patients in the hospital spend at least Rs.200/- per day. So the indoor patients spend Rs.500/- to Rs.600/- more than the usual Rs.300/- to Rs.400/- per course. Hence an indoor patient is required to spend Rs.1400/- to Rs.2000/- per year approximately.

b) <u>Chronic Bronchitis</u>

Chronic Bronchitis patients are required to be treated for a longer duration. They may have to be treated for 2-3 weeks to one month. Most of the times they require hospitalization. Chronic Bronchitis patients are to take medicines worth Rs.10/- to Rs.20/- per day throughout the year. They may suffer 2-3 times a year. So the overall expenditure for outdoor patients may range from Rs.5000/- to Rs.9000/- per year per patient.

The indoor patients are required to stay in the hospital for 10 to 15 days. So staying in the hospital costs them Rs.2000/- to Rs.3000/- per course. So the overall expenditure for indoor patients ranges from Rs.12,000/- to Rs.20,000/- per year.

c) <u>Asthma</u>

The Asthma patients also need to undergo a longer duration of treatment. Like Chronic Bronchitis, their treatment also continues from 2-3 weeks to one month. So the outdoor patients spend Rs.400/- to Rs.500/- per course. Since they suffer 1-2 times a year, therefore the overall expenditure comes to Rs.800/- to Rs.1000/- per year approximately.

The indoor patients are required to stay in the hospitals for at least 10 days. So the hospital stay costs them Rs.2000/- per course approximately. Hence the total expenditure per patient per year comes to about Rs.5000/- to Rs.6000/- approximately.

d) <u>Pharyngitis</u>

Pharyngitis patients require a shorter duration of treatment. They may suffer 3 to 4 times a year. For the outdoor patients, the medical cost comes to about Rs.300/- to Rs.400/- per course. So the overall expenditure comes to Rs.1200/- to Rs.1600/- per patient per year approximately.

The indoor patients need to stay in the hospital for 4 to 6 days. So the staying in the hospital costs at least Rs.800/- to Rs.1200/- per course. So the overall expenditure for indoor patients comes to Rs.4500/- to Rs.6500/- per year per patient.

e) <u>Respiratory Tract Infection</u> (RTI)

Like Pharyngitis, RTI patients also require a shorter duration of treatment. They are required to spend Rs.300/- to Rs.400/- per course approximately. They may suffer 2-3 times a year. So the overall cost for outdoor patients ranges from Rs.900/- to Rs.1200/- per year.

The indoor patients are required to stay in the hospital for 6 to 9 days. So they spend Rs.1200/- to Rs.1800/- more than the outdoor patients. Hence the total expenditure for indoor patients comes to Rs.4500/- to Rs.7000/- per year per patient approximately.

f) <u>Emphysema</u>

Emphysema also requires a long term treatment. The patients suffering from Emphysema are required to be treated for 2-3 weeks to one month. They suffer from it 1-2 times a year. So the total expenditure for outdoor patients comes to Rs.600/- to Rs.800/ per year per patient.

The indoor patients are required to stay in the hospital for 10 to 12 days. So the hospital stay costs a patient at least Rs.2000/- to Rs.2400/- more than the outdoor patients per course. Hence the total expenditure may range from Rs.4600/- to Rs.6000/- per patient per year approximately.

There are reports of deaths in the case of Chronic Bronchitis, Asthma and Emphysema. There are some cases of patients suffering from all these diseases together. In those cases, it becomes very difficult to treat them and as a result they become the victims of death.

B) Man-Days Lost

Depending on the severity of the effect of pollutants, an affected person may lose 30 to 90 days per year and in some cases he may be totally incapacitated. The minimum daily wage is Rs.100/- now-a-days. So the economic loss due to the man-days lost would be approximately between Rs.3000/- and Rs.9000/- per year per patient.

C) Academic Loss

For man-days lost upto 15 years of age, we do not consider the money cost of man-days as in normal circumstances they are students upto that age. So we may call it as academic loss.

5.2.5. <u>Cleaning Cost</u>

In order to collect this type of data, we have used a questionnaire which is given in the appendix. For this purpose, the survey was conducted on 500 houses from all parts of Meghalaya keeping in mind the various distances of the houses from the main roads. From this survey, it was found that people staying in roadside houses are to spend much more money for cleaning than compared to people staying away from the roadside houses. It was found that people staying in roadside houses are to wash their curtains 2 to 3 times a month; linens, bed covers, etc. 5 to 6 times a month; whereas people staying in a bit far away places are to wash the same items once a month and 3 times a month respectively. Those staying in quite far away places are to wash these items once or twice a year and once a month respectively.

Apart from washing, they have to paint their houses more often than the others. The survey says that the roadside residences are to be painted every year because of dust, smoke, etc. while the rest do it once in every 2 to 3 years. So the staying in roadside houses is more expensive than the others.

From the survey conducted, we have calculated the approximate cost of cleaning and painting. Since now-a-days, the prices of detergents, paints, labour charges etc. are very high, therefore the pollution is causing a great financial loss to them. The people staying in the roadside houses are to spend Rs.100/- to Rs.500/- more on washing depending on the types of cleaning (i.e., home washing or laundry dry-cleaning) every month. For painting the houses also, they spend approximately Rs.8000/- to Rs.10,000/- per year depending on the size of the houses (here painting includes paints, labour charges, etc.).

An interesting finding from the survey is that, about 73 per cent of the people do not prefer staying in road-side houses.

5.2.6. Devaluation of Property

The survey reveals that the road-side houses do not cost less. In fact, the prices go higher for road-side houses. One reason is that, at present, most of such properties are used for commercial purposes as well, such as making shops etc. Another reason is easy accessibility and communication facilities.

5.3. Analysis

For the analysis purpose, we have taken the following steps - first, we have arranged the data for Meghalaya, in general, and Shillong in particular, and then analysed them separately.

Table-5.1

Emission Factors per Litre of Fuel Used in Meghalaya

(in kg.)

Types of vehicles	PM	SO_2	NO_x	HC	CO
1. Light duty gasoline powered	0.0036	0.0009	0.0352	0.0659	0.4396
2. Light duty diesel powered	0.0028	0.0024	0.0062	0.0018	0.0069
3. Heavy duty diesel powered	0.0026	0.0052	0.0724	0.0072	0.0438
4. Two-wheelers	0.0061	0.0006	0.0021	0.3030	0.5152

Table-5.2

Passenger-Kilometre for Meghalaya

Year	Passenger-Km./day	Passenger-Km./day
1980	350341.9	127874793.5
1981	320705.2	117057398.0
1982	369674.6	134931229.0
1983	556428.0	203096220.0
1984	640967.3	233953064.5
1985	703764.5	256874042.5
1986	601769.6	219645904.0
1987	431609.9	157537613.5
1988	513138.2	187295441.0
1989	576089.9	210272813.5
1990	1039102.0	379272230.0
1991	920198.6	335872489.0
1992	837399.9	305650963.5
1993	800516.7	292188595.5
1994	768044.6	280336279.0

Table-5.3

Vehicle-Kilometre for different modes of transportation per day in Meghalaya

Year	Cars	Heavy vehicles	Two-wheelers
1980	140136.8	95370.9	175170.9
1981	128282.1	87303.1	160352.6
1982	147869.8	100633.6	184837.3
1983	222571.2	151472.1	278214.0
1984	256386.9	174485.5	320483.7
1985	281505.8	191580.3	351882.3
1986	240707.8	163815.1	300884.8
1987	172643.9	117493.8	215804.9
1988	205255.3	139687.6	256569.1
1989	230435.9	156824.5	288044.9
1990	415640.8	282866.7	519551.0
1991	368079.4	250498.5	460099.3
1992	334959.9	227958.9	418699.9
1993	320206.7	217918.4	400258.4
1994	307217.8	209078.8	384022.3

Table-5.4

Vehicle-Kilometre for different modes of transportation per day in Shillong

Year	Cars	Heavy vehicles	Two-wheelers
1980	119116.28	61991.09	122619.63
1981	109039.79	56747.02	112246.82
1982	125689.33	65411.84	129386.11
1983	189185.52	98456.87	194749.80
1984	217928.87	113415.58	224338.59
1985	239279.93	124527.20	246317.61
1986	204601.63	106479.82	210619.36
1987	146747.32	76370.97	151063.43
1988	174467.01	90796.94	179598.37
1989	195870.52	101935.93	201631.43
1990	353294.68	183863.36	363685.70
1991	312867.49	162824.03	322069.51
1992	284715.92	148173.29	293089.93
1993	272175.70	141646.99	280180.88
1994	261135.13	135901.22	268815.61

Table-5.5

Energy Consumption of Different Modes of Transportation per day in Meghalaya

(in litres)

Year	Cars	Heavy vehicles	Two-wheelers
1980	12739.7	27643.7	5839.0
1981	11662.0	25305.2	5345.1
1982	13442.7	29169.0	6161.2
1983	20233.7	43904.9	9273.8
1984	23307.9	50575.5	10682.8
1985	25591.4	55530.5	11729.4
1986	21882.5	47482.6	10029.5
1987	15694.9	34056.2	7193.5
1988	18659.6	40489.2	8552.3
1989	20948.7	45456.4	9601.5
1990	37785.5	81990.3	17318.4
1991	33461.8	72608.3	15336.6
1992	30450.9	66075.0	13956.7
1993	29109.7	63164.8	13341.9
1994	27928.9	60602.6	12800.7

Table-5.6

Energy Consumption of different modes of transportation per day in Shillong

(in litres)

Year	Cars	Heavy vehicles	Two-wheelers
1980	10828.75	17968.41	4087.30
1981	9912.70	16448.38	3741.57
1982	11426.30	18959.85	4312.84
1983	17198.65	28538.19	6491.66
1984	19811.72	32874.08	7477.96
1985	21752.69	36094.83	8210.58
1986	18600.13	30863.69	7020.65
1987	13340.67	22136.53	5035.45
1988	15860.66	26317.98	5986.61
1989	17806.40	29546.66	6721.05
1990	32117.68	53293.70	12122.88
1991	28442.53	47195.40	10735.62
1992	25883.27	42948.75	9769.69
1993	24743.25	41057.12	9339.33
1994	23739.67	39391.69	8960.49

Table-5.7

Volume of Pollutants caused by Cars in Meghalaya per day

(in kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	45.86	11.47	448.44	839.55	5600.37
1981	41.98	10.49	410.50	768.53	5126.62
1982	48.39	12.09	473.18	885.87	5909.41
1983	72.84	18.21	712.23	1333.40	8894.73
1984	83.91	20.98	820.44	1535.99	10246.15
1985	92.13	23.03	900.82	1686.47	11249.98
1986	78.78	19.69	770.26	1442.06	9619.55
1987	56.50	14.13	552.46	1034.29	6899.48
1988	67.17	16.79	658.82	1229.67	8202.76
1989	75.42	18.85	737.39	1380.52	9209.05
1990	136.03	34.01	1330.05	2490.06	16610.51
1991	120.46	30.12	1177.86	2205.13	14709.81
1992	109.62	27.41	1071.87	2006.71	13386.22
1993	104.79	26.19	1024.66	1918.33	12796.62
1994	100.54	25.14	983.09	1840.51	12277.54

Table-5.8

Volume of Pollutants caused by Heavy Vehicles in Meghalaya per day

(in kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	71.87	143.75	2001.40	199.03	1210.79
1981	65.79	131.59	1832.09	182.19	1108.37
1982	75.84	151.68	2111.84	210.02	1277.60
1983	114.15	228.31	3178.71	316.12	1923.03
1984	131.49	262.99	3661.67	364.14	2215.21
1985	144.38	288.76	4020.41	399.82	2432.24
1986	123.45	246.91	3437.74	341.87	2079.74
1987	88.55	177.09	2465.67	245.20	1491.66
1988	105.27	210.54	2931.42	291.52	1773.43
1989	118.19	236.37	3291.04	327.29	1990.99
1990	213.17	426.35	5936.09	590.33	3591.18
1991	188.78	377.56	5256.84	522.78	3180.24
1992	171.79	343.59	4783.83	475.74	2894.09
1993	164.23	328.46	4573.13	454.79	2766.62
1994	157.57	315.13	4387.63	436.34	2654.39

Table-5.9

Volume of Pollutants caused by Two-Wheelers in Meghalaya per day

(in kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	35.62	3.50	12.26	1769.22	3008.25
1981	32.61	3.219	11.22	1619.56	2753.79
1982	37.58	3.69	12.94	1866.84	3174.25
1983	56.57	5.56	19.47	2809.96	4777.86
1984	65.17	6.41	22.43	3236.89	5503.78
1985	71.55	7.04	24.63	3554.01	6042.99
1986	61.18	6.02	21.06	3038.94	5167.19
1987	43.88	4.32	15.11	2179.63	3706.09
1988	52.17	5.13	17.96	2591.35	4406.15
1989	58.57	5.76	20.16	2909.25	4946.69
1990	105.64	10.39	36.37	5247.48	8922.44
1991	93.55	9.20	32.21	4646.99	7901.42
1992	85.14	8.37	29.31	4228.88	7190.49
1993	81.39	8.01	28.02	4042.59	6873.75
1994	78.08	7.68	26.88	3878.61	6594.92

Table-5.10

Volume of Pollutants caused by Cars in Shillong per day

(in kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	38.98	9.75	381.17	713.62	4760.31
1981	35.68	8.92	348.93	653.25	4357.63
1982	41.13	10.28	402.20	752.99	5022.99
1983	61.91	15.48	605.39	1133.39	7560.52
1984	71.32	17.83	697.37	1305.59	8709.23
1985	78.31	19.58	765.69	1433.49	9562.48
1986	66.96	16.74	654.72	1225.75	8176.62
1987	48.03	12.01	469.59	879.15	5864.56
1988	57.09	14.27	559.99	1045.22	6972.35
1989	64.12	16.02	626.78	1173.44	7827.69
1990	115.63	28.91	1130.54	2116.55	14118.93
1991	102.39	25.60	1001.18	1874.36	12503.34
1992	93.18	23.29	911.09	1705.70	11378.29
1993	89.07	22.26	870.96	1630.58	10877.13
1994	85.46	21.37	835.63	1564.43	10435.91

Table-5.11

Volume of Pollutants caused by Heavy Vehicles in Shillong per day

(in Kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	46.72	93.44	1300.91	129.37	787.01
1981	42.76	85.53	1190.86	118.42	720.44
1982	49.29	98.59	1372.69	136.51	830.44
1983	74.19	148.40	2066.16	205.48	1249.97
1984	85.47	170.94	2380.09	236.69	1439.89
1985	93.85	187.69	2613.27	259.88	1580.96
1986	80.24	160.49	2234.53	222.22	1351.83
1987	57.56	115.11	1602.69	159.38	969.58
1988	68.43	136.85	1905.42	189.49	1152.73
1989	76.82	153.64	2139.18	212.74	1294.14
1990	138.56	277.13	3858.46	383.71	2334.27
1991	122.71	245.41	3416.95	339.81	2067.16
1992	111.66	223.33	3109.49	309.23	1881.16
1993	106.75	213.49	2972.53	295.61	1798.30
1994	102.42	204.83	2851.96	283.62	1725.35

Table-5.12

Volume of Pollutants caused by Two Wheelers in Shillong per day

(in Kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	24.93	2.45	8.58	1238.45	2105.78
1981	22.83	2.25	7.86	1133.69	1927.65
1982	26.31	2.58	9.06	1306.79	2221.98
1983	39.59	3.89	13.63	1966.97	3344.50
1984	45.62	4.49	15.70	2265.82	3852.65
1985	50.09	4.93	17.24	2487.81	4230.09
1986	42.83	4.21	14.74	2127.26	3617.03
1987	30.72	3.02	10.58	1525.74	2594.26
1988	36.52	3.59	12.57	1813.95	3084.31
1989	40.99	4.03	14.11	2036.48	3462.68
1990	73.95	7.27	25.46	3673.24	6245.71
1991	65.49	6.44	22.55	3252.89	5530.99
1992	59.59	5.86	20.52	2960.22	5033.34
1993	56.97	5.61	19.62	2829.81	4811.63
1994	54.66	5.38	18.82	2715.03	4616.44

Table-5.13

Volume of Pollutants caused by all Vehicles in Meghalaya per day

(in Kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	51.12	52.91	820.70	935.93	3273.14
1981	46.79	58.23	751.27	856.76	2996.26
1982	53.94	55.82	865.99	987.58	3453.75
1983	81.19	84.03	1303.47	1486.49	5198.54
1984	93.52	96.79	1501.51	1712.34	5988.38
1985	102.69	106.28	1648.62	1880.10	6575.07
1986	87.80	90.87	1409.69	1607.62	5622.16
1987	62.98	65.18	1011.08	1153.04	4032.41
1988	74.87	77.49	1201.78	1370.85	4794.11
1989	84.06	86.99	1354.93	1539.02	5382.24
1990	151.61	156.92	2434.17	2775.96	9708.04
1991	134.26	138.96	2155.64	2458.30	8597.16
1992	122.18	126.46	1961.67	2237.11	7823.60
1993	116.80	120.89	1875.27	2138.57	7478.99
1994	112.06	115.98	1799.20	2051.82	7175.62

Table-5.14

Volume of Pollutants caused by all Vehicles in Shillong per day

(in Kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	36.88	35.21	563.55	693.81	2551.03
1981	33.76	39.09	515.88	635.12	2335.24
1982	38.91	45.06	594.65	732.10	2691.80
1983	58.56	67.82	895.06	1101.95	4051.66
1984	67.47	64.42	1031.05	1269.37	4667.26
1985	74.08	70.73	1132.07	1393.73	2023.64
1986	63.34	60.48	967.99	1191.74	4381.83
1987	45.44	43.38	694.29	854.76	3142.80
1988	54.01	51.57	825.99	1016.22	3736.46
1989	60.64	57.89	926.69	1140.89	4194.83
1990	109.38	104.44	1671.52	1970.32	7566.30
1991	98.86	92.48	1480.23	1822.35	6700.49
1992	88.14	84.16	1347.03	1658.38	6097.59
1993	84.26	80.45	1287.70	1585.33	5829.02
1994	80.85	77.19	1235.47	1521.03	5592.57

Table-5.15

Volume of Pollutants caused by all Vehicles in Meghalaya per year

(in Kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	18658.80	19312.15	299555.5	341614.45	1194696.10
1981	17078.35	21253.95	274213.55	312717.40	1093634.90
1982	19688.10	20374.30	316086.35	360466.70	1260618.80
1983	29634.35	30670.95	475766.55	542568.85	1897467.10
1984	34134.80	35328.35	548051.15	625004.10	2185758.70
1985	37481.85	38792.20	601746.30	686236.50	2399900.60
1986	32047.00	33167.55	514536.85	586781.30	2052088.40
1987	22987.70	23790.70	369044.20	420859.60	1471829.70
1988	27327.55	28283.85	438649.70	500360.25	1749850.20
1989	30681.90	31751.35	494549.45	561742.30	1964517.60
1990	55337.65	57275.80	888472.05	1013225.40	3543434.60
1991	49004.90	50720.40	786808.60	897279.50	3137963.40
1992	44595.70	46157.90	716009.55	816545.15	2855614.00
1993	42632.00	44124.85	684473.55	780578.05	2729831.40
1994	40901.90	42332.70	656708.00	748914.30	2619101.30

Table-5.16

Number of Patients Suffering from Pollution-related Diseases in Meghalaya per year

Year	Acute Bron-chitis	Chronic Bron-chitis	Asthma	Pharyn-gitis	RTI	Emphy-sema
1980	9792	2808	749	85	6453	21
1981	10522	3143	833	74	7009	19
1982	11150	3441	1073	104	7560	16
1983	11480	3741	1190	50	8628	21
1984	12236	4008	1410	51	9252	29
1985	12925	4378	1716	144	9938	24
1986	13733	4570	1863	107	10469	14
1987	14207	4878	2006	76	10627	16
1988	15167	5324	2397	39	11818	31
1989	15422	5459	2585	70	11982	25
1990	17126	5767	6138	87	12901	21
1991	15785	6735	2951	140	11638	19
1992	24689	6345	2974	129	13148	37
1993	18639	2833	1517	178	7134	35
1994	38176	6865	3561	94	7219	50

Table-5.17

Volume of Pollutants caused by all Vehicles in Shillong per year

(in Kg.)

Year	PM	SO_2	NO_x	HC	CO
1980	13461.20	12851.65	205695.75	253240.65	931125.95
1981	12322.40	14267.85	188296.20	231818.80	852362.50
1982	14202.15	16446.90	217047.25	267216.50	982507.00
1983	21374.40	24754.30	326696.90	402211.75	1478855.90
1984	24626.55	23513.30	376333.25	463320.05	1703549.90
1985	27039.20	25816.45	413205.55	508711.45	738628.60
1986	23119.10	22075.20	353316.35	434985.10	1599368.00
1987	16585.60	15833.70	253415.85	311987.40	1147122.00
1988	19713.65	18823.05	301486.35	370920.30	1363807.90
1989	22133.60	21129.85	338241.85	416424.85	1531113.00
1990	39923.70	38120.60	610104.80	719166.80	2761699.50
1991	36083.90	33755.20	540283.95	665157.75	2445678.90
1992	32171.10	30718.40	491665.95	605308.70	2225620.40
1993	30754.90	29364.25	470010.50	578645.45	2127592.30
1994	29510.25	28174.35	450946.55	555175.95	2041288.10

Table-5.18

Number of Male Patients suffering from Pollution-related Diseases in the age group below 5 years in Shillong per year

(Both Indoor and Outdoor)

Year	Acute Bron-chitis	Chronic Bron-chitis	Asthma	Pharyn-gitis	RTI	Emphy-sema
1980	99	5	3	3	258	0
1981	131	5	2	4	274	0
1982	120	3	9	8	217	0
1983	78	0	2	0	418	0
1984	48	0	0	0	491	0
1985	89	0	47	2	469	0
1986	106	1	5	0	493	1
1987	84	0	1	0	273	0
1988	162	4	7	0	416	0
1989	122	5	38	0	415	0
1990	119	0	82	1	478	0
1991	48	1	38	24	74	0
1992	91	0	42	15	120	0
1993	54	0	36	5	368	0
1994	85	0	72	4	262	0

Table-5.19

Number of Female Patients suffering from Pollution-related Diseases in the age group below 5 years in Shillong per year

(Both Indoor and Outdoor)

Year	Acute Bron-chitis	Chronic Bron-chitis	Asthma	Pharyn-gitis	RTI	Emphy-sema
1980	58	3	2	4	240	0
1981	66	7	5	3	226	0
1982	83	6	10	9	143	0
1983	50	0	4	1	405	0
1984	44	0	0	0	404	0
1985	61	0	16	2	349	0
1986	76	0	1	0	350	0
1987	79	0	3	1	232	0
1988	87	0	11	0	357	0
1989	78	0	17	1	354	0
1990	83	0	55	0	468	0
1991	29	0	31	13	45	0
1992	39	1	19	13	91	0
1993	44	2	24	5	334	1
1994	79	0	35	0	238	0

Table-5.20

Number of Male Patients suffering from Pollution-related Diseases in the age group of 5 years and above in Shillong per year

(Both Indoor and Outdoor)

Year	Acute Bron-chitis	Chronic Bron-chitis	Asthma	Pharyn-gitis	RTI	Emphy-sema
1980	137	58	94	35	321	1
1981	127	37	83	24	310	0
1982	147	33	81	32	379	2
1983	90	47	88	37	305	2
1984	72	56	90	13	341	3
1985	186	88	113	52	371	4
1986	216	50	98	48	316	9
1987	118	40	65	17	201	12
1988	247	68	148	8	378	10
1989	190	52	131	27	172	0
1990	263	60	126	22	183	3
1991	184	42	105	32	53	0
1992	156	37	94	40	86	3
1993	151	34	98	70	242	0
1994	190	19	99	34	158	3

Table-5.21

Number of Female Patients suffering from Pollution-related Diseases in the age group below 5 years in Shillong per year

(Both Indoor and Outdoor)

Year	Acute Bron-chitis	Chronic Bron-chitis	Asthma	Pharyn-gitis	RTI	Emphy-sema
1980	186	37	149	34	349	0
1981	212	43	139	32	390	0
1982	199	43	161	42	328	4
1983	85	44	75	19	315	2
1984	90	37	76	24	397	4
1985	188	89	125	72	358	0
1986	240	19	140	42	305	4
1987	134	14	90	42	236	0
1988	273	54	142	13	455	0
1989	258	37	191	23	229	0
1990	324	54	250	45	223	0
1991	210	45	153	55	75	0
1992	214	12	185	46	74	0
1993	222	18	182	76	226	0
1994	210	31	141	30	178	6

5.3.1. <u>Relationship between Diseases and Pollutants</u>

We all are of the opinion that the pollutants have some direct effect on the diseases mentioned in this chapter, but no one is sure which pollutant is more influential for a particular type of disease. Therefore, we have adopted a general model.

$$D_i = f(PM, SO_2, NO_x, HC, CO) \quad \ldots\ldots\ldots\ldots \quad (i)$$

where

D_i = Diseases given in terms of the number of patients per year

i = 1 = Acute Bronchitis

2 = Chronic Bronchitis

3 = Asthma

4 = Pharyngitis

5 = Respiratory Tract Infection

6 = Emphysema.

We assume that equation (i) in linear form is

$$D_i = \alpha_0 + \alpha_1 PM + \alpha_2 SO_2 + \alpha_3 NO_x + \alpha_4 HC + \alpha_5 CO + U, \quad i=1,2,3,4,5,6$$

where

D_i = as mentioned above; PM = Particular Matter; SO_2 = Sulphur Dioxide; NO_x = Oxides of Nitrogen; HC = Hydrocarbons; CO = Carbon Monoxide, and U = the stochastic disturbance term.

In this regression, we have taken diseases as dependent variables and the pollutants as independent variables.

After estimating this equation empirically, for each type of diseases, we have made a thorough observation of the variance-covariance matrix. We have rejected those combinations which have very small co-variance. Then we have re-run the equations using different combinations of pollutants until we have found the desired result. This has been achieved not only from variance-covariance matrix but also from the signs of the parameters because we expect that if a certain pollutant is directly responsible for causing a particular disease, then it should bear a positive sign. But it must also be mentioned here that there are other extraneous factors over which we have no control like, for example, parents having these diseases might have affected the small children even without being exposed to pollution or people living in unhealthy dwelling may also develop any of these diseases without being affected by pollution. Therefore, in this kind of regression analysis, the constant terms, unlike in other type of econometric analysis, is very crucial. Hence we are trying to make an attempt as far as possible to pinpoint those pollutants which empirically support that a particular disease is affected by pollution. So for each disease we had to run more than 30 regression equations until we have found the desired empirical equations. We have estimated data categorized according to sex and age group for Shillong, whereas data on Meghalaya has no such categorization. We are now presenting all the estimated empirical equations.

5.3.2. Empirical Equations of the Econometric Analysis

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
1.	Acute Bronchitis 0-5, M, S	1) 157.9107	-0.0239 (0.4750)	-0.0026 (0.4015)	0.0042** (1.3382)	-0.0021**** (1.6650)	-0.0000025 (0.0872)	0.4263	2.1595
		2) 157.6540	-0.0246 (0.5236)	-0.0027 (0.4300)	0.0042** (1.4179)	-0.0021**** (1.7678)	-	0.4259	2.1804
		3) 158.5603	0.0326** (1.4194)	-	-	-0.0019** (1.5033)	-0.0000052 (0.1834)	0.3078	2.2145
		4) 164.5903	-	-0.0029 (0.4571)	0.0029**** (1.9662)	-0.0023* (2.0581)	-0.0000048 (0.1771)	0.4119	2.2437
		5) 164.4933	-	-0.00297 (0.4950)	0.0028* (2.0601)	-0.0023* (2.1497)	-	0.4101	2.2874
		6) 157.0184	-	-	0.0026* (2.0017)	-0.0023* (2.0952)	-0.0000058 (0.2224)	0.3997	2.0872
		7) 150.1032	-0.0264 (0.5862)	-	0.0041** (1.4357)	-0.002**** (1.7901)	-	0.4152	2.0309
		8) 156.6164	-	-	0.0026* (2.0881)	-0.0022* (2.1728)	-	0.3970	2.1289
		9) 157.8618	0.0314** (1.4861)	-	-	-0.0018**** (1.5615)	-	0.3057	2.2412
	Acute Bronchitis 0-5, F;S	10) 99.1710	-0.0262 (0.9714)	-0.0031 (0.8883)	0.0034* (2.0566)	-0.0013**** (1.9262)	-0.0000095 (0.0616)	0.5134	1.3736

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
		11) 99.0736	-0.0265**	-0.0032	0.0034*	-0.0013*	-	0.5132	1.3851
			(1.0499)	(0.9424)	(2.1750)	(2.0534)			
		12) 80.0697	-0.0445***	-0.0021	0.0030****	-	-	0.3079	1.3418
			(1.6510)	(0.5617)	(1.6868)				
		13) 106.5098	-	-0.0034	0.00202(*)	-0.0016(*)	-0.0000035	0.4624	1.223
				(0.9680)	(2.4789)	(2.4602)	(0.2300)		
		14) 106.4395	-	-0.0035**	0.0020(*)	-0.0015(*)	-	0.4595	1.2529
				(1.0351)	(2.5931)	(2.5643)			
		15) 97.5668	-	-	0.0017	-0.0015	-0.0000047	0.412	1.0765
					(2.2911)	(2.3699)	(0.3092)		
		16) 90.1851	-0.0286**	-	0.0033*	-0.0012****	-	0.4699	1.2363
			(1.1439)		(2.1011)	(1.9427)			
		17) 97.2442	-	-	0.0017*	-0.0015*	-	0.4069	1.0967
					(2.3717)	(2.4438)			
		18) 96.4906	0.0184**	-	-	-0.0011**	-	0.2572	1.3025
			(1.4400)			(1.5018)			
	Acute Bronchitis 5 -->, M, S	19) 166.6639	0.0249	-0.0143**	0.0032	-0.0031**	-0.0000019	0.4265	2.2466
			(0.2966)	(1.3023)	(0.6171)	(1.4823)	(0.3953)		
		20) 164.7253	0.0192	-0.0146**	0.0033	-0.00298**	-	0.4166	2.3231
			(0.2435)	(1.3910)	(0.6703)	(1.4986)			
		21) 131.9528	0.0524**	-	-	-0.0026**	-0.000024	0.3035	1.6787
			(1.3654)			(1.2762)	(0.5092)		
		22) 159.7134	-	-0.01402**	0.0045****	-0.0029**	-0.000017	0.4209	2.2428
				(1.3463)	(1.8777)	(1.5487)	(0.3672)		
		23) 159.3805	-	-0.0143**	0.0044****	-0.0028****	-	0.4131	2.3136
				(1.4377)	(1.9185)	(1.5764)			
		24) 122.8273	-	-	0.0034**	-0.0026**	-0.000021	0.3160	1.699
					(1.4483)	(1.3517)	(0.4596)		

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
		25) 121.3495	-	-	0.0032** (1.4277)	-0.0025** (1.3438)	-	0.3028	1.7442
	Acute Bronchitis 5 –>, F, S	26) 223.3408	0.0146 (0.1447)	-0.0174** (1.3136)	0.00503 (0.8038)	-0.0041**** (1.5975)	0.000014 (0.2406)	0.4051	1.9577
		27) 224.7647	0.0188 (0.1977)	-0.0172** (1.3666)	0.0049 (0.8312)	-0.0042**** (1.7555)	-	0.4013	1.8884
		28) 219.2486	-	-0.0172** (1.3754)	0.0058* (2.0014)	-0.0039**** (1.7478)	0.000015 (0.2831)	0.4037	1.9473
		29) 219.5572	-	-0.0169** (1.4177)	0.0060* (2.1827)	-0.0040**** (1.8824)	-	0.3989	1.8648
		30) 173.9331	-	-	0.0044**** (1.5600)	-0.0036**** (1.5367)	0.000009 (0.1673)	0.2909	1.5408
		31) 174.5821	-	-	0.0045**** (1.7119)	-0.0036**** (1.6456)	-	0.2891	1.5130
		32) 184.2553	0.066** (1.5334)	-	-	-0.0035** (1.4719)	-	0.2604	1.5536
	Acute Bronchitis allage, Meg.	33) 10964.39	-2247.69** (1.0314)	-1.6120 (0.6121)	1.5635 (0.3979)	121.4897** (1.0306)	-	0.3298	1.3449
2.	Chronic Bronch. 0-5, M, S	34) 7.8235	0.0031** (1.0665)	-0.00037 (0.9626)	-0.0001 (0.5798)	-0.000079** (1.0628)	0.00000073 (0.4377)	0.5544	1.7045
		35) 7.8987	0.0033** (1.2072)	-0.00036 (0.9763)	-0.0001 (0.6326)	-0.000085** (1.2139)	-	0.5449	1.6165
		36) 6.6655	0.00218 (0.8213)	-0.00029 (0.7848)	-0.00014 (0.7854)	-	-	0.4778	1.1513
		37) 6.5525	0.0011 (0.8681)	-	-	-0.000074** (1.0490)	0.00000068 (0.4236)	0.4853	1.6324
		38) 6.9482	-	-0.00034 (0.8778)	0.000064 (0.7113)	-0.000049 (0.7172)	0.0000010 (0.6230)	0.4980	1.5987

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
		39) 6.9690	-	-0.00032 (0.8549)	0.000074 (0.8650)	-0.000055 (0.8313)	-	0.4786	1.4687
		40) 6.0585	-	-	0.000036 (0.4354)	-0.000043 (0.6252)	0.0000009 (0.5606)	0.4594	1.4821
		41) 5.7755	-	-	-	-0.000013* (2.0764)	0.0000011 (0.7015)	0.4500	1.2978
		42) 6.888	0.0031** (1.1273)	-	-0.00013 (0.7366)	-0.000074** (1.0806)	-	0.5015	1.5022
		43) 5.9168	0.0019 (0.7105)	-	-0.00014 (0.7968)	-	0.0000009 (0.5757)	0.4647	1.2227
		44) 6.2577	-	-0.00024 (0.6866)	-	-0.000002 (0.1179)	0.0000013 (0.7852)	0.4726	1.2854
		45) 6.3488	-	-0.00031 (0.8176)	0.0000016 (0.0718)	-	0.0000012 (0.7421)	0.4722	1.2699
		46) 6.3041	-	-0.00028* (2.2336)	-	-	0.0000012 (0.8106)	0.4719	1.2716
		47) 5.6118	-	-	-0.000015* (2.0058)	-	0.0000011 (0.6753)	0.4401	1.2155
		48) 6.1222	-	-	0.000047 (0.5954)	-0.000048 (0.7351)	-	0.4439	1.4032
		49) 6.6446	0.0013* (1.0648)	-	-	-0.00008* (1.2010)	-	0.4769	1.5807
	Chronic Bronchitis 0-5, F, S	50) 4.8899	0.0016 (0.4858)	0.00046** (1.0412)	-0.000072 (0.3453)	-0.00006 (0.7146)	-	0.4363	1.3182
		51) 4.0129	0.00079 (0.2599)	0.00051** (1.1897)	-0.00009 (0.4551)	-	-	0.4076	1.418
		52) 6.0382	0.0011 (0.7152)	-	-	-0.00007 (0.8509)	0.0000004 (0.2197)	0.3747	1.0594

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
		53) 4.4295	-	0.00047** (1.0577)	0.000013 (0.1222)	-0.000044 (0.5426)	0.00000042 (0.2186)	0.4258	1.3189
		54) 4.438	-	0.00048** (1.1286)	0.000017 (0.1730)	-0.000046 (0.6038)	-	0.423	1.284
		55) 5.674	-	-	0.000051 (0.5237)	-0.000054 (0.6675)	0.0000006 (0.3023)	0.3616	1.0674
		56) 5.2724	-	-	-	-0.000012**** (1.5769)	0.0000008 (0.4466)	0.3456	1.1549
		57) 6.1919	0.0019 (0.5784)	-	-0.00005 (0.2404)	-0.000073 (0.8793)	-	0.3752	1.0529
		58) 5.2393	0.00081 (0.2469)	-	0.000067 (0.3107)	-	0.0000007 (0.3655)	0.3394	1.2237
		59) 4.2919	-	0.00049** (1.2316)	-	-0.000034**** (1.7423)	0.00000047 (0.2571)	0.4249	1.3437
		60) 3.9031	-	0.0005** (1.1670)	-0.000042**** (1.6293)	-	0.00000056 (0.3038)	0.4089	1.4058
		61) 5.7145	-	-	0.000058 (0.6329)	-0.000057 (0.7476)	-	0.3562	1.0055
		62) 6.0954	0.0012 (0.8431)	-	-	-0.000076 (0.9531)	-	0.3719	1.0162
	Chronic Bronch. 5 -->, M, S.	63) 65.8889	0.0092 (0.4203)	-0.0031** (1.0858)	0.00085 (0.6273)	-0.0009**** (1.6665)	-0.00004*** (3.2365)	0.5969	1.6869
		64) 58.6120	0.0174**** (1.7752)	-	-	-0.00081** (1.5245)	-0.00004*** (3.4339)	0.5322	1.5871
		65) 63.3090	-	-0.0030** (1.1032)	0.0014* (2.1205)	-0.0008**** (1.6969)	-0.00004*** (3.3526)	0.5890	1.6186
		66) 55.3536	-	-	0.0011**** (1.8332)	-0.0008**** (1.5633)	-0.00004*** (3.4181)	0.539	1.5068

Sl. No.	Dependent Variable	Constant	Independent Variables: PM	SO_2	NO_x	HC	CO	R^2	DW
67)		46.6998	-	-	-	0.00013(*) (2.4990)	-0.00004(*) (2.8172)	0.3982	1.2254
68)		46.4993	-0.0047 (0.2152)	-	0.00047 (0.3314)	-	-0.00004(*) (2.8804)	0.4389	1.1894
69)		48.6636	-	-0.00099 (0.3345)	-	0.00017** (1.2051)	-0.00004(*) (2.6248)	0.4042	1.253
70)		53.2183	-	-0.0025 (0.8417)	0.00031**** (1.7365)	-	-0.00004(*) (2.9146)	0.4707	1.3056
71)		44.7018	-	0.0023* (2.0691)	-	-	-0.00003* (2.4054)	0.3256	1.1501
72)		47.2432	-	-	0.00017(*) (2.7366)	-	-0.00004*** (3.0477)	0.4366	1.2415
73)	Chronic Bronch. 5 --> F, S	47.1214	0.0343**** (1.7062)	0.0028** (1.0586)	-0.0007 (0.5989)	-0.0012* (2.3618)	-0.00006(*)(*) (4.8464)	0.7498	2.0659
74)		53.6476	0.0272*** (3.0336)	-	-	-0.0013* (2.6769)	-0.00006(*)(*) (4.9129)	0.7119	1.9966
75)		37.5336	-	0.0031** (1.0924)	0.0011**** (1.6652)	-0.0009**** (1.7099)	-0.00005(*)(*) (4.2371)	0.6689	2.2186
76)		45.7502	-	-	0.0014* (2.1682)	-0.0009**** (1.8345)	-0.00005(*)(*) (4.1270)	0.6293	2.0715
77)		35.0863	-	-	-	0.00017*** (2.9589)	-0.00005*** (3.2623)	0.4709	1.5437
78)		38.6307	0.0176 (0.7697)	-	-0.0009 (0.6265)	-	-0.00005*** (3.5708)	0.5407	1.5868
79)		25.5384	-	0.0048**** (1.6612)	-	-0.00005 (0.3633)	-0.00005*** (3.7107)	0.5770	1.6691
80)		26.9285	-	0.0037** (1.2008)	0.000008 (0.0430)	-	-0.00005*** (3.7314)	0.5720	1.6129

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
		81) 26.7079	-	0.0038(*)(*) (3.6951)	-	-	-0.00005(*)(*) (3.9823)	0.5720	1.6172
		82) 35.8342	-	-	0.0002*** (3.2687)	-	-0.00005(*)(*) (3.5669)	0.5159	1.5402
	Chronic Bronch. allage, Meg.	83) 2221.617	-7.9452 (0.7936)	-0.0906 (0.2455)	0.5052 (0.8132)	-	-	0.4284	2.7784
		84) 2207.930	-	-0.0866 (0.2337)	0.4841 (0.7861)	-	-0.1188 (0.7663)	0.4263	2.2801
		85) 2388.678	-196.9573 (0.6533)	-	0.6507** (1.0076)	10.1901 (0.6263)	-	0.4451	2.2584
		86) 2390.768	-204.7529 (0.6815)	-	0.6601** (1.0208)	-	3.0332 (0.6544)	0.4468	2.2544
		87) 2348.881	-	-0.1159 (0.3196)	-	-	0.0030 (0.5225)	0.3941	2.1978
		88) 2092.349	-	-	0.4986 (0.8478)	-	0.1238 (0.8400)	0.4335	2.2604
		89) 2345.196	-87.9434 (0.3123)	-	-	4.8069 (0.3126)	-	0.3939	2.1562
		90) 3017.727	-338.4985 (+0.9159)	-0.3113 (+0.6970)	0.7074** (1.0614)	17.8876 (0.8947)	-	0.4708	2.3863
		91) 2092.349	-	-	0.4993 (0.8488)	-0.4337 (0.8409)	-	0.4235	2.2604
3.	Asthma 0-5, M, S	92) -31.3508	-0.0170 (0.5706)	-0.0011 (0.2886)	0.0022** (1.1881)	-0.0007 (0.8582)	-0.000014 (0.8068)	0.7180	1.476
		93) -32.7609	-0.0211 (0.7304)	-0.0013 (0.3483)	0.0023** (1.2598)	-0.0005 (0.7344)	-	0.6976	1.9582
		94) -40.5401	-0.0285** (1.0723)	-0.0009 (0.2449)	0.0021** (1.1975)	-	-	0.6813	1.8417

Sl. No.	Dependent Variable	Constant	Independent Variables PM	SO_2	NO_x	HC	CO	R^2	DW
95)		-30.246	0.0131 (0.9781)	-	-	-0.0005 (0.7240)	-0.00002 (0.9132)	0.6730	1.4774
96)		-26.5853	-	-0.0013 (0.3449)	0.0013** (1.4613)	-0.0008** (1.1881)	-0.00002 (0.9493)	0.7078	1.4232
97)		-26.8959	-	-0.0016 (0.4240)	0.0011** (1.3146)	-0.0007** (1.0755)	-	0.6815	1.9301
98)		-29.9969	-	-	0.0012** (1.4922)	-0.00078** (1.2049)	-0.0000016** (1.0217)	0.7044	1.3945
99)		-36.5208	-0.0220 (0.7969)	-	0.0022** (1.2832)	-0.0005 (0.7189)	-	0.69398	1.9251
100)		-42.3559	-0.0266** (1.0155)	-	0.00198** (1.1479)	-0.000011 (0.7203)	-	0.6940	1.437
101)		-35.6595	-	-0.0011 (0.2854)	0.00023** (1.0747)	-	-	0.6480	1.91798
102)		-36.0929	0.0031 (0.9244)	-0.00054 (0.1441)	-	-	-	0.6398	1.9192
103)		-32.2715	0.0097 (0.7578)	-	-	-0.0004 (0.5538)	-	0.6482	1.9030
104)		-37.2822	0.0034*** (2.9234)	-	-	-	-0.000013 (0.7985)	0.6574	1.5475
105)		-39.1734	-	-	-	0.00018(*) (2.7933)	-0.000011 (0.6673)	0.6445	1.5996
106)	Asthma 0-5, F, S	-11.5674	0.0082 (0.6111)	-	0.00051 (0.6023)	-0.0008* (2.3658)	-	0.7766	1.2106
107)		-21.6782	-0.0033 (0.2121)	-	0.0003 (0.2938)	-	0.000004 (0.4263)	0.6684	1.4862
108)		-22.7142	-	0.00065 (0.3177)	0.00006 (0.5103)	-	-	0.6649	1.2748

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
109)		-22.6725	0.00088 (0.4833)	0.0007 (0.3457)	-	-	-	0.6642	1.2839
110)		-10.6007	0.0154(*) (2.6286)	-	-	-0.0008* (2.3740)	-	0.7692	1.1853
111)		-11.7232	0.0080 (0.5324)	0.00003 (0.0168)	0.00051 (0.5420)	-0.00079* (2.0669)	0.0000004 (0.0501)	0.7767	1.2439
112)		-11.679	0.0082 (0.5784)	0.00004 (0.0212)	0.0005 (0.5692)	-0.0008* (2.2265)	-	0.7766	1.2097
113)		-23.1792	-0.0027 (0.1759)	0.0007 (0.3113)	0.0002 (0.2349)	-	-	0.6659	1.2470
114)		-10.6268	0.0153* (2.4093)	-	-	-0.0008* (2.2206)	0.0000002 (0.0247)	0.7693	1.1999
115)		-13.9682	-	0.00011 (0.0598)	0.0009* (2.1349)	-0.0007* (2.0880)	0.0000012 (0.1476)	0.7696	1.3889
116)		-13.9439	-	0.00014 (0.0752)	0.00095* (2.3047)	-0.0007* (2.2283)	-	0.7691	1.2982
117)		-13.6704	-	-	0.00095* (2.4139)	-0.0007* (2.2120)	0.0000012 (0.1603)	0.7696	1.3953
118)		-20.9113	0.0013**** (1.9112)	-	-	-	0.000004 (0.4217)	0.6658	1.5211
119)		-21.1057	-	-	-	0.00006**** (1.6849)	0.000006 (0.6153)	0.6475	1.62599
120)	Asthma 5 —>, F, S	126.5069	-0.0049 (0.0713)	-0.0069 (0.7716)	0.0042 (0.9794)	0.0028**** (1.6193)	0.000022 (0.5473)	0.4728	1.5857
121)		128.7120	0.0015 (0.0225)	-0.0066 (0.7646)	0.0040 (0.9839)	-0.0030**** (1.8154)	-	0.4552	1.4022
122)		114.7864	0.0461** (1.4982)	-	-	-0.0025** (1.4794)	0.000018 (0.4637)	0.3901	1.6697

Sl. No.	Dependent Variable	Constant	PM	SO_2	NO_x	HC	CO	R^2	DW
123)		127.8787	-	-0.0069 (0.8213)	0.0039**** (1.9755)	-0.0029**** (1.8637)	0.000021 (0.5723)	0.4725	1.5971
124)		128.3028	-	-0.0066 (0.8030)	0.0041* (2.1852)	-0.0030* (2.0207)	-	0.4552	1.3974
125)		109.4777	-	-	0.0033**** (1.8292)	-0.0027**** (1.8068)	0.000019 (0.5160)	0.4369	1.5430
126)		110.0351	-0.0029 (0.0465)	-	0.0037 (0.9290)	-0.0028**** (1.7527)	-	0.4234	1.3881
127)		117.1544	-0.0501**** (1.7540)	-	-	-0.0026**** (1.6624)	-	0.3781	1.5550
128)		73.6438	-0.0468 (0.7017)	-	0.0031 (0.7139)	-	0.00003 (0.7808)	0.3011	1.2709
129)	Asthma 5 —>, M, S	95.3673	-	-0.0046** (1.0235)	0.0010** (1.0119)	-0.0006 (0.7423)	-	0.2357	2.0979
130)	Asthma allege, Neg.	-779.2786	-122.9981 (0.3927)	-0.0065 (0.0172)	0.4184 (0.7408)	6.3559 (0.3751)	-	0.6226	1.9872
131)		-1073.722	-	0.0751 (0.2473)	0.3375 (0.5053)	-0.2949 (0.6629)	-	0.6168	1.9510
132)		-1073.89	-	0.0753 (0.2478)	0.3387 (0.6706)	-	-0.0847 (0.6655)	0.6169	1.9522
133)		-792.4649	-120.0311 (0.4810)	-	0.4172 (0.7805)	6.1946 (0.4600)	-	0.6226	1.9863
134)		-827.4121	-100.1497 (0.4009)	-	0.4051 (0.7534)	-	1.4639 (0.3798)	0.6203	1.9796
135)		-967.7032	-	0.0474 (0.1614)	0.0028 (0.1526)	-	-	0.6015	1.6229
136)		-820.3449	-50.1325 (0.2188)	-	-	2.7430 (0.2192)	-	0.6017	1.6033

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
		137) -975.3693	0.0376 (0.1269)	0.0548 (0.1857)	-	-	-	0.6012	1.6204
		138) -853.4574	-31.1742 (0.1366)	-	-	-	0.4883 (0.1370)	0.6007	1.6101
4.	Pharyngitis 0-5, M, S	139) -3.0931	0.0239*** (3.1073)	0.0006 (0.5504)	-0.0019(*)(*) (3.8963)	0.0002** (1.1061)	0.000002 (0.4648)	0.6978	1.7702
		140) -2.8836	0.0245*** (0.3673)	0.0006 (0.6064)	-0.0019(*)(*) (4.0942)	0.0002** (1.0813)	-	0.6905	1.6494
		141) 0.0024	0.0273(*)(*) (3.9580)	0.0004 (0.4442)	-0.0018(*)(*) (3.9551)	-	-	0.6543	1.5683
		142) -9.7844	-	0.0008 (0.5783)	-0.0006**** (1.7753)	0.0004**** (1.7669)	0.000004 (0.7361)	0.3736	1.3738
		143) -9.6965	-	0.0009 (0.6528)	-0.0005**** (1.7041)	0.0004**** (1.7197)	-	0.3396	1.2203
		144) -7.6985	-	-	-0.0005**** (1.7324)	0.0004**** (1.7653)	0.000005 (0.8096)	0.3526	1.2971
		145) -1.2343	0.0249*** (3.5379)	-	-0.0018(*)(*) (4.1754)	0.0002** (1.0309)	-	0.6791	1.5082
		146) 1.0032	0.0271(*)(*) (3.8991)	-	-0.0018(*)(*) (3.8797)	-	0.000001 (0.3127)	0.6512	1.5422
	Pharyngitis 0-5, F, S	147) -0.6159	0.0114**** (1.5616)	0.0006 (0.6035)	-0.0010* (2.1817)	0.0002 (0.9151)	0.000001 (0.3050)	0.4036	1.829
		148) -0.4853	0.0118**** (1.7166)	0.0006 (0.6553)	-0.0010* (2.3107)	0.0002 (0.9163)	-	0.3974	1.7584
		149) 1.8246	0.0140* (2.1839)	0.0005 (0.5262)	-0.0009* (2.2243)	-	-	0.3468	1.7232
		150) 1.1980	0.0122**** (1.8299)	-	-0.0010* (2.3169)	0.0001 (0.8489)	-	0.3715	1.5877

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
151)		2.9527	0.0140* (2.1464)	-	-0.0009* (2.1443)	-	0.0000007 (0.1924)	0.3326	1.6338
152)	Pharyngitis 5 -->, M, S	5.4737	-0.0249** (1.0066)	-	0.0004 (0.2475)	0.0011**** (1.7513)	-	0.2805	2.1309
153)		0.2301	-0.0226 (0.8657)	0.0025 (0.7375)	0.0002 (0.1173)	0.0010** (1.5812)	-0.00001 (0.8625)	0.3658	1.9924
154)		-1.0895	-0.0264** (1.0399)	0.0023 (0.6913)	0.0003 (0.1704)	0.0011**** (1.7943)	-	0.3133	2.0856
155)		6.5583	-	0.0023 (0.6820)	-0.0010** (1.3201)	0.0008** (1.3758)	-0.00002** (1.0369)	0.3129	1.9472
156)		6.2070	-0.0194**** (1.8211)	-	-	0.0011**** (1.8687)	-	0.2765	2.1277
157)		7.8558	-0.0166** (1.4845)	-	-	0.0010**** (1.6333)	-0.00001 (0.8864)	0.3247	2.0239
158)	Pharyngitis 5 -->, F, S	20.2304	0.0129 (0.4571)	-0.0010 (0.2653)	-0.0008 (0.4478)	0.0001 (0.1996)	-0.00003**** (1.7554)	0.4226	2.0151
159)		15.87	0.0004 (0.0325)	-	-	0.0001 (0.2041)	-0.00003**** (1.9077)	0.4035	2.0343
160)		16.6258	-	-0.0009 (0.2408)	-0.00009 (0.1047)	0.0003 (0.4112)	-0.00003**** (1.7742)	0.4092	2.0546
161)		14.3909	-	-	-0.0002 (0.2112)	0.0003 (0.4627)	-0.00003**** (1.8815)	0.4058	2.0705
162)		19.6536	0.0147 (0.6167)	-	-0.0008 (0.4997)	-	-0.00003* (2.0412)	0.4145	1.9733
163)		15.87	0.0004 (0.0325)	-	-	0.0001 (0.2041)	-0.00003**** (1.9077)	0.4035	2.0343
164)		17.6375	0.0028* (2.7389)	-	-	-	-0.00003* (2.0752)	0.4012	1.9971

Sl. No.	Dependent Variable	Constant	PM	SO_2	NO_x	HC	CO	R^2	DW
165)		15.6057	-	-	-	0.0002(*) (2.7519)	-0.00003* (2.0655)	0.4034	2.0401
166)	Pharyngitis allage, Meg.	19.1547	9.5698 (0.7789)	0.0076 (0.5105)	-0.0158 (0.7144)	-0.5091 (0.7661)	-	0.2819	1.9159
167)	5. RTI 0-5, M, S	325.8991	-0.3717**** (1.7571)	-0.0039 (0.1419)	0.03026* (2.3124)	-0.0042 (0.7829)	-0.00012 (0.9506)	0.4242	1.9653
168)		314.1289	-0.4057**** (1.9556)	-0.0056 (0.2057)	0.03099* (2.3838)	-0.0032 (0.6208)	-	0.3664	1.5158
169)		266.9415	-0.4503* (2.3811)	-0.0031 (0.1161)	0.0299* (2.3893)	-	-	0.3419	1.4563
170)		298.1985	-0.4095* (2.0741)	-	0.0307(*) (2.4859)	-0.0031 (0.6243)	-	0.3637	1.4934
171)	RTI 0-5, F, S	247.7054	-0.3496**** (1.9012)	0.0025 (0.1055)	0.0294(*) (2.5830)	-0.0051** (1.1075)	-0.00006 (0.5283)	0.4663	2.0621
172)		242.0190	-0.3661* (2.0968)	0.0017 (0.0738)	0.0297(*) (2.7184)	-0.0047** (1.0668)	-	0.4498	1.8749
173)		173.787	-0.4306* (2.6124)	0.0054 (0.2368)	0.0282(*) (2.5829)	-	-	0.3872	1.7241
174)		246.8271	-0.3649* (2.2004)	-	0.0298(*) (2.8728)	-0.0047** (1.1435)	-	0.4495	1.8862
175)		336.781	-	-	0.0094**** (1.7571)	-0.0078**** (1.7452)	-	0.2071	1.4247
176)	RTI 5 ->, M, S	432.0002	-0.1785** (1.2909)	-	0.0126** (1.4824)	-0.0011 (0.3186)	-	0.4976	2.1791
177)		474.511	0.03201 (0.5146)	-	-	-0.0017 (0.5101)	-0.00014**** (1.7853)	0.5358	2.7523
178)		432.1447	-	0.0069 (0.3617)	-0.0009 (0.8295)	-	-	0.3987	2.1672

Sl. No.	Dependent Variable	Constant	Independent Variables PM	SO_2	NO_x	HC	CO	R^2	DW
179)		456.0779	0.0009 (0.0143)	-	-	-0.0005 (0.1385)	-	0.4013	2.1111
180)		476.0024	-	-	0.0026 (0.6481)	-0.0026 (0.7807)	-	0.4215	1.9287
181)		451.4319	0.0004 (0.0756)	-	-	-	-0.00013**** (1.7729)	0.5248	2.8441
182)		452.6451	-	-	-	0.000008 (0.0281)	-0.00013**** (1.7645)	0.5246	2.8346
183)		438.4544	-	0.0086 (0.4887)	-	-0.0009 (0.9982)	-	0.4129	2.1101
184)		425.3745	-0.1435** (1.0771)	0.0093 (0.5313)	0.0114** (1.3794)	-0.00199 (0.5919)	-0.00013**** (1.7677)	0.6323	3.1057
185)		411.5896	-0.1834** (1.2683)	0.0072 (0.3781)	0.0122** (1.3493)	-0.0009 (0.2451)	-	0.5047	2.2463
186)		398.6061	-0.1956** (1.5082)	0.0079 (0.4393)	0.0119** (1.3891)	-	-	0.5017	2.28698
187)		465.5070	-	0.0078 (0.4468)	0.0036 (0.8922)	-0.0033** (1.0523)	-0.00015**** (1.9630)	0.58495	2.8206
188)		462.5162	-	0.0051 (0.2594)	0.0022 (0.4808)	-0.0025 (0.7099)	-	0.4250	1.9599
189)		426.1458	-	0.0133 (0.8189)	-	-0.0006 (0.7498)	-0.00014**** (1.8470)	0.5519	2.9921
190)		486.0889	-	-	0.0043** (1.1632)	-0.0035** (1.1551)	-0.00015* (2.0079)	0.5767	2.6804
191)	RTI 5 ->, F, S	511.6355	-0.1079 (0.7364)	-0.0003 (0.0152)	0.0115** (1.2727)	-0.0038** (1.0197)	-0.00011** (1.2943)	0.6002	2.7869
192)		500.5356	-0.1399 (0.9383)	-0.0019 (0.0970)	0.0122** (1.3077)	-0.0029 (0.7686)	-	0.5258	2.2338

Sl. No.	Dependent Variable	Constant	PM	SO_2	NO_x	HC	CO	R^2	DW
193)		458.5215	-0.1797**	0.0004	0.0113**	-	-	0.4978	2.2674
			(1.3084)	(0.0201)	(1.2391)				
194)		541.8099	-	-0.0014	0.0057**	-0.0048**	-0.00012**	0.5761	2.6277
				(0.0733)	(1.3192)	(1.4191)	(1.4739)		
195)		539.4166	-	-0.0036	0.0045	-0.0041**	-	0.4841	2.0174
				(0.1821)	(1.0131)	(1.1719)			
196)		479.7836	-	0.0073	-	-0.0005	-0.000099**	0.5024	2.6623
				(0.4024)		(0.5442)	(1.2119)		
197)		538.2106	-	-	0.0056**	-0.0047**	-0.00012****	0.5759	2.63596
					(1.4483)	(1.4892)	(1.5565)		
198)		495.1313	-0.1413	-	0.0121**	-0.0028	-	0.5254	2.2375
			(0.9967)		(1.3676)	(0.7996)			
199)		533.6406	0.0577	-	-	-0.0033	-0.0001**	0.5277	2.6047
			(0.8714)			(0.9101)	(1.3901)		
200)		489.3278	-	-0.0006	-0.0005	-	-	0.4196	2.2060
				(0.0303)	(0.4682)				
201)		518.3713	0.0319	-	-	-0.0022	-	0.4447	2.1014
			(0.4839)			(0.6176)			
202)		529.957	-	-	0.0042	-0.0040**	-	0.4825	2.019
					(1.0624)	(1.2078)			
203)		489.8365	-0.0023	-	-	-	-0.000098**	0.4921	2.6603
			(0.3938)				(1.2398)		
204)		494.2553	-	-	-	-0.0002	-0.00009**	0.4951	2.6476
						(0.4759)	(1.2061)		
205)		488.76	-	0.0038	-	-0.0007	-	0.4359	2.1824
				(0.2107)		(0.7562)			
206)	RTI allage, Meg.	6407.975	-35.0029	-0.3025	1.2748	0.8162	-	0.3677	1.1396
			(0.0518)	(0.3703)	(1.0457)	(0.0223)			

Sl. No.	Dependent Variable	Constant	Independent Variables						
			PM	SO_2	NO_x	HC	CO	R^2	DW
		207) 5667.507	344.9375 (0.6849)	-	-	-	-5.3851 (0.6847)	0.3007	1.0275
		208) 5951.261	-	-	1.2986** (1.2490)	-1.1328** (1.2427)	-	0.3569	1.0814
		209) 5951.754	-	-	1.3008** (1.2519)	-	-0.3245** (1.2456)	0.3573	1.0821
		210) 5796.729	102.5324 (0.1891)	-	1.2197 (1.0501)	-6.6634 (0.2277)	-	0.3590	1.1276
		211) 6371.648	-19.9194 (1.1304)	-0.2924 (0.4503)	1.2656** (1.1574)	-	-	0.3676	1.1435
		212) 6324.182	-	-0.2792 (0.4290)	1.2518** (1.1565)	-1.0765 (1.1293)	-	0.3675	1.1484
6.	Emphysema allage, Meg.	213) 21.2204	-2.7086 (0.8413)	-	-0.0021 (0.5420)	0.0019 (0.3247)	-0.1464 (0.8407)	0.2037	1.1791

Note : The figures in brackets indicate the t-values

Abbreviations :

* = Significant at 0.05 level; ** = Significant at 0.20 level; *** = Significant at 0.01 level; **** = Significant at 0.10 level; (*) = Significant at 0.02 level; (*)(*) = Significant at 0.001 level; PM = Particular Matter; SO_2 = Sulphur dioxide; NO_x = Oxides of Nitrogen; HC = Hydrocarbon; CO = Carbon monoxide; DW = Darbin-Watson; M = Male Patients; F = Female Patients; S = Shillong; Meg. = Meghalaya.

Reliability of an empirical equation specially in regression may be discussed from two angles - one is from the view point of the sampling distribution of the mean and another is from the angle of best fit given by R^2. Naturally, both are important to speak with confirmation about the validity and reliability of a model. Specially the mathematical statisticians give more importance to the reliability of the estimates of the parameter to that of the co-efficient of determination i.e., R^2. The ultimate objective of empirical regression model is that whether the model has the power of prognosis or simply taken for granted by the value of R^2. The co-efficients of the regression equations are the factors by which independent variables increase or decrease and accordingly the dependent variable is determined. Therefore, for prognosis purpose we do not use R^2 at all but we use the estimates of the parameters of the regression equation. Now from all our equations, we have found that some equations are best fit but they do not possess the estimates having the properties of best linear unbiased estimates. T-value itself suggests whether an estimator is consistent or not and consistency is a property which is complementary to minimum variance property of the estimator. That is why, usually we look for significant values of estimates in an empirical equation for the purpose of prognosis. We have seen in some of our equations that R^2

is much less than 0.40, yet the estimates of the parameters are significant at desired level of significance, say, at 0.05 level of significance whereas some empirical equations demonstrate that the factor R^2 is as high or higher than 0.60 and yet estimates of the parameters are not significant. Therefore, we have the tendency to make a conclusive remark that we shall go for reliability of estimate rather than for the best fit. That is why, we have presented those equations with R^2 less than 0.30 and sometimes R^2 very high by having less reliable estimates of parameters.

5.4. Interpretation from Regression Equations

For interpretation purpose, we have the following tables bearing the signs of the co-efficients as observed from the regression analysis.

Table-5.22

Signs of the Co-efficients as observed from the Regression Analysis
For Meghalaya (All Age Groups and Both Sexes)

Diseases	Pollutants				
	PM	SO_2	NO_x	HC	CO
Acute Bronchitis	-	-	+	+	
Chronic Bronchitis	-----	-----	+++++++	++-++	-++-
Asthma	-----	+-++	++++++	-+++	++-
Pharyngitis	+	+	-	-	
RTI	-++-	---	++++++	+---	--
Emphysema	-	-	+	+	

Table-5.23

Signs of the Co-efficients as observed from the Regression Analysis

In Shillong (Age Group below 5 years)

Diseases	Sex	Pollutants				
		PM	SO_2	NO_x	HC	CO
Acute Bronchitis	M	--+++-	----	+++++++	---------	----
	F	-----+	------	+++++++++	---------	----
Chronic Bronchitis	M	+++++++	-------	---+++--+	----------	++++++++
	F	++++++	++++-+	--++++---+	--------	++++++
Asthma	M	---+--+++	-----+--	++++++++++	---------	----++--
	F	++-++-+++	+++++++	+++++++++	------+---	++++-+++
Pharyngitis	M	+++++	+++++	--------	++++++	++++
	F	+++++	+++	-----	+++	++
RTI	M	----	---	++++	---	-
	F	----	+++	+++++	----	-

Table-5.24

Signs of the Co-efficients as observed from the Regression Analysis

In Shillong (Age Group of 5 years and above)

Diseases	Sex	Pollutants				
		PM	SO_2	NO_x	HC	CO
Acute Bronchitis	M	+++	----	++++++	------	----
	F	+++	----	++++++	-------	+++
Chronic Bronchitis	M	+++-	----+	++++++	----++	----------
	F	+++	+++++	-++-++	----+-	----------
Asthma	M		-	+	-	
	F	-++--+	----	+++++++	--------	+++++
Pharyngitis	M	-----	+++	++-+	++++++	---
	F	+++++	--	----	++++++	--------
RTI	M	---+++	++++++++	++++++-+	-------- -+-	-------
	F	----+++	--+--+-+	++++++++-	-------- ----	-------

Each `+' or `-' sign in the respective boxes means that there is an equation involving the particular pollutant. For example, if we consider the case of Meghalaya, we see that for Chronic Bronchitis, there are 5 negative signs against PM. This means that there are 5 regression equations having PM as one of the pollutants where the signs of the co-efficients are all negative. Similarly, there are 4 regression equations having SO_2 as one of the pollutants with all the negative co-efficients, 7 regression equations having NO_x as one of the pollutants with all positive co-efficients, 5 regression equations having HC as one of the pollutants with 4 equations having positive co-efficients and one having negative co-efficient and finally there are 4 regression equations having CO as one of the pollutants with 2 equations having positive co-efficients and 2 equations having negative co-efficients. Blank boxes mean that there is no regression equation (which could be reported) with that particular pollutant for that disease. Similar explanation holds good for each disease in all the three tables.

From these `sign'-tables, we have made the following interpretations about the respective diseases :

5.4.1. Acute Bronchitis

In case of Meghalaya, from regression co-efficients, it is found that Hydrocarbons (HC) and Oxides of Nitrogen (NO_x)

are the two main pollutants causing Acute Bronchitis.

For Shillong patients, it is found that children of both sex below 5 years of age are mostly affected by NO_x and to some extent by suspended particulate matter (PM) also. But HC has a negative effect on the children of this age group.

For Shillong patients in the age group of 5 years and above, PM and NO_x are responsible for this disease having all positive influence. It is true for both the sexes. HC has a negative effect on the patients of this age group also.

5.4.2. Chronic Bronchitis

In the case of Meghalaya, it has been seen that NO_x, HC and CO (to some extent) have positive effect on Chronic Bronchitis.

In case of Shillong, after analysing both the groups, a very interesting result is revealed. For children below 5 years of age, it is seen that PM, CO and NO_x (to some extent) have all positive influence on both male and female patients. But a very interesting feature in this age group is that female patients are susceptible to SO_2 where as it has no effect on male patients. HC has no influence on patients of Chronic Bronchitis in this age group.

For the patients, in the age group of 5 years and above, it is found that PM and NO_x have all positive effect on Chronic Bronchitis. The female patients in this group are positively affected by SO_2 whereas it has negative effect on male patients in the same age group. It is found that HC is not so important for Chronic Bronchitis. CO has not affected either male or female patients in this age group.

5.4.3. Asthma

From the table, we see that SO_2, NO_x, HC and CO are affecting Asthma patients in Meghalaya, but PM has no effect at all on the Asthma patients in Meghalaya.

From the patients of Shillong, in the age group below 5 years, we see that NO_x is mainly responsible for causing Asthma in both male and female patients. The next influencing pollutant is PM. An interesting observation is that SO_2 has positive influence on female patients in this age group but it has no negative influence on male patients in the same age group. CO also has all positive effect on female patients whereas it has negative effect on male patients.

In the age group of 5 years and above, it is found that NO_x is the only pollutant having all positive effect on both male and female patients. PM, to some extent, affected the female patients only in this age group. The analysis also reveals that CO has all positive effect on female patients only in the same age group.

5.4.4. Pharyngitis

For the patients suffering from Pharyngitis in Meghalaya, it is seen that PM and CO_2 are the main pollutants causing this disease. The other pollutants namely NO_x, HC and CO have negative effects on Pharyngitis in Meghalaya.

For Shillong, in the age group below 5 years, it is seen that PM, SO_2, HC and CO have positive influence in causing Pharyngitis in both male and female patients. Only NO_x has no effect on Pharyngitis in this age group.

Again for Shillong patients in the age group of 5 years and above, we have found that only HC has positive effect on both male and female suffering from Pharyngitis. But for other pollutants we have very interesting observations — PM has positive influence on females but negative influence on male; SO_2 and NO_x have positive influence on males and negative influence on females whereas CO has negative influence on both male and female patients in the same age group.

5.4.5. Respiratory Tract Infection (RTI)

It is found from the equations that NO_x is the main pollutant causing RTI in both male and female patients in Meghalaya. PM also has slight influence on RTI. The other pollutants namely SO_2, HC and CO have no influence on RTI patients in Meghalaya.

For Shillong, in the case of patients suffering from RTI in the age group below 5 years, it is found that NO_x is again the main pollutant causing RTI in both male and female patients. An interesting observation in this age group is that SO_2 has positive influence on female patients whereas it has a negative influence on male patients in the same age group. The other pollutants viz., PM, HC and CO have no influence on RTI patients in this age group.

Again for Shillong patients in the age group of 5 years and above, it is found that NO_x is again the main pollutant causing RTI in both male and female patients. PM also, to some extent, has influenced both male and female patients having RTI. SO_2 has affected male patients to a larger extent whereas female patients suffering from RTI are influenced to a lesser extent by SO_2. The other pollutants HC and CO have absolutely no effect on RTI patients in this age group.

5.4.6. Emphysema

Emphysema, the disease of lung, was known to have caused by smoking mainly. But the analysis reveals that NO_x and HC have some positive influence in causing Emphysema in patients of Meghalaya.

In case of Shillong patients, though the regression equations are not significant enough to be reported, yet it is found that NO_x is mainly responsible for causing Emphysema in both male and female patients in the age group of 5 years and above. For female patients in the same age group, PM, SO_2, HC and CO are also found to be responsible for causing Emphysema in Shillong.

5.4.7. <u>General Observation</u>

Thus from the overall analysis, we can see that Oxides of Nitrogen (NO_x) is the most harmful pollutant causing all these diseases mentioned above with the exception of Pharyngitis only. NO_x is negative in all cases of Pharyngitis, only exception being male patients in the age group of 5 years and above where it is all positive. The next harmful pollutant is Particulate Matter (PM) followed by Sulphur Dioxide (SO_2), Hydrocarbons (HC) and Carbon Monoxide (CO).

From the analysis, it is also seen that in some cases, the patients in Meghalaya are not at all affected by some of the pollutants but the patients in Shillong are greatly affected by the same pollutants for a particular disease. This could be because the vehicular traffic in some parts of Meghalaya is not so densely populated. So the effect of pollutants is much less in case of Meghalaya. But in case of

Shillong, since most of the vehicular traffic is concentrated in and around Shillong, the effect of pollutants is much more serious here in Shillong. This is the main reason for the same pollutants behaving differently with the patients suffering from the same diseases in Meghalaya and in Shillong.

Again from the analysis, we have noticed that for some diseases, the female patients are more susceptible to certain pollutants whereas the same pollutants have no influence on the male patients in the same age group. For this, it could be said that the females have less resistance than the males in fighting with some pollutants. A very interesting observation is that in the age group of 5 years and above, the male patients suffering from Pharyngitis are greatly affected by SO_2 and NO_x whereas the same pollutants have negative effect on female patients in the same age group. The reason behind this could be cigarette smoking. The females here do not smoke in general. Tobacco does give out SO_2 and NO_x when burnt. So it could be said that the male patients in this age group are suffering from Pharyngitis due to smoking also.

Chapter-VI

CONCLUSION

From our study we have seen that though Meghalaya is a very small State, yet it is not free from air pollution. The pollution scenario of Meghalaya is quite alarming. In Meghalaya, the pollution is mainly caused by road transportation as there are very few industries in Meghalaya and no industry in Shillong.

Shillong being a hill station, its roads are very narrow. As Shillong accounts for the highest number of cars in India, the traffic jams are unavoidable. The traffic congestion creates emission. Because of the traffic jams, the movement of the vehicles is very slow. The pattern of driving adopted here is mainly "stop-and-go" driving. In Shillong, free-driving is almost impossible except in the early morning hours. In stop-and-go driving, lots of energy get wasted resulting air pollution.

In our study we have considered those vehicles which are registered in Meghalaya only. But there are many other vehicles in the state bearing registration number of other states. These vehicles could not be taken care of as there are no provisions of maintaining records of these types of vehicles. Moreover, a large number of inter-state bus services ply through Meghalaya. These have also aggravated the pollution scenario of the State.

Another finding is that, in Meghalaya, bulk of the vehicles run on petrol. Only buses, trucks and a handful of jeeps run on diesel. The petrol driven vehicles are more responsible for emitting pollutants than the diesel driven vehicles as seen before.

The tables giving pollutants in Meghalaya and Shillong show a declining trend from 1990 onwards. This could be the result of the measures taken by the State Government to check pollution. The Government has set up State Pollution Control Board which is looking after the emission standards of the vehicles at regular intervals. If vehicles are found not complying with the standards, then they are asked to rectify their vehicles. So people are made aware of the fact that proper maintenance of the vehicles is absolutely necessary to run them on roads.

The air pollutants especially particulates, Oxides of Nitrogen and other pollutants have an almost immediate impact on the health of the individuals and acidification of the environment. Regarding health, we have seen that some of the pollutants are positively responsible for causing some of the respiratory illness. The most harmful pollutant is found to be Oxides of Nitrogen which is emitted mainly by heavy duty diesel vehicles, i.e., buses and trucks. The next harmful pollutant is the Particulate Matter. It is emitted mainly by the two-wheelers. The number of two-wheelers is on the steep rise. This is because, with the increase in fuel prices, people are going for two-wheelers to economise their expenses. Also for short distance travelling, it is easier to use two-wheelers than four-wheelers. Two-wheelers and four-wheelers running on petrol are also responsible for emitting large quantity of Hydro carbons and Carbon Monoxide in the air.

From the tables of number of patients suffering from pollution-related diseases, it is seen that pollutants are causing Acute Bronchitis and Respiratory Tract Infection in a very large scale. The Asthma cases are also quite high compared to other diseases.

From our observations, the following suggestions could be made :

i) The roads on the National Highways should be broadened to check traffic jams.

ii) The traffic in the peak hours should be diverted to different directions.

iii) Flyovers should be constructed at most congested points.

iv) Meghalaya should be brought under Railway Network.

v) Air services should be introduced between the neighbouring states.

vi) By pass should be constructed.

vii) Vehicle excise-duty should be put in application according to the emission limit their engines are designed to meet.

viii) Running of very old polluting vehicles should be banned.

ix) Technology has to be improved to cut fuel consumption and make vehicles less polluting.

x) Stricter legal limits on emissions from all types of road vehicles should be imposed.

xi) Changes in the composition of fuel should be made.

xii) Use of natural gas should be introduced.

Keeping all these in mind, the State Government should take strict and prompt measures to control air pollution before it becomes too late.

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APPENDIX

APPENDIX-I

Road Transport - Total Registered Motor Vehicles in India

(in thousands)

Year (as on 31st March)	All vehicles	Two wheelers	Cars, Jeeps and Taxis	Buses	Goods Vehicles	Others*
1951	306	27	159	34	82	4
1961	665	88	310	57	168	42
1971	1865	576	682	94	343	170
1972	2045	656	740	100	364	185
1973	2109	734	709	95	308	263
1974	2327	838	768	105	323	293
1975	2472	946	766	114	335	311
1976	2700	1057	779	115	351	398
1977	3260	1415	878	119	383	465
1978	3614	1618	919	124	403	550
1979	4059	1888	996	133	444	598
1980	4521	2117	1059	140	473	732
1981	5181	2530	1122	154	528	847
1982	5858	2966	1214	165	590	923
1983	6737	3533	1355	176	647	1026
1984	7883	4327	1439	196	728	1193
1985	9097	5149	1589	219	808	1332
1986	10489	6207	1758	223	848	1453
1987	12539	7703	1990	241	971	1634
1988	14732	9257	2279	265	1101	1830
1989	16919	10961	2485	278	1178	2017
1990(E)	19070	12371	2790	313	1320	2276

*Include tractors, trailors, three-wheelers (passenger and goods vehicles) and all other vehicles which are not separately indicated.

(E) = Estimated

Source: Ministry of Transport, New Delhi, 1992

Appendix-2

Vehicular Emission Load in Metropolitan Cities (1986-87)

Sl. No.	Name of the City	Vehicular Pollution Load (Tonnes per day)					
		Particulates	Sulphur Dioxide	Oxides of Nitrogen	Hydro-carbons	Carbon Monoxide	Total
1	Delhi	8.58	7.47	114.39	207.98	544.91	883.33
2	Bombay	5.32	4.34	71.87	94.90	407.55	583.97
3	Bangalore	2.18	1.46	21.85	65.42	162.1	253.01
4	Calcutta	2.71	3.04	45.58	36.57	156.87	244.77
5	Ahmedabad	2.46	2.41	33.33	56.46	149.28	243.94
6	Pune	1.99	1.07	13.57	61.02	135.22	212.87
7	Madras	1.95	1.68	23.51	42.05	119.35	188.54
8	Hyderabad	1.62	1.23	14.03	46.94	105.14	168.86
9	Jaipur	0.98	1.04	12.74	17.49	42.73	74.99
10	Kanpur	0.88	0.90	11.14	18.53	40.35	71.80
11	Lucknow	0.95	0.79	8.07	18.75	41.02	69.58
12	Nagpur	0.46	0.33	4.24	13.60	29.16	47.80
Grand Total		30.08	25.76	374.32	679.71	1933.68	3043.46

Source : Central Pollution Control Board, Delhi.

Appendix-3

Vehicular Emission Inventory - Delhi (1986-87)

Sl. No.	Category of vehicles	No. of registered Vehicles in Delhi	Pollution Load (Tonnes/day)				
			SPM	SO_2	NO_x	CO	HC
A.	Petrol Driven						
	1. Cars, Jeeps and Station Wagons	2,11,774	1.49	0.36	14.47	180.95	27.1
	2. Taxis	8,808	0.09	0.021	0.859	10.7	1.61
	3. Two wheelers	7,70,110	3.02	0.302	1.05	256.76	151
	4. Three-wheelers	41,651]-->	0.311	0.031	0.109	33.10	15.57
	5. Three-wheelers (Goods)	3,500]					
B.	Diesel Driven						
	1. Buses :						
	a) Registered in Delhi	14,766	1.4	2.8	38.9	23.5	3.9
	b) Entering and Leaving Delhi	1,500 (Approx.)					
	2. Goods vehicles	64,555	2.27	3.96	59	39.9	8.8
	Grand Total	11,16,664	8.58	7.47	114.388	544.91	207.98

Total Vehicular Pollution Load = 883.328 tonnes/day

Appendix-4

Vehicular Emission Inventory - Bombay (1986-87)

Sl. No.	Category of vehicles	No. of registered Vehicles	Pollution Load (Tonnes/day)				
			SPM	SO_2	NO_x	CO	HC
A.	Petrol Driven						
	1. Two wheelers	1,86,952	0.72	0.072	0.254	61.83	36.4
	2. Three wheelers	24,577	0.2	0.02	0.02	25.85	10
	3. Four wheelers	2,56,707	2.395	0.58	23.22	290.32	43.55
	Total		3.315	0.672	23.494	378.0	89.95
B.	Diesel Driven						
	1. Buses	6,714	0.484	0.969	13.566	8.20	1.3566
	2. Matadors etc.	11,072	0.2988	0.258	0.657	0.7304	0.185
	3. Trucks	34,616	1.218	2.436	34.104	20.62	3.4104
	Total		2.0008	3.663	48.327	29.55	4.952
	Grand Total		5.3158	4.335	71.867	407.55	94.902

Total Vehicular Pollution Load 1986-87 = 583.97 tonnes/day

Appendix-5

Vehicular Emission Inventory - Bangalore (1986-87)

Sl. No.	Category of vehicles	No. of registered Vehicles	Pollution Load (Tonnes/day)				
			PM	SO_2	NO_x	HC	CO
A.	<u>Petrol Driven</u>						
	1. Two wheelers	2,36,726	0.984	0.084	0.34	49.2	83.6
	2. Three wheelers	10,524	0.137	0.0137	0.04	6.8	17.0
	3. Four wheelers	61,724	0.42	0.102	4.09	7.68	51.2
	Total		1.541	0.1997	4.47	63.68	151.8
B.	<u>Diesel Driven</u>						
	1. Delivery Van	1,000	0.027	0.023	0.059	0.016	0.0
	2. Trucks	11,500	0.29	0.59	8.25	0.825	4.9
	3. Buses	5,800	0.324	0.648	9.07	0.9	5.4
	Total		0.641	1.261	17.38	1.741	10.3
	Grand Total		2.182	1.4607	21.85	65.42	162.1

Vehicular Pollution Load 1986-87 = 253.01 tonnes/day

Appendix-6

Vehicular Emission Inventory - Calcutta (1987-88)

Sl. No.	Category of vehicles	No. of registered Vehicles	Pollution Load (Tonnes/day)				
			PM	SO_2	NO_x	HC	CO
A.	Petrol Driven						
	1. Two wheelers	1,51,323	0.429	0.0429	0.15	21.46	36.48
	2. Three wheelers	1,865	0.016	0.0016	0.0056	2.3	1.7
	3. Four wheelers	1,78,078	1.125	0.272	10.91	20.46	136.4
	Total		1.570	0.3165	11.0656	44.22	174.58
B.	Diesel Driven						
	1. Buses	11,806	0.885	1.77	24.78	2.478	14.98
	2. Delivery Van	12,362	0.6	0.52	1.326	1.47	0.375
	3. Trucks	31,630	0.585	1.17	16.38	1.638	9.9
	Total		2.070	3.46	42.486	5.586	25.255
	Grand Total		3.640	3.7765	53.5516	49.806	199.835

Total Vehicular Pollution Load 1987-88 = 310.609 tonnes/day

Appendix-7

Vehicular Emission Inventory - Ahmedabad (1987-88)

Sl. No.	Category of vehicles	No. of registered Vehicles	Pollution Load (Tonnes/day)				
			PM	SO_2	NO_x	HC	CO
A.	Petrol Driven						
	1. Two wheelers	2,16,338	0.74	0.074	0.259	59.61	37.05
	2. Three wheelers	27,652	0.28	0.028	0.097	29.73	13.99
	3. Four wheelers	43,766	0.32	0.077	3.11	38.88	5.8
	Total		1.34	0.179	3.466	128.22	56.84
B.	Diesel Driven						
	1. Buses	18,469	0.134	0.268	3.757	2.27	0.3757
	2. Light and Medium transport goods vehicles	5,921	0.14	0.122	0.31	0.344	0.087
	3. Trucks	11,147	0.22	0.44	6.237	3.77	0.6237
	Total		0.494	0.83	10.304	6.384	1.0864
	Grand Total		1.834	1.009	13.77	134.6	57.926

Total Vehicular Pollution Load 1987-88 = 209.14 tonnes/day

Appendix-8

Vehicular Emission Inventory - Pune (1986-87)

Sl. No.	Category of vehicles	Pollution Load (Tonnes/day)				
		PM	SO_2	NO_x	HC	CO
A.	Petrol Driven					
	1. Two wheelers	0.86	0.086	0.3	43	73.1
	2. Three wheelers	0.28	0.028	0.098	14	35.7
	3. Four wheelers	0.312	0.038	1.536	2.88	19.2
	Total	1.452	0.152	1.934	59.88	128.0
B.	Diesel Driven					
	1. Delivery Van	0.14	0.12	0.3	0.008	0.341
	2. Trucks	0.3	0.6	8.4	0.84	5.08
	3. Buses	0.1	0.2	2.94	0.294	1.8
	Total	0.54	0.92	11.64	1.142	7.221
	Grand Total	1.992	1.07	13.57	61.02	135.22

Total Vehicular Pollution Load 1987-88 = 212.87 tonnes/day

Appendix-9

Vehicular Pollution Load in Metropolitan city of Madras (1987-88)

Sl. No.	Category of vehicles	Pollution Load (Tonnes/day)				
		PM	SO_2	NO_x	HC	CO
A.	<u>Petrol Driven</u>					
	1. Four wheelers	1.279	0.31	12.37	23.2	154.86
	2. Three wheelers	0.009	0.0009	0.003	0.46	0.987
	3. Tempos (Goods Veh.)	0.013	0.003	0.13	0.24	1.62
	4. Two wheelers	0.459	0.0459	0.16	22.97	39.06
	Total	1.76	0.3598	12.663	46.87	196.527
B.	<u>Diesel Driven</u>					
	1. Goods Vehicles	0.47	0.718	8.198	0.897	5.165
	2. Buses	0.4	0.798	11.17	1.12	6.76
	Total	0.87	1.516	19.368	2.017	11.925
	Grand Total	2.63	1.8758	32.031	48.887	208.452

Total pollution load generated by vehicles (tonnes/day) = 293.8758

Appendix-10

Vehicular Emission Inventory - Hyderabad (1986-87)

Sl. No.	Category of vehicles	Pollution Load (Tonnes/day)				
		PM	SO_2	NO_x	HC	CO
A.	Petrol Driven					
	1. Two wheelers	0.700	0.070	0.245	35.00	59.5
	2. Three wheelers	0.160	0.016	0.056	8.00	20.4
	3. Four wheelers	0.146	0.035	1.408	2.64	17.6
	Total	1.006	0.121	1.709	45.64	97.5
B.	Diesel Driven					
	1. Matadors	0.184	0.156	0.396	0.112	0.44
	2. Trucks	0.219	0.438	6.132	0.613	3.700
	3. Buses	0.207	0.414	5.796	0.579	3.500
	Total	0.61	1.008	12.324	1.304	7.64
	Grand Total	1.616	1.129	14.033	46.944	105.14

Total pollution load generated by vehicles (tonnes/day) = 168.86

Appendix-11

Vehicular Emission Inventory - Jaipur (1986-87)

Sl. No.	Category of vehicles	Pollution Load (Tonnes/day)				
		PM	SO_2	NO_x	HC	CO
A.	Petrol Driven					
	1. Two wheelers	0.29	0.029	0.1	14.5	24.65
	2. Three wheelers	0.004	0.0004	0.001	0.2	0.5
	3. Four wheelers	0.084	0.028	0.816	1.53	10.2
	Total	0.378	0.0574	0.917	16.23	35.35
B.	Diesel Driven					
	1. Tempos	0.202	0.1755	0.445	0.126	0.495
	2. Buses	0.11	0.22	3.108	0.31	1.88
	3. Trucks	0.295	0.591	8.274	0.827	5.0
	Total	0.607	0.9865	11.827	1.263	7.375
	Grand Total	0.985	1.0439	12.744	17.493	42.725

Total pollution load generated by vehicles (tonnes/day) = 74.99

Appendix-12

Vehicular Emission Inventory - Kanpur (1987-88)

Sl. No.	Category of vehicles	Total Distance travelled km/day	Pollution Load (Tonnes/day)				
			PM	SO_2	NO_x	HC	CO
A.	Petrol Driven						
	1. Two wheelers	19,09,189	0.380	0.0380	0.133	32.3	19.00
	2. Three wheelers	20,081	0.004	0.0004	0.0014	0.425	0.2
	3. Four wheelers	2,60,262	0.080	0.0200	0.832	10.4	1.56
	Total		0.464	0.0584	0.9664	43.125	20.76
B.	Diesel Driven						
	1. Tempos	3,87,000	0.17	0.15	0.38	0.425	0.108
	2. Light Commercial vehicles	44,800	0.01	0.018	0.044	0.0495	0.010
	3. Trucks	1,90,489	0.14	0.28	3.99	2.4130	0.399
	4. Buses	42,152	0.03	0.063	0.882	0.5330	-
	Total		0.35	0.511	5.296	3.4205	0.517
	Grand Total		0.814	0.5694	6.2624	46.5455	21.277

Total Vehicular Pollution Load 1987-88 = 75.47 tonnes/day.

Appendix-13

Pollution Generated by Vehicles in Lucknow (1987-88)

Sl. No.	Category of Vehicles	No. of registered Vehicles	Total running after correction factor	Pollution Load (Tonnes/day)				
				PM	SO_2	NO_x	HC	CO
A.	Petrol Driven							
	1. Two wheelers	1,12,306	20,04,662	0.40	0.14	0.14	20.04	34.07
	2. Auto-rickshaws	80	2,040	0.0004	0.00004	0.00014	0.02	0.050
	3. Taxis	448	11,424	0.003	0.009	0.0036	0.068	0.456
	4. Cars	11,036	2,25,134	0.074	0.018	0.72	1.35	9.05
	Total			0.4774	0.16704	0.86374	21.478	43.626
B.	Diesel Driven							
	5. Tempos	2,204	5,51,000	0.24	0.214	0.545	0.154	0.646
	6. Jeeps	5,483	2,74,150	0.12	0.106	0.271	0.076	0.301
	7. LCV (Three wheelers)	104	5,200	0.0023	0.002	0.005	0.0014	0.005
	8. LCV (Four wheelers)	393	17,685	0.0079	0.006	0.017	0.004	0.019
	9. Trucks	4,127	1,65,080	0.123	0.247	3.466	0.346	2.096
	10. Buses	1,066	53,300	0.039	0.079	1.119	0.111	0.676
	11. Mini Buses	112	11,200	0.008	0.106	0.235	0.023	0.142
	12. Tractors	774	23,220	0.017	0.034	0.487	0.048	0.294
	13. Others	1,792	44,800	0.020	0.017	0.044	0.012	0.049
	Total			0.5772	0.811	6.189	0.7754	4.228
	Grand Total - Petrol+Diesel			1.0546	0.97804	7.05274	22.2534	47.854

Total Vehicular Pollution Load = 79.19278 tonnes/day

Appendix-14

Vehicular Emission Inventory - Nagpur (1986-87)

Sl. No.	Category of vehicles	Pollution Load (Tonnes/day)				
		PM	SO_2	NO_x	HC	CO
A.	<u>Petrol Driven</u>					
	1. Two wheelers	0.230	0.023	0.08	11.5	19.55
	2. Three wheelers	0.019	0.0019	0.0069	0.98	2.45
	3. Four wheelers	0.039	0.009	0.3872	0.726	4.84
	Total	0.288	0.0339	0.4741	13.206	26.84
B.	<u>Diesel Driven</u>					
	1. Buses	0.0237	0.047	0.651	0.0651	0.39
	2. Trucks	0.108	0.216	3.024	0.3024	1.8288
	3. Delivery Van	0.0428	0.037	0.094	0.0266	0.1045
	Total	0.1745	0.300	3.769	0.3941	2.3233
	Grand Total	0.4625	0.3339	4.2431	13.6001	29.1633

Total pollution load = 47.8029 tonnes/day

QUESTIONNAIRE

1. Location of the house :

2. Type of the house :

3. Distance from the main road :

4. How often are the curtains washed ?

5. How often are the Lines, Bed Sheets etc. washed ?

6. Do you get the cleaning done at home ?

7. Do you go for laundry dry-cleaning ?

8. How much do you spend on washing every month ?

9. How often is interior cleaning required ?

10. How often is exterior cleaning required ?

11. Extent of damage done to the things inside the house due to pollution :

12. Do you feel the vibration of the motor cars ?

13. Do you get disturbed from noise by transportation ?

14. How often is painting of the house required ?

15. How much do you spend on painting the house ?

16. Do you prefer roadside residence ? If not, why ?

17. Do you think roadside residential property costs more ? If so, why ?

18. Does the pollution factor affect the value of the property ?

19. Suggestion, if any.