Chapter I

INTRODUCTION

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CONTENT PAGE

CONTENT		PAGE
1.1.	AIR POLLUTION PROBLEM	1
1.1.1.	Air pollution as global problem	1
1.1.2.	Air pollution problem in India	5
1.1.3.	Air pollution problem in Gujarat State	7
1.1.4.	Air pollution problem in Baroda and environs (Vadodara Urban Development Authority Area - VUDA)	8
1.1.4.1.	Location	8
1.1.4.2.	Climatic conditions	9
1.1.4.3.	Sources of pollution	9
1.1.4.4.	Industrial products and major air pollutants	12
1.2.	EFFECTS OF AIR POLLUTION	16
1.2.1.	Effect on vegetation	16
1.2.2.	Effect on crop plants	16
1.2.2.2.	Effect on trees	21
1.2.2.3.	Effect on lichens	28
1.2.1.4.	Amelioration of air pollution effect	29
1.2.1.5.	Factors altering plant response to pollution	30
1.2.1.6.	Effect on animal and human health	31
1.2.1.7.	Effect on abiotic components	33
1.3.	THE PRESENT INVESTIGATION AND CHIEF OBJECTIVES	35
1.3.1.	Plan of work	35
1.3.2.	Chief objectives.	36

INTRODUCTION

1.1. AIR POLLUTION PROBLEM

The greatest single change in man's surrounding during the past century has been the ever increasing chemicalization of his environment. Although this process started off with coal-burning, home heating units, kerosene lamps, fuel oil and gas-burning house hold utilities, it remained for modern petro-chemical revolution to stamp the imprint of the chemical environment on the present generation.

Air is essential to the sense of sight, smell and hearing, and its pollution assaults the first two of these. The average adult male requires about 13.64 Kg. of air each day compared with less than 1.3 Kg. of food and about 2.05 Kg. of water. Compared with the other necessities of life, obligatory continuous consumption is a unique property of air. The insensible, intimate interpenetration of air, which courses in and out of the lungs, gives to air pollution its essential importance. It has been estimated that a man can live five weeks without food, for five days without water but only for five minutes without air.

1.1.1. Air pollution as global problem:

The relationship between the use of fossil fuel and air pollution was recognised as early as the 13th Century

(Halliday, 1961). Use of fossil fuels, in rapidly increasing quantities to satisfy the energy demands associated with industrialization, higher standard of living and urbanization, results in the discharge of pollutants (both primary and secondary) at a rate sufficient for the concentrations to reach levels considered adverse to the vegetation and public welfare.

Inspite of the early recognition, positive actions to study this problem started only after dramatic disasters. We build dam only after floods devasted various regions; water pollution abatement was initiated only after typhoid epidemic or similar impressive episodes. Necessary action to control air pollution started only after its killing action or irritating potential have been realized on a large scale, as in London Smog 1952 or pollution episode in Los Angeles around 1945 (Chambers, 1976) which directed world wide attention to the need for the preservation of the healthy quality of our air. Besides these, number of industrial calamities leading to pollution deaths and deleterious effects occured around the world (Table 1).

Destruction of local vegetation due to pollution, especially agricultural crops, fruit trees and forests which ultimately reflected in state economy, caused awareness among the industrialized countries. Even the revegetation process failed at some places due to extreme change in the

Table 1. Some of the worst industrial disasters

1	Meuse Valley, Belgium	1st Dec., 1930	60 persons and many cattles died	Chemical substance was disputed SO_2 25 to 100 mg/m^3
2	Donora, Pennysulvania	26th Oct., 1948	20 persons died	SO_2 1.4 to 5.5 mg/m^3, particulate matter was also present.
3	Poza Rica, Mexico	21st Nov., 1950	22 persons died 329 hospitalized	Hydrogen sulphide.
4	London England	5th to 9th Dec., 1952	3500 to 4000 human death (occured till Jan. 53)	4.46 mg/m^3 of smoke, 3.75 mg/m^3 of SO_2.
5	New Orleans Louisiana	1958	Increased frequency of asthma from 25 to 200 persons per day	Singly or closely grouped pollutants are likely to be involved.
6	Seveso, Italy	July, 1976	Affected 4500 acres surrounding the source. Thousands of people had to flee for their lives	Dioxin.

Table 1. contd.

7	South East, Brazil	Feb., 1984	500 persons died	Fire caused by gasoline leakage from the pipeline.
8	Mexico city	Nov., 1984	452 persons died, about 4000 were affected	Liquid gas storage tanks exploded.
9	Bhopal, India	3rd Dec., 1984	More than 2000 persons died	Methyl isocyanide.
10	Chernobyl, USSR	26th April, 1986	1000 immediate injuries, 31 deaths and 1,35,000 people evacuated from their home	Accident in nuclear Power Station, released about 7000 Kg of material containing 50 to 100 million curies of radioactive materials to the environment.

soil environment. The best examples are Copper Basin at Copper hill, Tennessee and a similar area east of Butte, Montana where due to the fumes from copper smeltters all the plants exterminated over a wide area. The area is too raw for plants to obtain an effective foot-hold and start the rebuilding process (Miller and McBride, 1975).

Today in almost all the developed and most of the developing countries special legislations have been imposed to control pollution and to study the damage caused by air pollution. It is surprisingly true that in India too we have smoke nuisance act since 1966, an act which does not seem to have any practical value (Dave, 1976). Government of India has realized the graveness of the pollution problem and has recently established a separate Department of Environment at the National level.

1.1.2. Air pollution problem in India:

Industrial transformation during the past independence period (i.e. after 1947) has put India among the first ten industrialized countries of the world. However, pollution is an evil of all development. Bhopal industrial air pollution episode should be a constant reminder about fragile industrial safety systems. world could have learnt much more from this unfortunate incident.

The data on some of the parameters of ambient air quality (SO_2, NO_x and SPM) have been collected by National Environmental Engineering Research Institute (NEERI, 1978-79, 1980-81) from cities like Delhi, Kanpur, Calcutta, Nagpur, Hyderabad, Madras, Cochin, Bombay, Ahmedabad and Jaipur with a view to assess the extent and nature of deterioration in air quality due to industrialization and urbanization. Based on this data, the Government of India appointed Expert Committee (1972). It's report was processed by the Joint Select Committee of Parliament and enacted an Air Pollution Act in 1981.

For Sulphur dioxide, Calcutta has emerged as the most polluted city followed by Bombay, Ahmedabad, Kanpur, Hyderabad, Madras, Nagpur and Jaipur in decreasing order.

Suspended particulate matter (SPM) was the highest in Delhi and Calcutta followed by Ahmedabad, Jaipur, Kanpur, Hyderabad and Nagpur and the lowest in Madras and Bombay being coastal cities. The S P M level in all the cities are much above the International levels (Khoshoo, 1986).

Automobile exhaust in India contributes 70% of carbon monoxide, 50% of hydrocarbon, 30 to 40% of particulate matter and nitrogen dioxide (Dave, 1976). In Los Angeles air borne lead readhed upto 5.7 $\mu g/m^3$ (Bibbero and Young, 1974) whereas in Ahmedabad it reached upto 14.0 $\mu g/m^3$ (Vakil,1978, Chatterjee, 1979). Eye irritation and breathing troubles are often complained by urban dwellers of metropolitan of India.

1.1.3. Air pollution in Gujarat State:

Amongst the States in India, Gujarat jumped from the 8th position in industrial development in 1960 to 2nd in 1982. These industries varies from food products, cotton textiles, rubber products, petroleum products, chemical products etc. The state has set up number of corporations to promote the industrial growth.

Some of the important corporations are Gujarat Industrial Development Corporation (GIDC), Gujarat Mineral Development Corporation (GMDC), Industrial Extension Bureau (INDEXTB) etc. Among them, GIDC is the most important which has set up 139 industrial estates at the end of January 1983, in 18 districts of the state. As many as 30% of the total industrial sheds constructed by similar organisation in the country, were in GIDC estates (Gujarat Directory of Manufactures 1980, Moraes, 1984).

Some of the important and big GIDC industrial estates are located at Naroda, Odhav, Vatva in Ahmedabad district; Nandesari, Makarpura, Gorwa in Vadodara district; Veraval, Porbandar at Junagadh district; Vapi, Gundlav, Kapilpore (Navsari), Bilimora, Umargam at Valsad district; Ankleshwar, Rajpipla at Bharuch district; Limbdi, Wadgwan city at Surendranagar district. Apart from these, industries of private sectors are also scattered all over the State.

All these industrial areas are harbouring a variety of chemical industries which increases the state economy as well as alarmingly increases the environmental pollution problem in the State.

1.1.4. Air pollution problem in Baroda and Environs (Vadodara Urban Development Authority area - VUDA):

1.1.4.1. Location:

VUDA area is situated in the central region of Gujarat State, in Western India. It lies between 21° and 23° North latitudes and 73° and 74° 10' East longitude (Fig. 2.2.2.) Baroda (Vadodara) is more or less plain area with the M.S. University Campus in the centre.

Baroda area is traversed by a number of rivers and their tributaries, which flow in the same direction because of gentle slope i.e. towards south - west. Today, with its population of more than one million and an area of 714.56 Km^2, has earned an important industrial place in Gujarat State and India (Parthasathy, 1983).

The big river Mahi, about 19 Km. northwest of Baroda city forms the western boundary of the VUDA area. The river Mini, which originates from a tank Samlaya in Savli taluka falls into Mahi after traversing about 56 Km. The area under study is drained by a few rivers and their tributaries, hence is a vast alluvial deposit of black soil and red loam. The river Vishwamitri, divides Baroda and forms separating line between black soil and red loam. Both the regions are very fertile.

1.1.4.2. Climatic conditions:

The meteorological conditions generally prevail in Baroda is given in Table 2. The monthly mean values (March, 1984 to March, 1987) of maximum and minimum temperatures along with the average windspeed, relative humidity are summarized. The south west monsoon starts in Baroda generally in early July and withdraws by the end of October. Winter begins from November and extends to February and is comparatively a pleasant part of the year. The direction of wind is from north or northeast during winter. Summer season is from March to June. May is the hottest month. The wind is mostly from southwest or south during the remaining part of the year.

1.1.4.3. Sources of pollution:

In the beginning of 20th Century, there were only a few industries like Alembic Chemicals (1907), Shri Yamuna Cotton

Table 2. Meteorological parameters observed at Baroda *

Month	Average daily temperature		Wind speed Km./hr.	Relative humidity RH(%)
	Min °C	Max °C		
March	18.9	35.4	6.4	41
April	19.6	38.3	8.2	52
May	25.9	39.5	8.5	54
June	28.1	39.0	13.6	62
July	26.1	35.2	12.4	74
August	25.4	31.9	9.7	85
September	24.8	35.0	7.3	71
October	23.2	36.5	4.1	55
November	20.3	31.8	6.3	67
December	12.1	32.0	5.2	60
January	12.5	30.2	5.4	57
February	14.0	30.5	6.0	48

* Monthly mean values from March 1984 to March, 1987.

Mills (1920) followed by the establishment of Jyoti and Sarabhai Ltd. (1943). The discovery of oil and natural gas in 1960's near Baroda (Ankleshwar, Khambat and Kalol)boosted the industrial development. Since then, many heavy industries like Gujarat Refinery (GR) and Gujarat State Fertilizers Company (GSFC) in 1965, Indian Petrochemicals (IPCL) in 1969, Gujarat Alkalies and Chemicals Ltd. (GACL) in 1978 and other industries like Petrofils and Indo Nissan Oxo Chemicals were established. These heavy chemical industries gave way to several medium and small scale industries under organised and unorganised sectors. Under organised sectors Gujarat Industrial Development Corporation (GIDC) has started three big industrial estates. One lies on the southern side,on the out skirt of the city limit, between National Highway No. 8 and the railway line, known as ' Makarpura Industrial Estate ' consisting of mostly engineering industries. Another one known as 'Gorwa Industrial Estate ' lies on the Baroda - Bajwa road, within the corporation limit. GIDC has a very big industrial complex (third) on north - west of Baroda, known as ' Nandesari Industrial Estate ' housing 209 chemical industries. IPCL and Gujarat Refinery are located south of the Nandesari estate. About 3 Kms. east to the refinery complex and between National Highway No. 8 and Baroda - Ahmedabad railway line, is located Gujarat State Fertilizer

Fig.1.1.1. Major sources of air pollution in the study area

A. Gujarat State Fertilizer Company Ltd., located on National Highway No. 8 (Baroda - Ahmedabad)

B. Nandesari Industrial Estate of Gujarat Industrial Development Corporation harbouring 209 small and medium scale chemical industries.

A

B

Company (GSFC) (Fig.1.1.1.) These industrial complexes are located about 8 to 18 Km. away from Baroda on the Northwest direction occupying an area of 20 to 22 Km^2 fertile land. (Fig.2.2.2.) The diversified industrial activities in and around Baroda, have been polluting the once clean environment at an alarming rate seriously affecting biota.

The present study was conducted in the vicinity of petro-chemical, refinery, fertilizer, alkalies and chemical complexes and Nandesari (GIDC) industrial estate, and they were taken as major sources of air pollution.

1.1.4.4. Industrial products and major air pollutants:

In Gujarat refinery, crude oil from Ankleshwar, South Gujarat, Kalol and imported crude from Gulf countries are refined. Crude oil is predominantly a complex mixture of hydrocarbons. It also contains sulphur, oxygen and nitrogen as well as traces of metals as vanadium and nickel (Parkar, 1977). The products are naphtha, propane, superior kerosene, aviation and turbine fuel, motor spirit, high speed diesel, heavy sulphur and heavy stock furnace oil. The major products naphtha and superior kerosene are supplied to IPCL, where it is processed. During the processing of crude oil, sulphur breaks down and combines with oxygen to form sulphur dioxide, hydrocarbons are the other pollutants and they escape from the chimney.

The naphtha from refinery is supplied to IPCL where it is processed. The petrochemical complex comprises of following plants.

<u>Aromatic plant</u>	<u>Products</u>
-Dimethyl tetraphthalate unit	DMT
-Xylenes unit	Paraxyle, Orthoxylene, mixed xylenes.
<u>Olefins plant</u>	
-Naphtha craker	Ethylene, Propylene
-Pyrolysis gasoline hydrogenenation unit	Ethylene oxide, Ethylene glycol
-Benzene extraction unit	Benzene
-Butadiene extraction unit	Butadine.
<u>Down stream units</u>	
-Low density polyethylene	Indothene (used as raw material for plastic materials)
-Polypropylene	Koylene (used for electrical components, moulded textile, sterilisable hospital ware, pipes etc.)
-Polybutadiene rubber	Synthetic rubber (Tyres, foot-wear, sports goods, auto-motive moulded goods)

Aromatic plant	Products
-Ethylene glycol	Monoethylene glycol (Raw material for fibre, filament yarn, film and resin)
-Linen alkyl benzene	Synthetic detergents
-Acrylonitrile	Hydrocyanic acid
-Acrylic fibre	Synthetic fibre (substitute for wool)

During the breakdown of naphtha, ethylene, ethylene-oxides with other hydrocarbons are released from flare stacks. The gaseous emission consists of oxides of sulphur, nitrogen and malodorous vapours. Most of the hydrocarbons are paraffins, napthene, benzene and acetylene. Along with them relatively small quantity of aldehydes, organic acids and particulate matter are also discharged.

The Gujarat State Fertilizer Company Ltd. (GSFC) produces fertilizers like urea, ammonium sulphate and diammonium phosphate. This industry has Oleum plant, Caprolactum plant, Melamine plant, Inert gas plant, Demineralize plant, Steam generation plant and Verge gas plant. The oleum plant with a capacity of 80 metric tonnes/day produces oleum, sulphuric acid, ammonia etc. The capacity of two sulphuric acid plants are 480 and 500 tonnes/day. The major pollutant is sulphur dioxide. Ammonia is another noxious gas manufactured and often gets leaked. Besides these, other pollutants like oxides of nitrogen, carbon monoxide, hydrocarbons, suspended particulate matters and traces of hydrogen fluoride are emitted into the atmosphere. On the southwest side of GSFC, there is a mountainous heaps of gypsum. Due to wind, the chalk like white particulate matter is carried to a long distance. This particulate matter causes considerable damage to the vegetation, animals and human health.

Gujarat Alkalies and Chemicals Limited is located between IPCL and Nandesari industrial estate, at Ranoli village. The major products are chlorine gas, sodium carbonate, sodium hydroxide, hydrochloric acid, sodium chloride etc. Chlorine is the major localized pollutant at this station.

The Nandesari industrial estate houses 209 small and medium scale industries, which are producing variety of products like pharmaceuticals, dyestuffs, petrochemicals, laboratory chemicals like acids, alkalies etc. So, the ambient air contains sulphur dioxide, nitrogen oxides, chlorine, ammonia etc., besides many organic materials like hydrocarbons including carbon monoxide, causing severe irritation in the eyes and respiratory tract as well as damaging the surrounding vegetation.

1.2 EFFECTS OF AIR POLLUTION

1.2.1. Effects on vegetation:

Although, in the long run human beings are affected and the ecosystem greatly altered in any industrial area, injury to vegetation has been one of the earliest manifestations of air pollution. Infact, plants are more sensitive to many air pollutants than man, animals and materials. So, they have long been recognised as sensitive indicators of air pollution or specific air pollutants (Guderian & Reid, 1982, Chaphekar, 1971). Both gaseous pollutants, suspspended particulate matter and aerosols bring about considerable damage to the vegetation (Middleton & Darley, 1966).

The manifestation of these damages are either subtle or visible. The former being recognised only after critical anatomical or physiological studies and by analysing growth and yield of plants. The fact that different species respond differently to air pollution as well as to various environmental factors. However, the varietal differences are often equally great (Heck and Brandt, 1977).

1.2.1.1. Effect on crop plants:

Numerous publications during the past two decades have documented injury to crop plants from different pollutants.

Sulphur dioxide is the major pollutant causing extensive damage to the vegetation (Katz, 1949, Thomas & Hendricks, 1950).

Taniyama and Sawanaka (1975) found 65% loss in rice yield near Oil refinery in Yokkaichi city. SO_2, even in low concentration can retard the growth (Bell *et al*., 1979, Marchessani and Leone, 1980) and ultimately reflects in the yield reduction. 50% reduction in dry matter was in *Phelium pratense*, when exposed to 343 $\mu g/m^{-3}$ of SO_2 for 5 weeks (Bell, 1980).

Fumigation studies with labelled sulphur revealed that absorbed SO_2 is assimilated in leaves and converted into sulphates, sulphur containing aminoacids and proteins (De Cormis, 1968a).

Sensitive plants (*Medicago sativa*) absorb more gas per unit area than the resistant ones (*Phaseolus vulgaris* and *Lolium perenne*). The greater ability to absorb SO_2 was displayed by young leaves, as compared to mature or senescent leaves. Despite their greater rate of uptake, it has been reported that young leaves are more resistant than mature or old leaves (Garsed and Read, 1977).

Garsed and Mochrie (1980) determined in *Vicia faba*, that unoxidized sulphur compounds (sulfite) enters into phloem tissue and reaches meristem and other sites of accumulation. The accumulation of such compounds in meristem could then affect morphogenesis. Higher sugar content in phloem sap inhibits sulphite oxidation.

SO_2 can alter the epidermal traits in exposed leaves of *Ricinus communis* and *Pueraria lobata* by increasing trichome density, abnormal stomata and decreasing the stomatal frequency (Yunus *et al.*, 1979, Sharma *et al.*, 1980).

Majernik and Mansfield (1972), Biscoe *et al.*, (1973) found the stomatal resistance rapidly decreased when plants were exposed to SO_2. There was increase in the transpiration rate by 32% for a single leaf in growth chamber and 23% for a field growing *Vicia faba*.

Depending on the concentration of entered SO_2, the nature of intercellular damage may be collapse of spongy and palisade parenchyma, loss of structure and deformation of chloroplast (Chen, 1984).

SO_2 induced photosynthetic reduction in *Phaseolus vulgaris* (Saxe, 1983), wheat (Pandey and Rao, 1978), *Mentha piperita* and *Arabidopsis thaliana* (Santo *et al.*, 1979) were reported . Based on SO_2 exposure resultant decrease in cell sap pH, degree of chlorophyll destruction and sulphur accummulation. Santo *et al.*, (1979)concluded *M.piperita* as resistant species and *Arabidopsis thaliana* as sensitive one.

Diminution of protein content in the SO_2 exposed plants (Rudolf & Kreeb, 1979, Godzik and Linskens, 1974) may be due to increased protein degradation or reduced protein synthesis. Corresponding with this, there are changes in free aminoacids concentration (Erickson and Dashek, 1982, Cowling and Bristow, 1979, Jager, 1975).

Rudolf and Kreeb (1979) reported that the increase in activities of enzymes like glucose-6-phosphate dehydrogenase, isocitrate dehydrogenase, alanine aminotransferase, asparagin aminotransferase and glutamate dehydrogenase can be used as indicators of low pollution levels which do not produce visible damage to plants like Medicago sativa, Vicia faba, Beta vulgaris, Nicotiana tobacum, Lycopersicum esculantum etc.

Varshney and Varshney (1984a) formed following order of sensitivity, Brassica nigra > Phaseolus radiatus > Zea mays, based on the SO_2 enhanced glutamate dehydrogenase activity.

Sexual reproduction in plants also disturbed by SO_2 exposures. Dubay and Murdy (1983a) observed that SO_2 does not affect the number of pollens transfer to stigma in Geranium carolinianum (self pollination) but inhibit the pollen germination and reduced seeds by 20%, if exposed to SO_2 immediately after pollen transfer.

Growth suppression by nitrogen dioxide exposure was reported in *Nicotiana glutinosa*, *Phaseolus vulgaris* (Taylor & Eaton, 1966), wheat (Prasad and Rao, 1979a). NO_2 inhibits the net photosynthesis (Okano *et al*., 1985, Capron and Mansfield, 1976) and reduces the chlorophyll content. Chlorophyll *a* was more prone to NO_2 than chlorophyll *b* (Prasad and Rao, 1979b).

Okano *et al*., (1985) observed in sunflower and maize plants that the reduction in photosynthetic efficiency induced by NO_2 could in part be compensated by an increase in assimilatory area, suggesting an adaptive growth response of plants to air pollution stress.

Recently air pollution caused by photochemical oxidants has produced wide spread serious damage. Taniyama *et al*., (1976) observed a considerable decrease in apparent photosynthesis in corn, rice and peanuts when exposed to ozone. They concluded that the degree of visible injury and lowered photosynthetic rate by ozone could be arranged in the following order, peanut > rice > corn plant.

Similar damage to crop by ozone pollution was observed by Agrawal *et al*., 1985a, Kress and Miller 1983, Tingey *et al*., 1976.

Exposing grape plants to hydrogen fluoride (Murray, 1984a) showed reduction in chlorophyll a , total chlorophyll and increase in fluoride content and total acid content in the berries, but there was no effect on chlorophyll b, protein content and yield.

In tomato plants, hydrogen fluoride reduced the number of pollens retained on the stigma and pollen germination (Sulzbach & Pack, 1972).

Synergistic effect of various pollutants like ozone and sulphur dioxide (Tingey et al., 1973a, 1973b, Singh & Rao, 1982, Agrawal et al., 1983, Beckerson & Hofstra, 1979), sulphur dioxide and nitrogen dioxide (Ashenden, 1979a, 1979b, Bennett et al., 1975) on crop plants were reported.

1.2.1.2. Effect on trees:

Trees appear to be less sensitive than crop plants, to most air pollutants in terms of visible injury. However, due to their perennial nature they are continuously exposed for much longer time, accumulating pollutants in toxic doses. This may induce subtle effects resulting into physiological injury, growth suppression and reduction in yield. Plants in general and trees in particular function as sinks for gaseous pollutants (Smith, 1983).

Many workers conducted general survey of forest vegetation around the pollution source, to determine the nature of break-down in the community structure (Garyson, 1956, Gordon & Gorham 1963, Suzuki et al., 1969, Harney et al., 1973, Pell & Brennan 1975, Przybylski 1974, Guderian & Kueppers 1980, McLaughlin and Braker, 1985). Air pollutants first affect the most sensitive tree species in a forest and can lead to the total destruction of their canopy.

Gordan & Gorham (1963) observed traceable damage atleast 35 Kms.,from a sinter plant in windward direction, and is estimated as severe within 19 Kms. and very severe within 9 Kms.,at Wawa, in northern Ontario. Within 1.75 Km., from the pollution source 0 to 1 species per $40m^2$ quadrat were recorded, whereas beyond 17.5 Km.,20 to 40 species per quadrat. Pinus strobus was not observed within 52.5 Kms., from the sinter plant, while Picea glauca, P.mariana and Populus tremuloids were not recorded within 26 Kms.

Guderian and Kueppers (1980) observed, as SO_2 load from industries decreases the species diversity increases. The plant species like Deschampsia flexuosa, Sambucus racemosa, Solanum dulcamara and Rhamnus frangula were found near industrial waste land. These plant communities are called " Industrio-climax communities."

In India, such vegetation survey in the polluted areas were conducted by Chaphekar (1972) near Bombay, Prasad et al., (1979) near Barauni Oil refinery, Pawar (1981) near Birla Industrial complex in Nagda area, Trivedi & Dubey (1982), Trivedi (1985), on forest species in north Betul division near Satpura Thermal Power Station, Pal (1974), Prasad (1980) and Shringi (1986). They classified the plants into sensitive, intermediate and resistant based on the visual symptoms.

Pollution impact analysis on plants near Baroda, Gujarat has been extensively studied by @Bedi, (1977), @ Cross Bell (1981), @RaviKiran and Bedi (1982), @ Vijayan and Bedi (1985), @ Neeta and Bèdi (1986), @ Sisodia and Bedi (1986), @Bedi et al.,(1982,1983), @Krishnayya and Bedi, (1986), @ Patel et al.,(1987), @Bell and Bedi,(1983, 1985).

Many workers (Garsed et al., 1969, Connor et al., 1974, Chaphekar & Karbhari 1974, Dochinger and Jensen 1975, Constantinidou et al., 1976, Garsed and Rutter, 1984, attempted to determine the sulphur dioxide resistant tree species by fumigation experiments, on the basis of foliar injury, degree of damage to root, shoot growth, dry matter accumulation and sulphur accumulation in foliar tissues.

@ References cited are presented in the Page No. 333 - 335

Garsed *et al*., (1969) concluded that the broad leaves species (*Betula pendula*, *B. pubescens*, *Quercus robur* and *Acer pseudoplatanus*) are more tolerant to long term SO_2 exposure than *Pinus sylvestris*.

Connor *et al*., (1974) reported *Eucalyptus* as most sensitive and *Casuarina* species as resistant one, when exposed for 1 ppm of SO_2 for 3 hrs.

According to Constantinidou *et al*., (1976) the extreme sensitivity to SO_2 of pine seedlings in the cotyledon stage, suggests that their exposure to continuous fumigation in the field, even at low dosage may adversely influence seedling development and regeneration of pine community.

SO_2 effect on stomata is important in the process of predicting SO_2 resistance e.g. in Hawaii, mature *Metrosideros collina* leaves which closed stoma during a volcanic erruption excluded the volcanic SO_2 and thus stomatal response played a role in allowing this tree to withstand SO_2 concentration of more than 100 ppm (Winner & Mooney, 1980a).

In deciduous woody plants like *Quercus petraea*, SO_2 reduced the stomatal resistance and enhanced the SO_2 uptake (Williams *et al*., 1971, Ricks and Williams, 1974).

The deposition of particulate matter on Oak leaves decreased with increasing distance from the pollution source.

The accumulation of particles on the surface of the leaves interferred with normal stomatal behaviour resulting in high level of SO_2 accumulation in the leaf that induces degradation of chlorophyll and bring about the early senescence of leaves in the vicinity of source (Williams et al., 1971).

The air pollution caused, abnormalities in stomata, reduced stomatal frequency and increased the trichome density in *Trifolium repens* (Sharma and Butler, 1973) and *Psidium guajava* (Yunus & Ahmad, 1979).

Riding and Percy (1985) noted that SO_2 exposure delayed the wax deposition in elongating needles of *Pinus strobus* in the epistomatal chamber. This leads to increased wettability of needle and potentially increasing their sensitivity to SO_2 and acid rain, but no alteration in wax deposition was evident on needles of *Pinus banksiana* even under acute SO_2 dose.

In an effort to predict the SO_2 sensitivity of deciduous shrubs, evergreen shrubs (Winner & Mooney, 1980) and broad leaved trees (Winner et al., 1982) photosynthetic rate and stomatal conductance values were observed.

SO_2 induced chlorophyll reduction was observed in Quercus petraea (Ricks and Williams, 1975), Adina cordifolia, Buchnania lanzan, Diospyros melanoxylon (Dubey et al., 1982). Chlorophyll a degradation was high in comparison to chlorophyll b.

Murray (1984b) reported the response of three species of Eucalyptus to SO_2, differs in degree of damage although all are sensitive to SO_2.

Many workers (Roberts 1974, Farrar et al., 1977, Keller 1981, Boiko et al., 1985, Landolt & Keller, 1985) considered the SO_2 absorption by the leaves and accumulation of sulphur in the foliar tissues of exposed trees, as the scale of sensitivity.

Roberts (1974) observed Betula papyrifera, Acer rubrum absorbed more SO_2 per unit area from atmosphere than Fraxinus americana and Rhododendron maximum.

Farrar et al., (1977) correlated the sulphur content in needles of Pinus sylvestris with its distribution and atmospheric SO_2 level. The level of needle sulphur rising from 1.5 to 2.0 mg/g^{-1} needle dry wt., in 10 Km^2, showing a high occurence and 3.0 to 4.0 mg/g^{-1} sulphur in 1 Km^2 from source with a low occurence of trees.

SO_2 induced changes in aminoacids was observed in needles of pine (Malhotra & Sarkar, 1979), spruce seedlings (Jager, 1977).

The changes in organic acids like quinic acid, shikimic acid and syringic acid were also observed in SO_2 exposed Pinus banksiana needles (Sarkar & Malhotra, 1979). He concluded that malate dehydrogenase activity declined 50% before the visible symptoms appear.

According to Horsman and Wellburn (1977) the plants originated in the high annual mean SO_2 area are less affected by SO_2 exposure than plants from low mean SO_2 area.

Grill et al., (1979, 1982) reported toxicity of low concentration of SO_2, increased glutathione content significantly, eventhough it constitute less than 1% of the total sulphur.

The evolution of ethylene in the SO_2 exposed needles of spruce was noted by Helmut et al.,(1979) and in pine seedlings by Thomas & Kozlowski (1982). It may induce the early senescence of leaves in SO_2 exposed plants.

SO_2 inhibition of pollen germination and pollen tube elongation in invitro and invivo conditions, were observed in different tree species (Murdy, 1979, Hedwig, 1982; Dubey and Murdy, 1983b).

Murdy (1979) noted that the plants _Lipidium virginicum_ from copper basin of Tennessee (USA) are tolerant to SO_2 fumigation in respect to sexual reproduction than the plants from outside the copper basin.

Similar to sulphur dioxide, ozone is also causing considerable abnormalities in the plant metabolism even at low concentration (Dugger and Palmer, 1969; Barnes, 1972, Kress _et al._, 1982a).

Synergistic effects of ozone and sulphur dioxide were determined in _Liriodendron tulifera_ (Jensen, 1985, Chappelka _et al._, 1985), _Plantanus occidentalis_ (Kress _et al._, 1982b), _Abies_, _Acer_, _Betula_, _Pinus_, _Prunus_ (Elkiey _et al._, 1982) _Pinus taeda_ (Kress _et al._, 1982 c). In all the studies the growth suppression was significantly more in ozone + sulphur dioxide treatment than single pollutant effect added together.

1.2.1.3. _Effect on lichens_:

Epiphytic lichens are very sensitive to air pollution. Haksworth and Rose (1970), Leblanc _et al._, (1972) used the distribution of different species of lichens as a quantitative scale for the estimation of pollution in England and Sudbury, Ontario respectively.

Leblanc and Sloover (1970) and Leblanc et al.,(1974) conducted survey on epiphytic lichens at Montreal and Murdochville coppermine area, Quebec to determine the Index of Atmospheric Purity (IAP value) of different species. Based on this IAP value they divided the area of these cities into five isotoxic pollution zones.

Depending on the concentration of pollution the epiphytes showed a range of symptoms like detachment from its substrate, cracks appearing on the outer surface of the thalli, reduction in number of isidia and biomass value and progressive loss of chlorophyll (Leblanc et al., 1976)

1.2.1.4. Amelioration of air pollution effect:

Recently investigators have been attempting to reduce the pollution effect on plants by treating with different nutrients or antidote chemical sprays.

To achieve a significant improvement in SO_2 affected plants, researchers employed urea spray on wheat (Pandey, 1982), potassium ascorbate spray on *Vicia faba* (Nandi et al., 1981), sodium benzoate on *Vigna sinensis* (Rao et al.,1985) and paclobutrazol on *Phaseolus vulgaris* (Lee et al., 1985). They have been found to be highly potent protectant against SO_2 induced injury to plants.

Jager and Klein (1976), Cowling and Lockyer (1978), Ayazloo *et al*., (1980) attempted different nutrient treatments by various doses of sulphur and nitrogen.

Klein and Jager (1976) observed that nitrogen supply as ammonia increased the susceptibility of plant to SO_2 than the nitrate supplied ones. Decreased sulphur nutrition considerably delayed the beginning of SO_2 injury.

Siegel (1962) used a variety of oxidation inhibiting or reducing substances (IAA, Tryptophan, Dinitro pyridine nucleotide) to protect the cucumber seedlings against acute ozone exposure.

Olszyk and Tingey (1984) sprayed Fusicoccin, a myco-toxin (which affects membrane transport properties) before exposing the pea and tomato plants to SO_2 and O_3. It increased the SO_2 injury in tomato and reduced the O_3 injury to pea plants.

Calcium hydroxide spray effectively reduced the hydrogen fluoride damage to plants (Pandey and Rao, 1980, 1981).

1.2.1.5. Factors altering plant response to pollution:

It is well known that all environmental factors like temperature, light, humidity, wind, water, soil characters etc., may alter the plant response to pollution stress

(Heck and Brandt, 1977). Horsman *et al.*, 1978 have shown a wide range of genotypic variability in response to air pollution within a population of rye grass.

Norby and Kozlowski (1981) observed that seedlings of *Betula papyrifera*, *Pinus resinosa* and *Fraxnus pennsylvanica* absorbed more SO_2 at 30°C exposure than at 12°C.

The uptake of SO_2 by rice plants was more in higher wind velocity, upto 2m/sec., and in the range of 2 to 5m/sec., no apparent differences in absorbtion was observed (Matsuoka, 1978).

The role of temperature in the susceptibility of plants to SO_2 was observed by Norby and Kozlowski 1981, Shanklin and Kozlowski, 1984. Noland & Kozlowski (1979) reported the sulphur uptake of fumigated *Ulnus americana* seedlings depended on stomatal aperture and was much higher in light than in dark.

Ozone injury to tobacco and pinto beans increased with increasing humidity (Harry and Robery, 1969; Kobriger and Tibbitts, 1985).

1.2.2. Effect on animal and human health:

Air pollutants are primary agents of respiratory ailments (Southwick, 1976). Sulphur dioxide is an irritating gas for upper respiratory tract and throat. In higher concentration it causes mortality associated with congestion and haemorrhage of the lungs, pulmonary edema, thickening of inter-alveolar septa.

Number of occupational syndromes and pathological entities attributed to nitrogen dioxide have been described as Silo filler's disease and bronchiolitis obliterans (Goldsmith and Friberg, 1977).

The oxidants like ozone and Peroxy acetyl nitrate are capable of causing death, if present in sufficient concentration. At sublethal concentration they produce eye irritation.

Carbon monoxide is an odourless and colourless gas and evokes no potent warnings before actual poisioning occurs. It reacts with haemoglobin to form carboxy haemoglobin. It has more affinity to combine with haemoglobin than oxygen molecules and has less affinity to dissociate. The symptoms are headache, dizziness, flickering before the eyes, nausea, vomitting, muscular weakness, unconsciousness and death.

Asbestos causes pulmonary lesions associated with asbestos inhalation. The diseases are fibrosis or asbestosis, carcinoma and mesothelioma (Goldsmith and Friberg, 1977).

Fluoride generally affects the livestock, ingesting fluoride rich forage. The effects are abnormal calcification of bones (hyperostoses) and tooth structures (fluorosis) owing to a large increase in fluoride in these structures. Animals lose weight, acquire a stiff posture, become lame, hair coat becomes rough and milk production also decreases (Shupe et al., 1955, Phillips and Suttie, 1960).

1.2.3. Effect on abiotic components:

Air pollution damages generally all sorts of things like metal, paper, leather, rubber, textiles etc. (Table 3). Some monuments of antiquity, thousands of pieces of sculpture and carvings on historic buildings and cathedrals show vivid evidence of the insidious effects of polluted atmosphere. Taj Mahal is an important example, which is threatended by air pollution caused by thermal power plants, Mathura refinery and local tanneries (Kapoor & Gupta, 1985).

Many workers confirmed that the soil acts as an important sink for different air pollutants through chemical or by microbial degradation (Abeles et al., 1971, Inman et al., 1971). The acidification of soil due to acidic gases inhibited the soil microbs, leading to an accumulation of soil organic carbon (Tsuneo et al., 1979, Agrawal et al., 1985b). SO_2 induced acidity may cause greater solubility and mobility of soil constituents, particularly phosphorus

Table 3. Effect of air pollution on economic materials
(Yocom & Upham, 1977)

Materials	Typical manifestation	Principal causative pollutant/s	Other environmental factors produce similar damage
Metals	Spoilage of surface, loss of metal tarnishing	SO_2, acidic gases	Moisture, temperature
Building materials	Discoloration, leaching weathering	SO_2, acidic gases, smoke sticky particulate	Moisture, freezing
Paint	Discoloration, softened finish	SO_2, H_2S, sticky particulate	Mositure, fungus
Leather	Powdered surface, weakening	SO_2, acidic gases	Physical wear
Paper	Embrittlement	SO_2, acidic gases	Sunlight
Textiles	Reduced tensile strength, spotting	SO_2, acidic gases	Moisture, sunlight, fungus
Dyes	Fading	NO_2, oxidants, SO_2	Sunlight, moisture
Rubber	Cracking, weakening, loss of elasticity	Oxidants, Ozone	Sunlight
Ceramics	Changed surface appearence	Acid gases, especially fluorides	Mositure

and depletion of potassium, calcium in SO_2 exposed soil. A survey conducted by Taniyama et al., 1977 near a Zinc refinery revealed the synergistic effect of soil and air pollution which killed many tree species like Prunus mume Sieb, et Zucc, P. subhirtella Miq., Quercus aliena Blume, Cryptomeria japonica D. Don. etc., near that region. It was observed that about 5000 plants of Japanese Cedar had been injured.

Abeles et al., 1971 experimentally proved that the ethylene in the atomosphere has been removed by the soil bacteria.

1.3 THE PRESENT INVESTIGATION AND CHIEF OBJECTIVES

1.3.1. Plan of work:

The investigation was conducted in the following three stages:

I. Field survey:

A. Survey of general vegetation near a fertilizer complex.

B. Study on trees growing along the National Highway No. 8 - Gradient analysis.

C. Survey of selected fruit trees viz.

Mangifera indica L. Sp. Pl. 200, 1753:
Fl. Brit. Ind. 2 : 13 (Eng. Mango;
Vern. Keri, Ambo : Family Anacardiaceae).

Manilkara hexandra (Roxb.) Dubard. in Ann. Mus. Coll. Marseille 3 : 9. f.2. 1915. Mimusops hexandra Roxb. Pl. Cor 1: 16.t. 15. 1795; Fl. Brit. Ind. 3 : 549. (Vern. Rayan, Kirni : Family Sapotaceae).

Syzygium cumini Skeels in U.S. Dept. Agri. Bur. Pl. Ind. Bull. 248 : 2. 1912. Myrtus cumini L. Sp. Pl. 471. 1953. Eugenia jambolana Lam. Encycl. 3 : 198. 1979; Fl. Brit. Ind. 2 : 499. (Eng. Jamun; Vern. Jambu, Jambhal : Family Myrtaceae).

II. Field exposure study on experimental potted plants of mango, rayan and jamun.

III. Artificial fumigation study on mango, rayan and jamun.

1.3.2. Chief objectives:

To study the response of different plant species to air pollution.

To assess the extent of damage caused by air pollution to selected fruit trees growing in pollution zone. This may form the material for the preparation of pollution map of the region.

The morphological observations and phytochemical analysis may provide an authentic data, to trace the cause of damage as well as to determine the source of pollution.

To study the variations in seasonal response of the plant species under investigation and their recovery during favourable spell in the pollution zone.

To determine damage caused by known concentration of sulphur dioxide on tree saplings and mitigating the SO_2 effect with ascorbic acid treatment under laboratory conditions.