Chapter 1

INTRODUCTION

1.1 POLLUTION - GENERAL REVIEW

Atmospheric pollution is a major problem faced by the present day human beings. It is creating drastic changes in the tranquility of the atmosphere, composition and distribution of forests, reducing the produce of agricultural lands and of aquatic ecosystems, threatening the survival of the biota and altering the global climate as a whole. It has hence become a major concern for researchers and urban planners. Pollution in a broad sense, is defined as excessive accumulation of any substance which becomes toxic to the surrounding environment. The form and nature as well as the medium of pollution differ from place to place. These are gaseous pollutants through air; pesticides, herbicides etc., through soil and organic wastes, sewage etc., through water. Besides, the transfer of pollutants from one compartment to another is also a natural phenomenon. Water pollution is caused by effluents from various industries as well as household sources. Various chemicals used in farm management increase soil pollution, affecting the micro-organisms in soil. Air pollution is due to an accumulation of aerial wastes beyond the concentrations that the atmosphere can absorb and thereby cause injury to the environment. It is getting much attention as air is needed for the oxidative process of various organisms and for the supply of carbon dioxide to the primary producers.

1.1.1 A historical perspective

Pollution is an age old problem but has gained more attention in recent times because of the necessity for a healthy survival of human beings and an increase in the awareness. Pollution of air had started with the use of fire by the primitive man. Gradually as the population started growing the needs increased and firewood was replaced by coal as an alternative. This aggravated the problem of air pollution. After the invention of steam engine, industrial revolution geared up. To run the massive industries man started exploiting fossil fuels such as coal, natural gas and petroleum, thereby, augmenting the problem and making it a major threat for his own survival.

In the history of pollution there were many episodic emissions which had caused various losses to vegetation, human beings and materials. These are listed in a chronological order. These occured because of accidental leakage and/or due to sudden climatic changes trapping the pollutants at a particular point, whereby the living organisms were threatened and property was damaged. The recent episodes such as the Bhopal tragedy, Chernobyl disaster etc. are due to human negligence and/or failure of machinery.

1.1.2 A global perspective

The problem of pollution in the developed countries received a wider attention due to the perception of people and their commitment for healthy environs. The most common pollutant damaging vegetation in all the countries is sulphur dioxide, emitted from the combustion of fossil fuels. In Czechoslovakia, GDR and Poland sulphur dioxide is the major pollutant with an annual emission between 10-12 Tg. Other pollutants like fluorides, organic compounds and heavy metals are more confined, but cause serious problems to vegetation in the vicinity of the sources. The total area of forests injured by air pollutants in all the three countries exceeds 8.94×10^5 ha. Injury ranging from slight to severe was sustained when seasonal sulphur dioxide concentration was $30 - 40\ \mu g.m^{-3}$ (Godzik, 1984). Gaseous pollutants with significant effects on vegetation in North America are ozone, sulphur dioxide and nitrogen dioxide. They are ubiquitous across the continent as a result of mobile source emissions and the increased number of power plants with high stacks. Ozone results from secondary atmospheric reactions (Heck, 1984). Sulphur dioxide is the main pollutant in China as coal furnishes over 70% of the energy (Yu Shu-Wen, 1984). In Japan sulphur dioxide, carbon monoxide, suspended particulate matter and nitrogen dioxide are the main pollutants (Furukawa, 1984). The conditions are similar in U.K., U.S.S.R. and Australia. Occurence of acid rain in European and American countries is also a well known phenomenon.

Faced with growing pollution problems and increased public concern, a number of countries over the last 15 years established national ambient air quality standards for a number of pollutants that are thought to be critical. In general these standards have not been comparable across countries because of the differing averaging times specified for the maximum allowable concentrations.

In developing countries also the consciousness for pollution control is growing and different countries in collaboration with Environmental Protection Agency (EPA, USA) are monitoring ambient air for different pollutants and making standards suited to their requirements. As majority of the industries are situated near the urban and fertile agriculture lands, the population has started feeling the pinch of industrial pollution.

1.1.3 In India

In India also the industrial revolution has altered the environmental conditions affecting the air, water, soil resources and biota. The Environment (Protection) Act 1986 received the assent of the President on 23rd May 1986. This specific piece of legislation is comprehensive in nature, and its effects have an economy - wide significance. Partial variability is a strength of Indian pollution standards (Pachauri, 1986). The Central Pollution Control Board with the help of National Environmental and Engineering Research

Institute and National Institute of Occupational Health, is monitoring the atmospheric pollutants in different cities, keeping a regular vigil. In addition to this various State Pollution Control Boards are also assisting in monitoring ambient air quality. The interest for a cleaner and better environment has increased after the Bhopal disaster.

This is in brief the past and present state of air pollution problem at global and national levels.

1.2 TYPES OF POLLUTANTS

Air pollutants are mainly of two types -

Primary pollutants

Emissions directly evolved from an identifiable source of pollution.

Secondary pollutants

Pollutants that result from the chemical reactions involving primary pollutants.

1.2.1 Primary pollutants

Carbon-containing gases are mainly carbon monoxide, carbon dioxide and hydrocarbons emitted during combustion process. Leakages or losses of gas or liquid fuels, solvents etc., would be direct sources of many organic compounds.

Sulphur-containing gases are principally oxides of sulphur. Although both sulphur dioxide and sulphur trioxide might be considered in this category, sulphur trioxide occurs in particulate form as sulphuric acid droplets. Hydrogen sulphide, the most reduced form of sulphur, is an occasional air contaminant; the principal source is decomposing organic material. Forest vegetation also emits hydrogen sulphide

(Stern, 1977). Ores of copper, lead, zinc, nickel and iron are often found as sulphides in minerals, containing as much as 10% or more of sulphur. This waste product combines with oxygen in the air at the higher temperature of the smelter to produce principally sulphur dioxide, which is released into the atmosphere (Treshow, 1970).

Nitrogen-containing gases are mainly group of nitric oxide and nitrogen dioxides. During combustion some of the nitrogen in the air is oxidized to nitric oxide and nitrogen dioxide. Once the gases are ejected into the atmosphere they are diluted and part of the nitric oxide is oxidized to nitrogen dioxide (Mudd & Kozlowski, 1975). Ammonia is another nitrogen-containing gas emitted from fertilizer industries.

Fluorides and Chlorides are from various metallurgical processes and also from commercial acid manufacturing and glass making units.

Particulate matter includes primarily soot, dust from cement - kilns and fertilizer plants, metal processing units and lead particulates from traffic and industrial sources. It can also come from volcanic eruptions.

1.2.2 Secondary pollutants

Ozone is mainly in urban areas and is predominantly due to automobile exhaust components.

Peroxyacetyl nitrates are formed by photochemical reactions involving the primary pollutants emitted in automobile exhaust (Mudd & Kozlowski, 1975).

Acid rain or technically acidic deposition is atmospheric precipitation that is composed of the hydrolyzed by-products from oxidized halogen, nitrogen and sulphurous substances.

Radioactive pollution is an increase in the natural background radiation arising out of human activities involving the use of naturally occuring or artificially produced radioactive substances. Main sources are production of nuclear fuel, operation of nuclear reactors, nuclear tests, peaceful use of radionucleides etc., (Jammet, 1961).

1.3 GENERAL EFFECTS OF AIR POLLUTION

Pollution effects on materials, crop productivity and changing the climatic conditions are wide-ranging.

The increase of hydroflurocarbons and other toxic chemicals which breakdown the ozone molecule, are damaging the ozone layer which protects the living organisms from harmful ultra violet radiation. The EPA (USA) is proposing to freeze and then halve the emissions of chloroflurocarbons (CFC) in the U.S. over the next decade (Crawfold, 1987).

The possible effects of acid rain, aquatic impacts are currently of greatest concern because of the sensitivity of surface waters to acidification and the known potential damages to fish and other organisms (Brady & Maloley, 1984). The composition of precipitation in China is highly influenced by fossil fuel combustion and agriculture practices (Galloway et al., 1987).

In India acid rain was first noticed in Bombay in 1974. Observations of rain at Trombay and Chembur, two adjacent suburbs of Bombay revealed rain of pH 4.5 and 4.8 respectively. Later on acid rain was also recorded from Vashi (Bombay), Delhi, Nagpur and Pune. Although harmful effects have not been recorded, we must be aware of such damages as evident in European countries (Melkania & Melkania, 1987).

The increasing carbon dioxide concentration is raising the earth's surface temperature due to green house effect. The earth is already more than 0.5°C warmer than a century ago (Schneider, 1987). The increase in carbon dioxide concentration has shown large scale shifts in precipitation which are of great significance for food production and water resource management even more so, than changes in temperature (Bradley et al., 1987). All these are some of the important climatic changes due to pollution.

1.4 THE DAMAGE AND COST CONTROL OF AIR POLLUTION

Halving the sulphur dioxide emissions in eastern U.S. would cost \$ 5 billion. Loss to materials is estimated to cost \$ 7 billion annually in U.S. Reduction of existing sulphur emissions in countries of the European Economic Community would cost \$ 4.6 to 6.7 billion per year. Damage to crops, forests and health are estimated to exceed \$ 10 billion per year. Japanese studies indicate that pollution damage to wheat and rice crop production can be as much as 30% (Anonymous, 1987). Thus, control of pollution and damages caused by pollution have a major impact on the economy.

1.5 EFFECTS ON MINERAL CYCLES

Pollutants such as S and N containing gases influence the nutrient cycling and uptake by plants which in turn effects the distribution of vegetation. Air pollutants effect the nutrient availability and distribution in the environment (Maynard et al., 1984). Decrease in forest growth is presumed to be due to acidification of the soil (Hari et al., 1986). Even though short term productivity responses are positive at low sulphur dioxide concentration greater quantity of sulphur would be introduced into the soil and on long term basis, the decreased nutrient availability to plants and decreased decomposition rates may decrease nutrient cycling rates and the productivity of the system (Lauenroth et al., 1983). In central Europe the input of acidity and many chemical elements into forest ecosystems has been increased by a factor 10 (Ulrich, 1984). Contamination of forest soils was reported by Freedman & Hutchinson (1980).

1.6 METEOROLOGICAL FACTORS AFFECTING THE IMPACT OF AIR POLLUTION

Meteorological factors such as wind, temperature, humidity etc., have a major impact on pollutant distribution at various levels. Change in any of these influences pollutant effects on plants. Some of these effects are listed here. Though each factor has its own role, it is often the **combined effect** which plays a major role. Air pollution consists of 3 phases, release of air pollutants at the source, transport & diffusion and reception of air pollutants by biotic and abiotic components. Meteorological factors have some influence on all these phases and greatest during the diffusion and transport phase.

Wind is the factor of most concern during transport and diffusion of pollutants. These are dependent on wind speed and wind direction. Wind speed will determine the travel time of a pollutant from a source to receptor and the amount of pollution dilution. The mean direction of the wind will be indicative of the direction of travel of the Pollutants (Painter, 1974). Uptake of gaseous pollutants by plants is strongly influenced by wind speed (Ashenden & Mansfield, 1977; Grace et al., 1985; Wesely & Hicks, 1977; Wesely et al., 1985).

Temperature differences create imbalancae in pressure, causing air to flow from areas of high pressure to areas of low pressure. Varying temperatures create thermal turbulence and contribute to wind variability and its effect on atmospheric stability. Thermal inversions are caused by variations in temperature (Painter, 1974). Temperature has a major impact on the effects of pollutants on plants (Norby & Kozlowski, 1980, 1981[a], Wesely et al., 1983). Changes in temperature alter the stomatal mechanism and influences the pollutant uptake by vegetation.

Radiation has a strong influence on the sensitivity of vegetation to air pollutants, especially when various radiation dependent physiological processes are considered. It heats up the surfaces and changes wind turbulence. Radiation effects stomatal function and influences size and number of developing stomata. It can be said that light conditions during plant development determine the predisposition of plants to atmospheric pollutants (Guderian, 1977).

Precipitation is the most effective scavenger of the atmosphere. Meteorological precipitation includes not only rain and drizzle, but snow and other forms of water vapour in the solid phase. Precipitation scavenges from air columns which extend to the height from which it fell. Precipitation removes the particulates and also some of the gases soluble in water.

Water vapour and humidity normally present in air is probably most important in relation to the effects of air contamination. Some undesirable pollution effects could not occur without water in either vapour or condensed form. The presence of some visibility - reducing particulates is partially dependent upon the presence of water. Increase in humidity generally enhances the pollution effect. Changes in humidity modify stomatal response to gaseous uptake (Jensen & Roberts, 1986).

Topography modifies the temperature, wind and their profiles, because of the combined effect of surface friction, radiation and drainage. The radiation and thermal properties of surface features influence the heating and cooling of the ground surface. These all in turn influence the impact of air pollution (Stern, 1977).

1.7 EFFECTS ON VEGETATION

A vast amount of literature is available on the effect of air pollution on vegetation. In the present investigation importance has been given to the recent findings, and to the impact of low concentration pollutants (augmented with peak concentrations) on vegetation. Preliminary studies conducted were mainly concerned with the visible effects such as foliar injury, reduction in growth parameters etc. The degree of damage varied with concentration, type of pollutant and duration of exposure. Studies under simulated conditions were more extensive and these results could not be correlated with field level damages. In the recent years the impact assessment of pollution has been shifted to field studies but the amount of work done is comparatively less. Here some of the important observations of earlier workers in various aspects are enlisted in both simulated and field conditions.

1.7.1 On growth

Growth of the plant is influenced to the maximum by air pollution. Reductions in various growth parameters results in the reduction of plant productivity and sometimes it leads to death of the plant. Visible injury is a common symptom shown by plants when exposed to gaseous pollutants (Andrea & Ormrod, 1986; Beckerson & Hofstra, 1979[a]; Chaphekar & Karbhari, 1974; Heagle & Heck, 1980; Heagle et al., 1983[c]; Thompson & Kats, 1978; Zech et al., 1985). Foliar injury was recorded in Petunia and Kidney bean plants exposed to ozone and PAN (Isamu et al., 1984). Annual species were more severely affected by 2.00 ppm sulphur dioxide than the perennials and extensive injury or death of plants occured in all annuals (Thompson et al., 1980). Observations from extensive regions in Europe and North America suggest that many forests may be in early stages of decline. Reduction in productivity and height occured without visible symptoms of foliar injury, is typical of tree species (Wang et al., 1986). Air pollutants caused reductions in the growth of the plant (Agrawal et al., 1983; Carlson & Bazzaz, 1982; Norby & Luxmoore, 1983). Ballantyne (1984) reported that mitochondrial damage may account for a considerable amount of pollutant induced necrosis and decreased agriculture productivity. Economic loss in production, resulting from sulphur dioxide pollution is the result of continuous process of growth reduction during the life cycle of a species. Reduced harvest is usually not the result of a single episode of elevated sulphur dioxide concentration, but rather the cumulative effect of reduced growth rate over the whole growing season. In particular, growth rate at any time will depend upon the prevailing sulphur dioxide concentration (Larry, 1982).

1.7.2 On Stomata

Uptake of gaseous pollutants is dependent on stomata. Stomatal behaviour influences the pollutant entry into plants. It varies from species to species and is highly influenced by meteorololgical factors. Absorption rates into stomates differ among cultivars and generally decreased with longer exposure. The uptake rate may depend upon the plant's capacity to maintain a continuous gradient by removing the absorbed pollutant from the absorbing medium through metabolism, translocation or chemical reactions (Hill, 1971). Pollutants may influence leaf diffusive resistance by modifying one or more of the processes that control stomatal movement. Higher humidity causes stomata to open so that more pollutants could enter. The presence of pollutants may have directly affected cell permeability to potassium ions, which is believed to be important in controlling changes in turgor (Jensen & Roberts, 1986). In both water stressed and non water stressed plants abscisic acid was a significant factor in inducing stomatal closure. This closure mainly protects from ozone injury (Tingey

& Hogsett, 1985). Ozone, sulphur dioxide or combinations of both gases all decreased stomatal conductance in short - term, low pollutant concentration exposures (Olszyk & Tingey, 1986).

1.7.3 On anatomy and permeability

Structural changes are seen in plants exposed to gaseous pollutants. Some of the adaptations such as development of epidermal hairs, thick cuticle etc., give tolerance to plants. Damages to cellular organelle can also be seen. Changes in membrane permeability influences pollutant uptake and effects the role of plasma membrane as a barrier to cell. Black et al., (1982) reported increase in reduction of epidermal - cell survival with SO_2 concentration. Uneven distribution of wax and complete collapse of spongy tissue was seen in Commelina communis leaves exposed to sulphur dioxide and nitrogen dioxide pollution (Pande & Oates, 1986). Epistomatal wax formed a contact covering over the stomata of tolerant clones, but was split longitudinally over the stomata of sensitive clones (Krause & Houston, 1983). Low concentration of sulphur dioxide and ozone brought ultrastructural changes preceeded and accompanied by decrease in photosynthetic rates. The study showed that species vary in their responses to pollutants and combinations of pollutants may give results different from those obtained with single pollutants (Eversman & Sigal, 1987).

Pollutant - induced ion leakage and increase in membrane permeability are very common in plants (Chimiklis & Heath, 1975; Dominy & Heath, 1985; Feiler, 1985; Frederick & Heath, 1970; Grace et al., 1984; Grace et al., 1985; Pearson, 1985). Sulphur dioxide + ozone mixture produced more injury than ozone alone, increasing the membrane permeability temporarily for radish and cucumber. The effect of pollutants on membrane permeability appears to offer an explanation of differences in species responses (Beckerson & Hofstra, 1980). Sulphur dioxide fumigation caused an increase in diffusate conductivity (Keller, 1986).

1.8 RESPONSE OF PLANTS TO AIR POLLUTION UNDER STRESS CONDITIONS

Plants exposed to stress conditions respond differently to air pollution. In general they become more susceptible and the injury levels are aggravated. Conidia of Botrytis suspended in dew of ozone-exposed onion plants induced significantly more lesions per square cm of leaf surface than did conidia suspended in dew from leaf of unexposed plants (Rist & Lorbeer, 1984). Preliminary evidence was provided for an enhancement of frost sensitivity by ozone which may be significant in the current wave of forest decline affecting high-altitude forests in central Europe (Brown et al., 1987). During drought stress photosynthetic capacity of needles from trees grown in the presence of sulphur dioxide decreased much more than that of trees grown in clean air (Cornic, 1987). Ozone decreased tolerance of soybeans to soil moisture stress and increased yield losses (Heggestad et al., 1985). Higher humidity apparently caused the stomata of yellow poplar to open, so that more pollutants could enter the leaves (Jensen & Roberts, 1986).

1.9 BIOCHEMICAL EFFECTS

Under field conditions pollutants occur in low concentrations with occasional peaks. Plants are continuously exposed to this stress and subtle effects of pollutants are prominent. These alter various biochemical parameters which ultimately reflects in the loss of plant productivity. There are many reports on the reduction in protein content and increase in total free amino acids (Constantinidou & Kozlowski, 1979; Malhotra & Khan, 1983; Ito et al., 1986; Zedler et al., 1986). Destruction of chlorophyll and reduction in its content was also very widely reported (Norby *et al.*, 1985; Rao & Le Blanc, 1966; Trites & Bidwell, 1987). Free radicals and their reaction products are potent inhibitors of biochemical reactions within the plant cell (Jager *et al.*, 1986). Combination of ozone and sulphur dioxide could produce increased injury from an increased plasma membrane load of oxyradicals produced during sulphur dioxide metabolism (Olszyk & Tingey, 1985[a]). Stimulation of peroxidase activity was reported in plants exposed to different pollutants (Castillo *et al.*, 1984; Ernst *et al.*, 1985; Khan & Malhotra, 1982[a]). Neither ozone nor sulphur dioxide significantly increased the levels of superoxide dismutase activity (Matters & Scandalios, 1987). Accumulation of sulphydryl compounds was seen in plants exposed to hydrogen sulphide and sulphur dioxide. The increase in sulphydryl content was greater in hydrogen sulphide exposed than the sulphur dioxide exposed plants (Maas *et al.*, 1987[b]). Increase of antioxidants was a general response to air pollution action. To detect oxidative processes glutathione is very likely the most sensitive short-term indicator followed by the less sensitive Vitamin E & C (Mehlhorn *et al.*, 1986).

Many reported the inhibition of photosynthesis by different pollutants (Heath *et al.*, 1982; Carlson, 1983[a,b]; Reich *et al.*, 1987). Sugahara (1984) reported that SO_2 and O_3 inhibited photosystems in the cells. Sulphite ion inhibits the activity of ribulose biphosphate carboxylase-oxygenase in isolated spinach chloroplasts. It shows a non-competetive inhibition pattern with respect to ribulose biphosphate and magnesium ions, but a competitive one with respect to HCO_3 (Ziegler, 1972). Photosynthetic carbon dioxide fixation in isolated pea chloroplasts, during induction was markedly inhibited by 0.4 m M sulphite (Marques & Anderson, 1986). Allocation of ^{14}C was also affected by different pollutants (Jones & Mansfield, 1982; Blum *et al.*, 1983). The membrane component of the light modulation system was more sensitive to arsenite and to sulphite in the sensitive *Pisum* cultivar nugget than in the resistant cultivar progress no. 9 (Muschinek et al., 1987). Reduction in seed weight of wheat caused by ozone were highly correlated with measured reductions in whole plant and individual leaf photosynthesis (Amundson et al., 1987).

Nitrogen dioxide assimilated by bean leaves can serve as an alternate source of nitrogen to a limited extent only (Srivastava & Ormrod, 1984). Soybeans exposed to chronic levels of ozone showed a linear decrease in biomass with increasing concentration. The alteration in the sterol content may affect the membrane structure leading to plant damage (Grunwald & Endress, 1985). Treatment of the seedlings with vanadium, nickel or with sulphur dioxide resulted in reduced biosynthesis of polar lipids (Khan & Malhotra, 1987). Exposure to ozone resulted in a depletion of the cell's energy reserves as sustained by changes observed in processes which both utilize and generate ATP (Heath, 1984).

Forest trees exposed upto 0.225 ppm sulphur dioxide for several weeks showed a dramatic rise of ethylene evolution during the first few days of fumigation before symptoms got visible (Bucher, 1978). Ethylene production increased in response to ozone exposure with a greater average increase in sensitive cultivars (Dijak & Ormrod, 1982). Hydrogen sulphide evolution was found in tomato and pine plants in protection against high concentration of cysteine, sulphur dioxide and other sulphur compounds. The function of emission is to maintain safe reductor and carrier balance and to buffer cell's thiol concentration (Staszewaski, 1985).

1.10 AIR POLLUTION vs PLANT DISEASES

Air pollution together with climate and soil reactions, might well provide one more enviornmental component influencing the development of plant diseases. Pollutants have greater effect on the host, modifying its physiology, weakening it and rendering it more susceptible to infection. Further, more pollutants may injure host leaf or fruit tissues causing necrotic lesions that would provide courts of entry for certain pathogens, thereby enhancing infection and disease development. Conversely the presence of some diseases might modify the plant sensitivity to pollutant also (Mudd & Kozlowski, 1975).

1.11 VEGETATION AS A SINK FOR POLLUTANTS

Plants being stationary are continuously exposed to air pollutants. During the photosynthetic and respiratory processes pollutants are absorbed along with CO_2 and O_2. Thus plants absorb some of the pollutants and scavenge the environment to a certain extent. This uptake varies from plant to plant and those having tolerance can act as efficient bio-sinks for gaseous contaminants. Garsed (1984) reported that exposure of foliage to atmospheric pollutants normally results in an increase in the concentration of the constituent element in plants. Norby & Kozlowski (1983) concluded that uptake of SO_2 by fumigated seedlings would be equal to the difference in sulphur concentration of leaves of fumigated and unfumigated seedlings. Bytnerowicz et al., (1987[a]) reported dry deposition of nitrate and ammonium ions on plant canopy. Uptake of metabolized pollutants such as certain sulphur and nitrogen dioxides, is related with rate of plant metabolism and is highly influenced, of course, by ventilation of the canopy and the state of the plants and plant parts. Light exposure should affect plant's uptake rates. The steady state absorption rate depends upon the plant's capacity to metabolize, translocate, or otherwise remove active pollutant solutes from the absorbing medium (Mudd & Kozlowski, 1975). The removal rates for ozone are greatest to lush vegetation and less to water-stressed vegetation (Wesely, 1983). Leaf conductance to ozone is dependent on cultivar, age of cultivar and on ozone flux (Amiro & Gillespie, 1985).

Sulphur concentration and deposition rate gradients indicate that forest is providing a net sink for sulphur pollutants during period with foliage (Vandenberg & Knoerr, 1985). Deposition of different constituents at forest edge is significantly enhanced compared to closed forest (Hasselrot & Grennfelt, 1987). The sulphur content from the high ambient sulphur dioxide site suggests that all species tested were capable of filtering some sulphur dioxide from the atmosphere, with the foliage being the most effective sorptive tissue (Roberts & Schnipke, 1983). It has been suggested that carbonyl sulphide represents the major form of atmospheric sulphur and vegetation may be the global sink for the gas as compared to soil (Brown & Bell, 1986).

1.12 PLANT RESPONSE TO

1.12.1 Mitigation

Mitigation of air pollution damage to plants is getting wider attention as the plant productivity losses are increasing. With the supply of nutrients or any reductants pollutant injury can be minimised. The effect of sulphur dioxide pollution on chlorophyll and biomass accumulation has been mitigated by urea spray (Pandey, 1982). A supposition is advanced that one of the sides of dimethyl sulphoxide protective mechanism is in some way associated with the preparation ability to decrease the functional activity of cells against a background, of which a damaging effect of sulphur dioxide is manifested later (Popovicheva & Grodzinklii, 1985). Treatment with ethylene diurea treatment reduced the appearance of ozone-induced symptoms on the foliage of red maple, honey locust and pin oak (Roberts _et al._, 1985).

1.12.2 Resistance

Resistance of a plant against stress conditions depends on its ability to cope up with the changing conditions. Adaptations for a better survival vary from species to species. They may be anatomical, biochemical or genetic. The tolerance against the very low overall background level of toxic elements may be connected with the turnover of proteins, which is characteristic feature of all living cells (Ulrich, 1984). The resistance may be due to a genetic factor which could limit the gas exchange potential of the insensitive varieties, thereby reducing diffusion into the leaf, the second is a genetically controlled biochemical reaction to inactive the ozone after diffusion into the leaf (Elkiey & Ormrod, 1981[b]). Differences in the sensitivity of cultivars is due to their relative ability to detoxify exogenous sulphite. More sulphite accumulated in the leaves of sensitive cultivar than in those of the insensitive (Alscher et al., 1987). Metabolic pathways for sulphur dioxide detoxification involve both photo-oxidation yielding free radicals and photo-reduction of sulphite to hydrogen sulphide (Olszyk & Tingey, 1985[b]). In six spinach cultivars, two cultivars having tolerance to ozone were found to have higher ascorbate and glutathione content than the other cultivars (Tanaka et al., 1985). Acute doses of sulphur dioxide increased stomatal resistance in tolerant but not in sensitive species (Ayazloo et al., 1982). Tolerance in grass populations may evolve within 17 to 25 years (Ayazloo & Bell, 1981). Ernst et al., (1983) reported that a long-term exposure of organisms to heavy metals will influence the genetic structure of populations.

1.12.3 Low concentrations of pollutants

Mixture of low concentrations of pollutants have major influence on the subtle changes in plants. These changes alter plant metabolism and often lead to loss in productivity. Pretreatment with sub-acute levels of sulphur dioxide can significantly alter a plant's response to ozone or a mixture of sulphur dioxide/ozone, the change in response being sensitive to the pretreatment of sulphur dioxide dosage (Hofstra & Beckerson, 1981). The results suggest that sulphur dioxide-induced injury is potentiated by the presence of nitrogen dioxide, and indicates the importance for consideration of combined polluted concentration when attempting to set standards for air quality criteria (Carlson, 1983[b]). Plants exposed to sulphur dioxide and nitrogen dioxide showed that the effects are greater when applied together than would be predicted from individual effects (Pande & Mansfield, 1985).

The review of literature presented gives a clear description of various pollutants, their effects and meteorological factors influencing the pollution damage. Various reductions reported indicate the impact of air pollutants on plant productivity. Biochemical and ultrastructural changes reveal the subtle effects of pollutants on plants. Various explanations were given for the differential response of plants to air pollutants in yield losses, tolerance mechanisms and scavenging capacity. These studies have been taken as the base for the present investigation.

1.13 OBJECTIVES

Previous work in the field has mainly been through experiments carried out under simulated conditions. In recent years greater emphasis has been given to field studies. Some of the findings (as mentioned earlier) contradict the earlier observations in damage assessment. For example, some of the in vitro studies reported significantly less damage to plants than those of the field studies, although the concentrations of the pollutants were much higher. There was thus no satisfactory explanation for the heavy loss in yield under field conditions.

Some workers (Guderian, 1977; Ormrod, 1982; Freer-smith, 1984) suggested that a possible explanation for this phenomenon has been the occurence of peaks in the prevailing concentrations and interactions between the pollutants. However, the literature on this aspect is scanty and the evidences are not strongly confirmatory.

Response of tree species to pollutants in vivo is not very well documented. Some studies were conducted in vitro using tree saplings and these observations cannot be correlated to assess the damage to plants growing in the vicinity of industries. Though some reports are available from the European and American continents literature on tropical tree species is meagre.

Several biochemical mechanisms were offered as explanations for the resistance shown by plants to air pollution. However, the parameters of these studies were isolated; there is hardly any study looking at all the mechanisms as a whole. Further there have been no attempts to link the damages and the capacity of plants to scavenge the pollutants.

The present work is an attempt to fill some of these gaps by looking at all the parameters as a comprehensive whole. An attempt is also made to relate the parameters to the scavenging capacity and to study the efficiency of some ameliorating agents in mitigating pollution damage.

1.14 APPROACH FOR ACHIEVING THE OBJECTIVES

The area chosen for study has been the Vadodara Urban Development Area which has different localities with a wide range of pollutants in concentration as well as in number. A locality having high concentrations of pollutants has been taken for the general vegetation survey to assess the damage on herb, shrub and tree species in their distribution and diversity. Three tree species having different responses have been taken for a detail study. Two types of species - deciduous and evergreen are taken for a better comparison. Of the two deciduous species, one is a faster growing. The rates of recovery during lag phases of pollution have been compared for the two species.

Various biochemical parameters which were already used as markers under different conditions for different species have been studied to test the tree species sensitivity/resistance against air pollution. Growth and yield studies have been carried out to assess the damage on tropical tree species. Sulphur in the plant tissues has been estimated to see the capacity to scavenge the air contaminants and to correlate the accumulation with ambient concentrations.

Saplings of all the three tree species have been exposed to different field conditions. Saplings have been obtained from nursery of State Forest Department from the same lot for uniformity and same cultural practices have been maintained. Various growth studies and pollutant accumulation have been studied to assess the damage.

Saplings have been exposed to sulphur dioxide _in_ _vitro_ and ascorbic acid has been used as mitigating agent to study the affect in counteracting the damage.

TABLE - 1 : SOME OF THE MAJOR AIR POLLUTION EPISODES

Location	Year	Climatic conditions	Sources of pollutants	Pollutants	Effects
Donara U.S.A.	Oct., 1948	Anticyclonic weather, temp. inversion	Highly industrialized areas including steel and zinc plants	SO_x with particulates	17 persons died, and few 1000's were effected.
Poza Rica Mexico	Nov., 1950	--	Accidental mishandling of natural gas processing machinery	Accidental spillage of H_2S	22 persons died, and 320 effected.
London U.K.	Dec., 1952	Anti-cyclonic weather, temp. inversion, Fog, Low Temp.	House-hold coal burning etc.	SO_x and solid matter in coal smoke	4000 persons died and many 100's were effected.
Bhopal India	Dec., 1984	Winter	Union Carbide Industry	Methyl Isocyanate	More than 2000 persons died, and 30000 effected.
Chernobyl U.S.S.R.	Apr., 1986	Strong wind currents	Nuclear plant	Radio-active emissions Volatile cesium, iodine 131	31 persons died, and 1000's were immediately effected.