CHAPTER-I

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Pollution of atmosphere by various gases and particulate matter has been a global phenomenon in the recent years. The ever increasing population and industrialising society is primarily accounting for the deteriorating air quality. This causes diverse health hazards to living organisms and particularly to human being. Control of various pollutants at source has always been major concern of most of the developing and developed countries.

Air pollution means the presence in the outdoor atmosphere of one or more contaminants, such as dust, fumes, gas, mist, odour, smoke, or vapour in quantities, of characteristics, and of duration, such as to be injurious to human, plant or animal life or to property, or which unreasonably interferes with the comfortable enjoyment of life and property. It is also defined as the presence in the atmosphere of a substance or substances added directly or indirectly by an act of man, in such amount as to affect humans, animals, vegetation, or materials adversely (Arora, 1999).

The word pollution has been taken from the Latin word 'Pollutionem' (means to defile or make dirty). Sax (1974) described pollution as a social phenomenon. According to him "the communal activities of man as a social being have created a new order of products which have increased in volume at a faster rate than population and have resulted in, increasing contamination of the environment, where the natural purifying activities can no longer keep up with it, and what was once contamination, now becomes pollution.

In another words pollution can be described as "an undesirable change in the physical, chemical or biological characteristics of our air, land and water that will harmfully affect human life or that of desirable species, living conditions etc." According to 'The Indian Environment (Protection) Act 1986, pollution has been defined as 'any solid, liquid or gaseous substance present in each concentration as may be or tend to be injurious to environment'. Arora (1999) has quoted composition of dry atmosphere which reveals as many as eighteen constituents (Table 1.1).

Table1.1 Composition of the Dry Atmosphere

Constituent	Chemical formula	Abundance by Volume
Nitrogen	N_2	78.084 ± 0.004 %
Oxygen	O_2	20.948 ± 0.002 %
Argon	Ar	0.934 ± 0.001 %
Water vapour	H_2O	Variable (%- ppm)
Carbon dioxide	CO_2	325 ppm
Neon	Ne	18 ppm
Helium	He	5 ppm
Krypton	Kr	1 ppm
Xenon	Xe	0.08 ppm
Methan	CH_4	2 ppm
Hydrogen	H_2	0.5 ppm
Nitrous oxide	N_2O	0.3 ppm
Carbon monoxide	CO	0.05-0.2 ppm
Ozone	O_3	Variable (0.02-10 ppm)
Ammonia	NH_3	4 ppb
Nitrogen dioxide	NO_2	1 ppb
Sulphur dioxide	SO_2	1 ppb
Hydrogen sulphide	H_2S	0.05 ppb

Multiple exposures of pollutants, within or between classes, may include synergistic or antagonistic biological effects. In addition, interaction with other environment parameter may further alter biological activities. In many cases the combined effects of two or more pollutants are more severe or even qualitatively different from the individual effects of the separate pollutants the phenomenon is known as Synergism. Numerous studies have shown that some types of particulate matter, such as aerosols, of soluble salts of ferrous iron, manganese and vanadium, can increase the toxicity of sulphur dioxide. Such increase in toxicity is usually referred to as Potentiation. Sometimes the combined effects of two pollutants are less rather than more severe, and this situation is referred to as Antagonism (Arora, 1999).

There are seven main recognised types of pollutions in the environment. They are 1) Air pollution, 2) Water pollution, 3) Land pollution, 4) Industrial pollution, 5) Sewage pollution, 6) Noise pollution and 7) Radiation pollution.

1.2 Air Pollutants

Air pollutants can broadly be classified into two general groups:

a) Primary air pollutants and b) Secondary air pollutants

a) Primary Air Pollutants

These are emitted directly from identified air pollutants such as

i) Finer particles (less than 100 μ in diameter).
ii) Coarse particles (greater than 100 μ in diameter).
iii) Sulphur compounds.
iv) Oxides of nitrogen.
v) Carbon monoxide.
vi) Halogen compounds.
vii) Organic compounds.

viii) Radioactive compounds.

Finer aerosol including particles of metal, carbon, tar, resin, pollen bacteria, etc.

b) Secondary Air Pollutants

These are produced in the air by the interaction among two or more primary pollutants or, by reaction with normal atmospheric constituents, with or without photo-activation. Examples of this category are

i) Ozone
ii) Formaldehyde.
iii) PAN (Peroxy acetyl nitrate).
iv) Photochemical smog.

For example formation of acid mists (H_2SO_4) takes place due to reaction of sulphur dioxide and dissolved oxygen, when water droplets are present in the atmosphere (Arora, 1999).

c) Air Pollutants and Their Sources

In the context of growing environmental degradation today, from the local level to the global climate change, it is necessary to know the characteristics of different pollutants. Air pollutants are varied in nature and their sources are equally diverse. The major air pollutants and their sources are given below.

Dust, SPM	:	Grinding, quarrying, erosion, automobile.
SPM	:	Mining wind erosion, spraying, cement, steel industries, automobiles.
Sulphur oxides:		Power houses, smelters, fuel combustion oil refineries, automobiles, H_2SO_4 acid plants.
H_2S	:	Petroleum industries, tanneries, oil refineries.
NO_x	:	fuel burning, automobile exhaust, acid manufacturing
CO	:	fuel combustion, metabolic activity, automobile

Ozone	:	photochemical reaction
Lead	:	automobile exhaust
Hg	:	pesticides paints
Organic solvents:		solvents use, paint, pesticides, cosmetics, Fluorides glass and ceramic, aluminium industries, fertilizer Industry etc.

1.3 Studies from Abroad

Human development in the world, particularly in the developed countries, is based on socio- economic progress, which is mainly based on energy resources. The main source of energy today is fossil fuels, which are primarily used for transportation in the industrialised modern societies. In turn unplanned use of transportation causes air pollution leading to degradation of environmental health.

From 1970 to 1986, the number of passenger cars sold in the United States increased 51 percent but in comparison sales in the non-communist industrial world increased by 71 percent. The cost of motor vehicle emission abatement, which included the cost of equipment and increased fuel cost and maintenance, was estimated at approximately $8 billion a year in 1985 (Renner, 1988). In all countries, research is broadly concerned with the causes and consequences of air pollution and the means of abating or overcoming it. But because of the varying nature of the problem in different countries there is considerable variation both in the organisation and responsibility for research and in the administrative machinery to control it.

In the United States and most European countries, a great deal of research has been, and is currently being, undertaken into air pollution from both diesel and petrol engines. But in the United States more research is concerned with petrol engines. In the Federal Republic of

Germany, research is initiated and conducted mainly by a working party consisting of representatives of motor manufacturers, refineries, research bodies and engineering association. The Pure Air Commission of the Association of German Engineers prepares directives, which serve as a scientific and technical basis for action to combat air pollution from motor vehicles. The control of air pollution in France is of the public administration type. Each ministry having specialist from various fields which enact legislations on the basis of the research facilities provided by the public laboratories and by the private associations. The Belgian system is similar to that of France, while in the other countries of Western Europe the research is less well developed (Arora, 1987).

In the United Kingdom the Ministry of Transport Co-ordinates all activities relating to pollution caused by motor vehicles. The minister is responsible for issuing Government regulations designed to prevent or reduce air pollution from motor vehicles and for supervising their enforcement in collaboration with the police. It is interesting to note that the great bulk of technical research is undertaken by the motor industry and the oil companies which are normally blamed for causing air pollution.

Air pollution may cause different disease to man, animal and plant, and contribute to the general deterioration of our cities and country-side, damage to materials, cause intangible losses to historical monuments and thus bring about vast economic losses. It also has a direct or indirect effect on climate. Significant and sometimes devastating effects of air pollutants have been recognized on plants. Thick smog has killed more than a million trees in southern California. The visible injury symptoms on plants and leaves are tissue collapse and necrotic patterns, chlorosis, colour patterns and growth alterations (Chhatwal, 1997).

Researches have also been initiated to measure air pollution and to find out the chief pollutants. In this regard, studies have been made about

the carbon monoxide (CO) content of the air in large towns. Carbon monoxide has been chosen because it is regarded as the most dangerous or representative of all pollutants emitted by petrol engine motor vehicles. Research regarding this helps to place motor vehicles as a main source of air pollution. Research has also been made to find out the nature of motor vehicle pollutants and their quantitative measurement with a view to minimise or eliminate emissions. The extent to which such research is conducted differs widely from country to country. It is advanced in the United States; in Europe it is most actively undertaken, and it is conducted voluntarily by the motor industry in West Germany, France, and the U. K., Italy and Sweden. American research has revealed some 150-200 different substances in motor vehicles exhaust gases, identifying the most dangerous and significant of them and determining the proportions in which they are emitted under various running conditions. It has also established agreed criteria for pollution limits, invented and perfected measuring methods and instruments and means of keeping within those limits (Arora, 1999).

The atmosphere is used as a natural sink for gaseous pollutants. The contamination of this atmosphere is so severe that it was recognized as the top most issue among the ten major environmental issues identified by the UNEP report (Kumar, 1999). Air pollution is faced by all the developing and now also the developing countries and therefore is termed as "the price of Industrialization".

Growing cities, increasing traffic, rapid economic development and higher levels of energy consumption lead to the pollution of air. Air pollution caused by automobiles has been described as the "disease of wealth". Around the world, five major types of materials are released directly into the atmosphere in their unmodified forms and in sufficient quantities to pose a health risk. They are carbon monoxide, hydrocarbons, particulates, sulphur dioxide and nitrogen compounds. This group of

pollutants is known as primary air pollutants. These materials may interact with one another in the presence of an energy source to form new secondary air pollutants such as Ozone and other very reactive materials. Secondary air pollutants also form from reactions with natural chemicals in the atmosphere (Miller, 2002).

The above studies show the major pollutants emitted by automobiles, their extent in the air and their impact on environment. Moreover they have attributed a direct correlation between increasing environmental pollution with factors like urbanisation, industrial pollution, and vehicle growth.

Streets *et al* (2007) have reviewed that the massive efforts are being taken to improve the ambient air quality during the forthcoming 2008 Beijing Olympic Games. The present high level of pollution is largely attributed to outside sources from the neighbouring districts. It is concluded that even if the pollution levels will be brought down to some extent, controlling only local sources in Beijing will not be sufficient to attain the air quality goal set for the Olympics. The only possible solution is the regional air quality management on urgent basis.

1.4 Studies from India

In developing countries the growth of both industrial and residential areas is unplanned, unstructured and un-zoned. This leads to housing being built alongside factories and industries, increasing the risk of industrial accidents. Rapid and unplanned development often results in growing levels of air pollution, more pollution-related health problems, lost working days and economic dysfunction.

Sundaresan (1971) in his paper claimed that in India apart from the industries, automobiles add to the air pollution to a considerable extent, in

metropolitan and industrialised cities and that the exhaust emissions are significantly large due to low-grade fuel and defective engine performance

The Central Pollution Control Board (CPCB), Ministry of Environment and Forests, Govt. of India conducted tests in more than 1000 Vehicles (two-wheelers, three-wheelers and four-wheelers including cars and buses) in Haryana, Himachal Pradesh, Delhi and Chandigarh. Indian Institute of Petroleum has also conducted a survey on various types of vehicles in Delhi. The tests were conducted to measure the level of carbon monoxide (CO) emissions in the petrol driven vehicles and smoke density in the diesel driven vehicles (Arora, 1987).

A report by Arora (1999) revealed that the environmental pollution is concentrated primarily around the major metropolitan areas of both developed and developing countries. The report also emphasised that the rate of increase in the use of motor vehicles has been even more than the rate of general public being aware of the seriousness of the environmental pollution caused by automobiles. In most of the developing countries there is no effective legislation to control the invisible emissions and visible smokes.

Boralkar *et. al.* (1988) made a study on the lead content in vegetation during the months of October, November and December 1982. The study showed that the increased fleet of transport buses during the IX Asian Games, held between 19th November—4th December in Delhi, had increased the lead content in the plants. It was higher during the month of November when compared with October and December.

A report by Swaminathan (1990) revealed that about 60 % of pollutants were emitted by 90 million motor vehicles in 1965 in the United States and it reached 100 million mark in 1970. Exhaust by automobiles

accounted for generation of about 11,657 tons per day, as against 272 and 106 tons in the case of power plants and jet aircraft respectively.

A study conducted by Chakravarthy (1983) showed that concentration of carbon monoxide in the air go up particularly during traffic jams, slow driving and idling of engines. Serious and even fatal cases of carbon monoxide poisoning may occur from automobiles being 'warmed-up' in closed garages located under the living quarters of houses. This could also happen during severe winter when the passengers are trapped in their motor vehicles for a longer duration.

According to a survey conducted by the National Environmental Engineering Research Institute, (NEERI) Nagpur, the peak hour pollution in certain localities of Calcutta exceeded even that of New York. Even pollution concentrations in a city like Madras were not far from the danger level. The study had also emphasised the need for emission control laws and improvement in technologies in improving the internal combustion engines (Arora, 1999).

A study conducted by CPCB has indicated that Indian vehicles are emitting more pollutants than the vehicles in the West. A report by Shivaji Rao (1985) showed that the density of vehicles per unit area in most of our congested cities is high. Also the maintenance of vehicles and highways is poor and fuels are adulterated. As a result the emission is very high. The paper also called for pragmatic legislative measures and their implementation. A study undertaken in Ahmedabad City on the effect of carbon monoxide exposed traffic policemen showed that the level of Carboxy haemoglobin (COHB) varied directly in proportion to ambient carbon monoxide. Occupationally exposed population like traffic policemen and shopkeepers near the busy traffic lane are more concerned with the effect of carbon monoxide in particular, and other pollutants from

automobile exhaust like oxides of nitrogen, lead in general. The study also revealed that in Nagpur city deaths occurred due to chronic non-specific lung diseases caused by smoke from diesel vehicles

A survey conducted in Delhi observed that in the Tilak Bridge area, the presence of carbon monoxide in the air is 10 times more than the permissible limit. It is reported that about 80,000 to 90,000 vehicles were added every year to Delhi's already packed roads and the two-wheelers account for 60 % of the total one million vehicles. Hardly 25 per cent of DTC buses in Delhi were found to have the ISI standards for emission of air pollutants. Further, it is noted that almost 100 per cent of cars exceeded the ISI limits.

From the analysis of air pollution levels of different cities of our country, it is concluded that the metropolitan system is gradually tending towards the poor air quality and Kolkata and Jaipur are the highest and least polluted metropolitan cities respectively. Carbon Monoxide and Sulphur Oxide content are found to be significantly increasing in cities like Mumbai, Kolkata, Durgapur, Baroda, Ahmedabad and Pune. According to extrapolation of the trend, the air pollution in our metropolitan cities will be three times more than what is today unless drastic actions are taken immediately.

Study carried at Mumbai, Delhi and Kolkata by Air Pollution division of the then CPHERI (1968 and 1969) indicated a concentration of dust in the atmosphere from two to five times greater than that of cities in Europe or North America. According to a NEERI, Nagpur study Kolkata emits a total of 1299 tones of pollutants per day, about 43 % of which are in the form of suspended particulate matter and about 35 % are in the from of carbon monoxide from about 0.3 million automobiles in the city.

A study conducted in Mumbai has shown that 1,600 tones of air pollutants are thrown every 24 hours. Total amount of Sulphur dioxide (SO_2) given out in the city is 300 tones, out of which the Chembur area accounts for 240 tones per day. A report by Singh (1990) revealed that in 2000 A.D. two stroke engines would emit 5,000 million tones of un burnt fuel as hydrocarbons (HC). In Mumbai as far back as 1978 motor vehicles spewed a daily discharge of 400 tones carbon monoxide, 38 tones hydrocarbons, 28 tones nitrogen oxides and 41 tones sulphur dioxide. Nearly 35 to 40 per cent of individuals questioned in a survey in Sion, Kurla, and Sakinaka in Mumbai complained of annoyance from traffic noise and it was cited as the chief source of nuisance in about 80 per cent of the residences surveyed (Raju, 1991).

1.5 Automobile Growth and Air Pollution in India

The pollutants in the atmosphere occur mostly as a result of human activities, high standard of living at a minimal cost. Without regard to the environment together with greater industrialization are leading to the increased concentration of atmospheric pollutant causing dangerous effect. Due to rise in modern civilization there is improvement in transportation. In the development of transport the internal combustion engines, both petrol and diesel engines, occupy a very important position. Besides increase in the numbers of vehicles in metropolitan cities like Delhi, Chennai, Kolkata, Mumbai etc, smaller district places like Kolhapur are also not far behind. Today the vehicular population of smaller cities and large towns is also increasing very rapidly making it essential to understand the vehicular trend and related air pollution in the city.

For example, the daily registration of new vehicles in Delhi varies between 370-600. This implies that approximately 150,000 to 200,000 new vehicles are added in the metropolis every year (Kathuria, 2004).

An earlier study by Central Road Research Institute (CRRI) found

that in 1996, 321 kilolitres (KL) of petrol and 101 KL of diesel was wasted everyday at 466 intersections in Delhi. Thus, by causing an annual loss of about Rs. 2,450 million at 1996 prices (Hindustan Times, 14.1.1999). A simple solution that would minimise this loss is by proper synchronization of traffic signals.

According to MoEF, GOI Bharat Stage II emission norms for 2 and 3 Wheelers were to come into force in the entire country from 2005. It was also estimated that there were about 60 Million vehicles in 2002 and each year about 0.5 million new vehicles were added. Based on the vehicles sale data, the year wise vintage percentage of population of the vehicles was as follows:

- 1971-1991 33%
- 1991-1996 21%
- 1996-2000 29%
- 2000-2001 08%
- 2001-2002 09%

This clearly showed that a larger proportion of vehicles were of older vintage and therefore majority of them contributed to vehicular air pollution. Today the number of vehicles in smaller cities like Kolhapur is also increasing rapidly, making it essential to study the trend in the city and the resultant air pollution.

In the past few decades India has seen tremendous growth in various sectors of economy. The progress in industrial sector marked by establishment of new refineries, petrochemical industries and other industrial units has further nourished the transportation sector. Transportation sector being one of the key areas of any industrial and economic growth, it is reflected in multiplying of transport vehicles which are in diverse designs and for applications. If the present trend continues, It is obvious that national growth will continue and will need increasing

number of specialised vehicles and increasing amount of fuel, industrial chemicals, plastic, metals, dyes, adhesives and countless other products, which will continuously pollute the air. Today as it is the urban population is choked with combined onslaught of smoke spewing industries and automobiles.

Automobile pollution today is posing a serious problem, especially in metropolitan areas. It is the major causes of pollution in big cities in India, though they may not be as polluted as Mumbai, are not very different. This is because about 25% of the vehicles registered in the country are in Maharashtra and about 30% of these are either registered or move in Mumbai. Though the volume of vehicular traffic in our cities is not as high as compared to Western cities, high concentration of pollution is created due to old age, poor performance and non-maintenance of most of our vehicles. Narrow roads, poor geometrics, frequent traffic jams and congestion aggravate this situation.

Though central and state governments are concerned about the cost of private motoring, energy consumption, pollution, congestion and noise nothing much to curb air pollution has happened yet. During 1978-79 the amount of energy consumed in transport sector in India was as high as 31.7 % of the total energy. The vehicle population, which was around 2 million at the beginning of the 1970s, had reached the 8 million mark in 1987 and by the end of 2000 it was to touch the 10 million mark. The total quantum of freight handled by road transport, which was around 66 billion tone kilometre in 1970-71, had grown up to 211-billion tone kilometre in 1985. Similarly the passenger traffic by road, which was 169-billion passenger kilometre in 1970-71, had moved up to 657-billion passenger kilometre in 1985 (Patnakar, 1987).

The current situation, after two decades since, is expected to be much worse as there has been exponential growth in vehicular population, where as not much change in fuel quality, road condition, traffic ethics, traffic management and law enforcement. Though the number of vehicles is far less in India than in the developed countries, exhaust emissions are significantly huge due to:

(a) Low grade fuel,
(b) Defective engine performance,
(c) Poor maintenance of engines,
(d) Lack of traffic planning leading to traffic jams in cities like Mumbai, Kolkata, Delhi, Chennai etc., on account of narrow carriage ways, low speed vehicles, over aged vehicles, and
(e) Multiplicity of types of vehicles on the same road.

According to the specifications prescribed by the Indian Standards Institution, the vehicles powered by spark ignition should not emit CO exceeding 3% by volume of exhaust gases and vehicles, which have completed 5 years of life or 80,000 kilometres distance, should not emit CO exceeding 4.5 % by volume. However, findings made by the survey conducted by the Indian Institute of Petroleum indicated that a sizable number of vehicles are exceeding the limits. About 38% of two-wheelers, 53% of three-wheelers and 24%t of four-wheelers meet the limit of 3 per cent CO emission. The percentage of vehicles meeting the limit of 4.5 per cent CO emissions was two-wheelers 87 %, three-wheelers 79% and four-wheelers 41% (Anonymous, 1985).

As regards diesel driven vehicles, the ISI standards prescribed that the smoke density should not exceed the following:

1. For vehicles operating in urban areas, the smoke density shall not exceed 65 Hartridge Smoke Units (HSU) as measured by free

acceleration method, or 5.2 Bosch or 75 HSU as measured by full load method.

2. For vehicles operating in non-urban areas the smoke density shall not exceed 70 HSU as measured by free acceleration method or 5.5 Bosch or 80 HSU as measured by full load method.

However, the findings of the above mentioned tests reveal that less than 20 per cent buses meet the standard of 70 HSU regardless of location. Only 41 per cent and 23 per cent of four-wheelers, cars, monitored at various places meet the limit of 4.5 per cent and 3 per cent carbon monoxide emissions respectively.

Only 18 % cent and 12 % of diesel driven vehicles monitored at various places meet the limit of 70 and 65 HSU respectively (Varadarajan & Subramanian, 1993). Data collected from some American cities show that traffic police and automobile employees contain 30-35 mg. of lead in 100 ml. of blood in urban people and the concentration of lead in non-urban people is found to be 10-16 mg. in 100 ml. of blood. Data collected from the different cities have shown that the level of carbon monoxide in vehicles some times exceeds 100 ppm in peak hour of traffic movement. Mathur (1988) has stated one of the main pollutants- carbon monoxide could produce dizziness, lassitude, and headache and even cause death if it present in excess amounts.

Once emitted, however, much of the CO_2 will remain in the atmosphere for a very long time and after a few decades enough could build up to cause dramatic alterations in the temperature and rein fall patterns of the world (Anthony Tucker, 1988). Carbon monoxide combines with haemoglobin of the blood 210 times faster than oxygen, thus reducing the intake of oxygen. Prolonged exposures to carbon monoxides levels above 9 ppm can lead to reduce mental activity (Srinivasan *et al*, 1981).

Some studies have revealed that 60% per cent of air pollution in India is caused by the motor vehicles (Bhardwaj, 1991). The number of vehicles in 1951 it went up to 102.26 lacks in 1986 (Chand, 1990), and in that about 27.00 lacks increase in 1990 (Chatwal, 1990). Out of the total number of vehicles registered in India 20 lacks are two wheelers. Some important observations by the workers were as follows

1. By 1991-92, the vehicles in Mumbai released 1,07,000 tones of carbon monoxide and 3700 tones of hydrocarbons per year in the atmosphere.
2. 400 tones of pollutants were emitted every day in Delhi.
3. An ordinary person requires 14000-litre fresh air for breathing 21600 to 23250 times a day.
4. A car pollutes such an amount of fresh air in travelling 1000 kilometre, which is sufficient for an adult respiration.
5 A car uses as much fresh air in a minute, which is sufficient for 1135 persons to breath for a minute.

Automobiles vitiated the atmosphere in Delhi to an alarming extent. In many parts of Delhi, the concentration of poisonous gases like carbon monoxide, sulphur dioxide and nitrogen oxide were three to five times above the safety limits. An average vehicle emits 2.5 kg of pollutants per day and all the vehicles put together emit whopping 170 tones of hydrocarbons, 80 tones of nitrogen oxide and 2 tones of sulphur dioxide, not to speak of carbon monoxide and suspended particulate matter. This is where the total number of vehicles registered in Delhi was 1.075 million.

Shah and Ramprasad (1979) estimated carbon monoxide emission from automobiles in Surat. They showed that the levels of CO in the

walled city were comparable to those of other major cities in India. The air pollution due to automotive vehicle emission had assured an alarming magnitude and posed a potential threat to the very existence of a healthy life (Bandyopadhyay, 1979).

The scooters/motor cycles ownership rate in metropolitan cities is expected to increase from 102 per 1000 population at present to 393 by 2021. Considering this, the number of scooter/motor cycles is expected to be 130 million in 2021 from 1994 level of 16 million, i.e. 8 times (Anonymous, 2002). The second important air pollutant from vehicular pollution is SO_2. Table 1.2 gives concentration of SO_2 in big cities of India (Agarwal, 1997).

Table 1.2: SO_2 Concentration in some Big Cities of India

Sr. No.	City	Amount of SO_2 observed maximum in the city (µg/m3)
1	Delhi	239
2	Kanpur	292
3	Kolkata	154
4	Mumbai	456

For complete combustion, air to fuel ratio is computed as 14:5. This ratio is stoichiometric ratio. But in spark engines (using petrol), complete combustion does not take place and pollutants are produced even at stoichiometric values of air fuel ratio. This is because the spark-induced reaction is not fully propagated inside the piston chamber. In the four-stroke cycle petrol engine, as the air-fuel ratio and operating temperature are low, substantial quantities of un burnt hydrocarbon and carbon monoxide with low quantities of oxides of nitrogen are emitted.

While in diesel engine, due to high fuel-air ratio and operating temperature, the concentration of oxides of nitrogen is high in emissions. Since the diesel has low vapour pressure, the emission of the carbon particles is also very high. Two, three and four wheelers are the major contributors of the total vehicular pollution and more particularly the two stroke engine vehicles are responsible for release of large amount of pollutants (Mani 1995). Table 1.3 gives pollutant emissions depending on different type of vehicle and type of engine / fuel combinations (Arora, 1999).

Table 1.3 Vehicle Types and Emissions for Various Engine / Fuel Combinations

Engine type	Fuel type	Vehicle type	Major emissions
Otto cycle	Petrol	Cars(also buses, lorries/trucks, aircraft, motorcycles, tractors)	HC, CO, NO_x, Pb
Diesel	Diesel oil	Lorries, trucks, buses, trains, ships, tractors (also cars)	NOx, SO_x, Soot particulates
Two-Stroke cycle	Petrol	Motorcycles, outboard motors	HC, CO, NO_x, particulates
Gas turbine (jet)	Turbine	Aircraft, marine (also rail)	NO_x, particulates
Steam	Oil, coal	Marine	NOx, SO_x, particulates

It is observed that emission values increase considerably with the age of vehicle. The high emissions from most of the vehicles irrespective of their age may be due to so called adulteration of fuel with kerosene in a bid to economize the fuel costs and addition of engine oil presuming smooth running of vehicles which results in dense smokes (Venkateshwar *et al.,* 1995). Table 1.4 shows comparative emissions from petrol and diesel engines at various modes of operation in petrol and design engine vehicles (Agarwal, 1997).

Table 1.4: Comparative Emissions from Petrol and Diesel Engines

	Idling	Acceleration	Cruising	Deceleration
Petrol				
CO %	6.9	2.9	2.7	3.9
HC (ppm)	5300	1600	1000	10000
NOx (ppm)	30	1020	650	20
Aldehydes (ppm)	30	20	10	290
Diesel				
CO %	0	0.1	0	0
HC (ppm)	400	200	100	300
NOx (ppm)	60	850	240	30
Aldehydes (ppm)	10	20	10	30

Interestingly, lack of maintenance does not cause major increase in air pollution levels although there may be some increase in emissions due to improper functioning of spark plugs or carburettor. Generally, the owners correct these almost immediately since they drastically change the operating characteristics of the vehicle (Srinivasan and Subramaniam, 1979).

Out of all the four sources exhaust pipe is the major source of air pollution from automobiles and accounts for about 60 to 70 %, crankcase blow by gases account for more than 20 %, and the remaining through evaporative emissions from fuel tank and carburettors. A very small amount is also contributed by spillage losses. Nitric oxide reacts with oxygen in the air to form an equilibrium mixture of nitric and nitrous oxides (MAC5 ppm), usually known as NO_x. Not only are these compounds dangerous on their own but also they react with each other photo chemically in the sunlight to from a whole series of other unpleasant compounds such as peroxy-acetyl nitrates (PAN).

The incidence of respiratory diseases in most of the major cities in India has also increased considerably over the years. In a study of 2031 children and adults in five major cities of India, of the 1852 children tested, 51.4% had levels of lead in their blood above 10 µg/dl. The percentage of children having 10 µg/dl or higher lead levels ranged from 39.9% in Bangalore to 61.8% in Mumbai. Among the adults, 40.2% had lead levels of about 10 µg/dl (CPCB, 1999).

This changing scenario of air pollution, particularly due to vehicular exhaust, in smaller cities like Kolhapur prompted the candidate to undertake the present field study.
