Chapter 1

INTRODUCTION

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1.1 ENVIRONMENTAL POLLUTION

The environment we live in is a composite structure of various components. Everything on and around the earth, the soil, the sky, the water, the solar radiation, the finest particles of minerals and every living and even dead organism is an integral unit of our ecosystem. The fact to understand is that everything on earth is interwoven, linked and shared. It is a fantastic story of natural cooperation, connection, interdependence, evolution and survival now under the shadow of disruption.

Air is essential for life on earth and preservation of its quality is a matter of utmost concern. A human living can survive in absence of food and water for sometime but not without air even for few minutes. He inhales about 13.5 Kg of air per day with 1.35 Kg of food and 2.0 Kg of water. The normal air is a mixture of various gases; Nitrogen (78.09%), Oxygen (20.9%), Argon (0.9%), Carbon dioxide (0.03%), with traces of Methane, Ozone, Carbon monoxide, oxides of Nitrogen, noble gases and various particles.

The quality of air is gradually degrading by human activities. Mankind is in the process of conducting a major unintentional experiment of feeding back into the atmosphere, in a short span of geological time, the fossil fuels, that have slowly accumulated over the past 500 million years. Now the joining of chemical era to the age of combustion has expanded that experiment. We are in the midst of a chemical revolution in which some 65,000 commercial compounds enter our environment each year, some are proven carcinogens and many more are suspected of being so. Continuous addition of these compounds is polluting our environment.

1.2 HISTORY OF AIR POLLUTION

The history of pollution started even before the proper civilisation of man, with smoke from forest fires, volcanoes and crude heating or cooking. The discovery of energy potential of coal resulted in industrial revolution. The amount of atmospheric pollution which we endure today is partly the consequence of our living in communities where all kinds of fuel may be burnt in various processes and partly due to our voracious demand for goods manufactured with the help of heat and power. The blind economic readjustment due to industrialization and unbalanced urbanization has worsened the living conditions. In enormous number of ways the miasma of atmospheric pollution has lowered our vitality and enjoyment of life.

The increased use of coal as fuel resulted in serious smoke and gas problems in London. In 1273 British Parliament passed an act for restricted use of coal in London. In 1422 Henry V. established a taxation to oversee the use of coal in the city. But the laws were not strictly followed and the result was smog episode in London in 1952 killing about 4,000 persons in few days. After this Clean Air Act (1956) was passed by a select committee in Britain. In United States of America smoke control law was implemented in 1881. After this in 1963 Federal Clean Air Act was implemented which was later amended in 1971. The major episodes occured in pollution history are given in Table 1.

1.3 SOURCES AND TYPES OF AIR POLLUTANTS

The sources of pollution are both natural as well as anthropogenic. Natural sources include volcanoes, forest fires, etc. Anthropogenic sources are industries, automobiles, fuel burning, agricultural practices etc. Pollutants emitted from different sources can be classified in two types (a) Primary (Tebbens, 1968) and (b) Secondary (Fontan & Lopez, 1984).

1.3.1 Primary Pollutants

They are directly emitted from an identifiable source. The common primary pollutants are sulphur dioxide, hydrogen sulphide, oxides of nitrogen, ammonia, fluorides, chlorides, carbon monoxide, carbon dioxide, hydrocarbons and suspended particulate matter. The common sources of these pollutants are different industrial processes, fuel burning and oil refining.

1.3.2 Secondary Pollutants

They are formed by the reaction of two or more emitted or pre-existing chemicals in the atmosphere or by reactions of chemicals with temperature, light etc. Ozone and peroxyacetyl nitrate (PAN) are important secondary pollutants formed by the photochemical reactions involving primary pollutants emitted by automobile exhaust. Acid rain, smog and radioactive substances are also secondary pollutants.

1.4 EFFECTS OF AIR POLLUTION

Effects of air pollution are vast and numerous because it affects all the components (abiotic and biotic) of the ecosystem directly or indirectly. Though the components (soil, water, atmosphere and plants) are capable of absorbing the pollutants to some extent and thus serve as sinks, the effects are reflected when the concentrations of pollutants exceed the capacity of these components to change them to nontoxic compounds and their concentration goes on increasing, producing deleterious effects on the ecosystem.

1.4.1 On Abiotic Components

1.4.1.1 Climate

Air pollutants can exert notable effects on clouds, temperature and precipitation often resulting in considerable modifications in weather at local as well as at global level. The ozone layer which protects the living organism from harmful ultraviolet radiation is getting degraded by continuous addition of toxic chemicals like hydroflurocarbons. The EPA has proposed to cut down the emissions of these compounds to protect the ozone layer (Crawfold, 1987).

Combustion of coal and other fossil fuels generates two important problems viz. acid rain and CO_2 build up. Atmospheric CO_2 level has increased by about 5% during the last three decades. This build up of CO_2 led to **the green house effect** and has raised the earth's surface temperature by 0.5 °C more in the last century (Schneider, 1987). This has also affected the precipitation which influences food production and water resource management (Bradley*et al*. ,1987).

1.4.1.2 Soil

Soil is an important sink for air pollutants. Addition of pollutants to it changes its quality. Soil acidity increases through acid rain and deposition & modification of pollutants. The change in pH, percentage of porosity, water holding capacity, organic carbon, nitrogen, C/N ratio and exchangeable ions have been observed in soil of polluted areas (Maynard *et al.*, 1984). The microbial activity is slowed down which results in slow rate of decomposition of organic matter and mineralisation process. These changes subsequently lead to changes in the distribution, density and diversity of plant species growing in the area (Rao, 1982; Pawar & Dubey, 1980). Increased acidity of soil has also been presumed to be a factor for decrease in forest growth (Hari *et al.*, 1986).

The pollutants also affect biogeochemical cycles. N_2 and S cycles are more affected because of continuous addition of sulphur dioxide and oxides of nitrogen through various sources. These compounds are formed in normal cycling also but at transitory steps. Continuous addition and inhibition of further degradation through checking of microbial activity results in imbalance in their cycles. The flora and fauna both ultimately are affected by this imbalance (Turk *et al.*, 1981).

1.4.1.3 Water

Natural water is a dilute solution of biogenic materials including nutrients, salts and gases. Because of great solvent property all nutrients supporting life are soluble in it. Gaseous pollutants dissolve in it and alter its pH. The acidification of water, causes potential damage to fish and other organisms (Brady & Maloley, 1984). Besides direct effect of air pollutants, discharge of industrial wastes also alter physical, chemical and biological properties of waste resources (Hawkes, 1982).

1.4.1.4 Metals & Materials

Corrosion of metals is very common in polluted atmosphere. Rusting of iron is accelerated by presence of SO_2, smoke or ash. Metals like Nickel, Chromium, Zinc, Copper and Silver form sulphates in presence of SO_2 and corrode rapidly (Meetham *et al.*, 1981).

Building materials are affected by atmospheric pollutants. Taj Mahal a historic monument is gradually losing its beauty due to effects caused by pollutants emitted from thermal power plant, oil refinery, many tanneries and local industries (Kapoor & Gupta, 1985). Smoke, smog and SPM strike on the surface of stones, bricks, paints and glass which get corroded and disfigured.

1.4.2 On Biotic Components

1.4.2.1 Human health

Air pollution effects on human health were previously studied only in serious or acute pollution conditions, but now greater attention has been paid to know the effects even in mild or low doses, because the prolonged exposures result in chronic effects. Eyes, nose, throat and lungs are the common organs affected by different pollutants. Headache, shortness of breath, irritation in eyes, nose, itching of skin and nausea are caused by presence of pollutants in the atmosphere.

1.4.2.2 Animals

Animals may be expected in general to suffer similarly as human beings. Cattles are found to be less resistant than sheep and pigs. Fluorosis is very common in animals grazing in fluoride accumulated fields. Molybdenum accumulation near furnaces has been reported to cause death of animals (Meetham *et al.*, 1981).

1.4.2.3 Vegetation

The earliest recorded air pollution damage to vegetation was by sulphur dioxide. Complete destruction of vegetation was recorded near copper smelter in Tennesse, Ducktown (Seigworth, 1943), Sudbury, Ontario (1958) etc. Continuous efforts have been made to know the type, extent and mechanism of pollutant effects on vegetation. Injury caused by pollutants to plants are of two types :

(1) Visible injury and **(2) Invisible or Subtle injury.**

Visible injury - It can be classified as acute or chronic (Heck and Brandt, 1977) and is a common symptom of pollutant exposed plants (Andrea & Ormrod, 1986; Bytnerowicz *et al.*, 1987[a] ; Muir & McCune, 1988; Peterson & Arbaugh, 1988).

a. Acute injury - appears by rapid absorption of high concentration of pollutant in a short span which results in localized death of tissues i.e. necrosis ,the pattern of which may be pollutant specific.

b. Chronic injury- appears by slow and prolonged absorption of sublethal doses of pollutant/s.

Invisible or Subtle injury - The concept of invisible injury was termed as **hidden injury** by Stoklasa (1923). It can also be termed as physiological and biochemical injury as it is the result of alteration in many physiological and biochemical processes. Previously the idea of hidden injury was not accepted because of lack of experimental support (Thomas ,1951), but later studies (Bleasdale, 1973; Bull and Mansfield, 1974; Crittenden & Read, 1978; Bell, 1980; Wang *et al.*, 1986) showed that pollutant injury can occur in absence of visible symptoms also, and now the subtle injury concept is universally accepted. The concept can be summarized in five steps : (1) a reduction of plants photosynthetic activity which is brought about either by a direct effect on the photosynthetic mechanism or by closure of stomata, (2) a build up of the pollutant or its by products within the leaf, (3) overall unhealthy appearance without necrosis, (4) reduced growth or yield in long term, (5) increased susceptibility to disease, parasite or insect invasion (Heath, 1980), and other environmental stress eg. frost and drought.

Pollutants and their symptoms in plants

Chlorosis is a very common and nonspecific symptom in plants. It is the loss or reduction and deficiency of chlorophyll. Visibly it results in pale green or pale yellow to yellow pattern. Some of the common pollutants and their specific symptoms are given in Table 2.

Studies have been conducted to record the effects of air pollutants on different plant species. Various parameters viz. morphological, growth, biochemical, productivity and yield have been studied.

i. Growth and productivity

Pollution effect on growth reduction of vegetation has been widely studied. Reduction in various growth parameters like root length, shoot length, number of tillers, inter-nodal length, leaf area, number of leaves etc. has been observed (Baker *et al.,* 1987; Goodyear & Ormrod, 1988). Reduction in agricultural productivity and yield of economically important plants has also been observed. Reduction in rye grass yield was observed under high, as well as low concentration of SO_2 (Bell, 1980). SO_2 reduced most of the growth parameters in *Mentha* and *Arabidopsis* (Santo *et al.*, 1979) tobacco and *Cucumis* (Mejstrik, 1980) and *Phaseolus* (Saxe, 1983). Yield reduction was observed in soybean & wheat (Pandey & Rao 1979; Prasad & Rao, 1982) and jowar (Boralkar & Chaphekar, 1979).

Pollutant combination exposures also reduced the growth (Freer-Smith, 1984; Elkiey *et al.*, 1988). Exposure to combination of SO_2 and NO_2 caused growth reduction in field grown plants (Ashenden & Mansfield, 1978; Pande & Mansfield, 1985). Ozone in combination with SO_2 resulted in reduced growth of egg plants (Agrawal *et al.,* 1983) beans (Sabratnam *et al.*, 1984), gram (Singh & Rao, 1982) and radish (Reinert *et al.,* 1982). Reduction in yield of potato (Pell *et al.*, 1980) sweet corn (Mandl *et al.*, 1980) and wheat (Sharma & Rao, 1983) was observed due to exposure of mixture of SO_2 and HF.

Plants growing in the vicinity of industrial complexes have shown reduction in their growth and yield with or without visible injury. Differential response of various species depending on their susceptibility was observed. Tomato, beans, potato and sweet corn showed reduction in growth and yield in industrially polluted area (Heggestad & Bennet, 1981). Similar types of responses were observed by Taniyama *et al.*,(1977), Patel *et al*.,(1977), Prasad *et al.*,(1979), Bell & Bedi (1985), etc. on different species. To measure more precisely the direct effect of air pollutants, on growth and yield of a number of agricultural crops in fields, methods involving standardized soils and cultural practices were used. Significant decrease in yield of potato, beet, lettuce and spinach ranging from 20 - 60% (as compared to control crops) were observed, in absence of visible injury at polluted zone with 100 μgm^{-3} SO_2 in the ambient air (Szalonek & Warteresiewiez ,1966 [a,b]). By reviewing results of various experiments on this line Godzik & Krupa (1982) concluded that long term, time-averaged concentrations of pollutants are of little value in relating pollutant stress and plant response, because response often depend critically on short term peak concentrations. Similar observations were recorded by L'Hirondelle *et al.* ,(1986).

Recent studies have shown that with reduction in growth and yield, air pollutants can also cause change in nutritional quality of crops. Significant decrease in protein content of seeds of soybean (96%) and pea (87%) was observed by SO_2 exposure (Sardi, 1981). Reduction in protein content of soybean seeds (Sprugel *et al.*, 1980) and starch & sugar content of potato tuber (Pell *et al.*, 1980) was recorded. Dassler and Bortitz (1988) emphasized that decreased yields and changes of constituents can occur even at low concentration of pollutants in long term exposures as is found in field conditions.

The increased importance of concept of subtle injury instigated scientists to study the mechanism of injury, most of the researches concluded that the effect is the result of many complicated processes working together. Sensitivity or tolerance of plants depend on various biochemical parameters such as turnover rate of proteins (Ulrich, 1984), ascorbic acid content (Tanaka *et al.*, 1985) or rate of pollutant accumulation (Alscher *et al.*, 1987). Jager *et al.*, (1985) suggested that formation of free radicals and their reaction products within the cell potentially inhibit the biochemical reactions. Initially each pollutant interacts biochemically with the most sensitive receptor, which ultimately is reflected in some loss of production. The ultimate response of plant depends on various factors (Treshow, 1984). The common parameters affected are:

ii. Cuticle and stomata

The cuticle and stomata are the initial receptors or targets to which pollutants ~~first~~ have to encounter first. Uptake of pollutants is greatly influenced by stomatal behaviour which again differs with species. Closing of stomata was observed due to SO_2 exposure in tobacco (Black & Unsworth, 1980) and due to $NaHSO_3$ treatment in *Vicia faba* (Kondo *et al.*, 1984). Wider opening of stomata was observed in tobacco leaves (Unsworth & Black, 1981). Exposure to mixture of pollutants create a complex situation. More closing of stomata was observed in presence of SO_2 and O_3 together, than in O_3 alone (Beckerson & Hofstra, 1979; Olszyk & Tingey, 1986). Initial closing of stomata in silver birch was followed by permanent opening in prolonged exposure to $SO_2 + NO_2$ (Mansfield & Freer-Smith, 1984). Jensen & Roberts (1986) suggested that pollutant's presence may directly affect cell permeability to potassium ions, which is important in controlling changes in turgor.

Though the main pathway of entry of pollutants is through stomata, their effects on cuticle also modify the net results. Erosion of the cuticular wax around stomata was the most obvious effect of air pollutants (Godzik & Sassen, 1978). Uneven distribution of wax and collapse of spongy tissue was seen in *Commelina communis* (Pande & Oates, 1986).

After entering, the gaseous pollutants dissolve in moist surfaces and form by products e.g. sulphur dioxide forms sulphite (SO_3^{--}) and bisulphite (HSO_3^{-}) ions. Cellular pH is influenced which produces secondary effects (Smith & Raven, 1979; Pfanz & Heber, 1986).

iii. Transpiration

Wider opening of stomata results in excessive transpiration. Severe wilting and necrosis due to enhanced rate of transpiration was observed in plants exposed to SO_2 (Mansfield & Davies, 1981; Rao & Dubey, 1988).

iv. Photosynthesis

The pollutants reduce the rate of photosynthesis (Ormrod *et al.*,1981; Krishnamurthy & Rajachidambaram, 1986; Plucinska, 1988). The reduction may be either by inhibition of enzyme activity or by degradation of chlorophyll (Ziegler, 1974; Silberstein & Galum, 1988). SO_2 induced reduction in rate of photosynthesis was observed in tobacco and blue green alga (Hallgren & Huss, 1975), spinach (Enser & Heber, 1980). Reduction due to NO_2 exposure was observed in alfalfa and oat (Hill & Bennett, 1977) and wheat (Prasad & Rao, 1982). Taniyama (1979) found decrease in apparent photosynthesis in rice and corn exposed to different pollutants singly, the extent of damage was SO_2, $O_3 > Cl_2 > NO_2 > NO$. Combination of pollutants also reduced the photosynthesis rate in *Vicia faba* (Ormrod *et al.*, 1981) in pea (Bull & Mansfield

, 1974), and in white pine (Reich *et al.*, 1987). Reduction in rate of photosynthesis reduces the biomass accumulation. Amundson *et al.*, (1987) reported significant correlation between reduction in seed weight and photosynthetic rate of wheat plant.

v. Chlorophyll

Probably the first and most widely studied biochemical parameter, since start of pollution effect studies, is chlorophyll. In their studies on lichens Rao & Le Blanc (1966) observed reduction in chlorophyll content, under SO_2 exposure and suggested that in low pH, Mg^{++} ions from chlorophyll molecules get removed and chlorophyll is converted into phaeophytin. Many workers have found reduction in chlorophyll content of pollutant exposed plant spp. (Le Blanc & Rao, 1973, Pandey & Rao, 1979; Mandl *et al.*, 1980; Bell, 1983; Pawar & Dubey, 1983; Norby *et al.*, 1985; Mendre *et al.*, 1986; Sisodia & Bedi, 1986; Ayer & Bedi, 1986; Trites & Bidwell, 1987). In most of the cases chlorophyll *a* was more sensitive than chlorophyll *b*, conversion of chlorophyll *a* to phaeophytin *a* and chlorophyll *b* to chlorophyllide *b* was suggested by Malhotra (1977).

Chlorophyll loss can occur by disruption of chloroplast structure also. Swelling of chloroplast envelope and thylakoids has been observed (Wong *et al.*, 1977).

vi. Carbohydrate pool

Carbon status of a plant plays a major role in its growth and development. Normally mature leaves produce sufficient amount of carbohydrates but in presence of pollutants the balance is disturbed, through various processes, resulting in reduction of growth and yield (Koziol, 1984). Decrease in the concentration of storage carbohydrate and increase in free carbohydrates was observed in rye grass (Cowling & Koziol, 1978; Koziol & Cowling, 1980). Decrease in carbohydrate content in leaves of *Ulmus americana* was reported by Constantinidou & Kozlowski (1979). Increase in reducing sugars and decrease in soluble sugars and starch was also observed (Koziol & Jordan, 1978; Malhotra & Sarkar, 1979). Reduction in glucose content in Kidney bean was observed by Ito *et al.* (1984[a]).

vii. Proteins and amino acids

Protein synthesis is also an important biological process. Change in this results in reduction of quantity and quality of plant products . Mostly it is altered through change in amino acid pool. SO_2 exposure can cause inter-conversion of amino acids (Jager, 1974) & decrease in protein content (Malhotra & Sarkar, 1979; Sardi, 1981; Zedler *et al.*, 1986). Ito *et al.*, (1986) observed increase in free amino acid content in kidney bean due to SO_2 +NO_2 exposure.

viii. Translocation

One factor responsible for proper growth is translocation of manufactured or synthesized food material to different parts of plant body. Reduction in transloction was observed in SO_2 exposed bean plants (Teh & Swanson, 1982). Starch accumulation in needles and reduced translocation of assimilates to roots in other pollutant exposed plants were also observed (Plucinska, 1986; Kuppers & Klumpp, 1988).

ix. Pollutant accumulation

Exposure of plants to atmospheric pollutants generally results in an increase in the concentration of the constituent element in plants (Ozone, PAN, and ethylene are non accumulative). The accumulation of pollutant depends on various factors like duration of exposure, concentration, turnover of pollutant derivatives in plants, environmental factors and individual metabolic system of a particular species/variety. (Garsed, 1984; Amiro & Gillespie, 1985). Sulphur accumulation with SO_2 exposure has been reported by many workers (Le Blanc & Rao, 1973; Pyatt, 1973; Posthmus, 1983; Addison *et al.*, 1984; Renneberg, 1984; Koziol *et al.*, 1986).

Correlation between SO_2 concentration and sulphur accumulation was found (Keller, 1981; Prasad & Rao, 1982; Vandenberg & Knoerr, 1985). Exposure to NO_2 has also been reported to increase nitrogen content of plants (Omasa *et al.*, 1984; Kondo *et al.*, 1984). In exposure to mixture of pollutants accumulation of single pollutant varies. Elkiey & Ormrod (1981) observed that when *Petunia* leaves were exposed to SO_2, NO_2 and O_3 singly or in combination, sulphur accumulation was more in SO_2 exposure alone and less in mixture of SO_2 and NO_2. No correlation between nitrogen content and NO_2 concentration was observed in mixture. Bytnerowicz *et al.*, (1987 [b]) reported dry deposition of nitrate and ammonium ions on plant canopy. Okano *et al.*, (1988) observed that the absorption of atmospheric NO_2 was primarily dependent on the size of the plants.

1.5 SOME IMPORTANT FACTORS INFLUENCING THE POLLUTION EFFECTS

1.5.1 Meteorological Factors

These factors such as wind, temperature, humidity etc. influence the effects of pollutants by modifying their dispersion. Wind speed determines the travelling span and dilution of the pollutant. Wind direction determines the pollutant dispersion path, both these factors are very important in determining effects of pollutants in field conditions (Larry, 1982).

Temperature has a great influence on air flow and therefore on dilution of pollutants. It was observed that at low temperatures, effects were more in plant species growing in polluted atmosphere (Baker *et al.*, 1986). Vertical gradient of temperature also has great influence on the motion of air pollutants. Discontinuities in thermal stabilities causes trapping of pollutants and limits the diffusion within a limited vertical height which adversely effects the ground level vegetation (Perkins, 1974).

Humidity of air is very important in relation to the effects of pollutants. It also influences atmospheric oxidation processes (Satoshi, 1986). Temperature and humidity both influence the regulation of stomatal movement and therefore pollutant uptake. Higher humidity causes wider opening of stomata and increases the pollutant uptake (Norby & Kozlowski, 1982; Jensen & Roberts, 1986).

1.5.2 Cultural Practices

The nutritional status greatly influences growth of plants. Pollution effects are also modified by these factors. Mineral deficiency may add to the deleterious effects and/or on the contrary proper fertilization may reduce the damage. Addition of fly ash in mineral deficient soil improved the growth of maize plants (Pawar & Dubey, 1986). Davison & Bailey (1982) observed that ryegrass growth was better in medium which had high nitrogen content. The use of pesticides and concomitant pollution problem has created the pesticide dilemma. The combined effect of an insecticide and herbicide indicated a loss of viability of about 60% in the pollen of the egg plant (Dubey *et al.*, 1984). Similarly Sikka & Dubey (1985) observed that growth, pigment and nucleic acid levels were reduced in 2,4-D treated maize plants. Lorenzini *et al.*, (1987) recorded antagonistic effect of few fungicides on ozone affected tobacco plants. Such factors should be considered in visualizing pollution effects, specially in case of cultivated crops/plants. Watering practices may also influence the effects. Cornic (1987) observed that photosynthetic capacity of pine needles growing in sulphur dioxide dominant atmosphere was much less under drought stress.

1.5.3 Relative Sensitivity or Tolerance of Species

The expression and extent of pollution damage on plants differ widely with pollutants as well as with the plant species, varieties, cultivars and individuals. A reduction in toxicity is dependent on type and rate of biochemical and physiological reactions. Alscher *et al.*, (1987) explained the differential sensitivity of pea leaves on account of relative ability to detoxify exogenous sulphite and this detoxification was associated with the glutathione content. Detoxification of sulphur dioxide involves photooxidation yielding free radicals and photo reduction of sulphite to hydrogen sulphide (Olszyk & Tingey, 1985). Emission of H_2S is considered as a factor responsible for tolerance in plants (Sekiya *et al.*, 1982; Tomascz, 1985). Conversion rate of more toxic sulphite to less toxic sulphate also determines the relative sensitivity (Jager *et al.*, 1985). Activity of some enzymes has also shown association with tolerance capacity (Tanaka *et al.*, 1988). Higher content of endogenously synthesized chemicals like ascorbic acid, glutathione, proteins etc. also increase plant's resistance (Ulrich, 1984; Tanaka *et al.*, 1985).

1.6 MITIGATION OF POLLUTION EFFECT

Pollution causes damage to plants which reduces growth and productivity of plants. Attempts have been made to reduce the pollution damage by different means. It was observed that change in nutrient supply of pollutants exposed plants may modify/reduce the damage (Cowling & Lockyer, 1978; Ayazloo *et al.*, 1980; Davison & Bailey, 1982). Antioxidants like ascorbic acid and its salts have also helped in minimizing the pollution effects (Freebairn & Taylor, 1960; Nandi *et al.*, 1981; Vijayan & Bedi, 1988[a]; Krishnayya & Bedi, 1988). Foliar spray of some other chemicals like calcium hydroxide, urea, fungicides could also minimize the pollution effects, (Nandi et al., 1985; Olszyk & Tingey, 1985; Singh & Rao, 1985; Lorenzini (et.al., 1987). Roberts *et al.*, (1985) observed that injection of ethylene diurea can reduce the pollution injury.

1.7 POLLUTION SCENARIO

1.7.1 Global

Presently all countries of the world are suffering from pollution problems. Though the abatement and prevention measures have been given much importance, the problem is not fully solved in developed countries and the magnitude of the pollution problem is increasing in developing and under developed countries. In Western Europe SO_2, NO_2 and O_3 are major pollutants. Annual average concentrations of SO_2 (> 0.038 ppm) and NO_2 (> 0.042 ppm) in agricultural land have caused a great economic loss in U.K., France and West Germany (Bell, 1984). In central European countries like Czechoslovakia, Poland and Germany SO_2, HF and NO_X are major pollutants. Forests of these countries have suffered a huge loss due to these pollutants (Godzik, 1984). In North America annual average concentrations of SO_2, NO_2 and O_3 recorded were 0.052 - 0.074 ppm and caused 2-5% crop loss (Heck, 1984). In Japan though through continuous efforts condition has been improved, smog problems still are serious (Furukawa, 1984). Studies have indicated that pollution damage to wheat and rice crop production can be as much as 30% (Anonymous, 1987). There is improvement in environmental status of developed countries, but even then pollution levels at some places still cause damage, specially to vegetation. Transport of pollutants from these countries has resulted in a tremendous loss to nearby countries.

1.7.2 National

The developed countries like U.S.A., U.S.S.R., U.K. and Japan have shown decline in their pollution problem by developing better safety measures through improved technology. In India due to lack of proper planning and chaotic growth of urbanization and industrialisation, devoid of concomitant investment in urban facilities and pollution control, there is a rapid increase in environmental pollution problem. Poor awareness amongst common people may be the reason for lax implementation of control methods. The Bhopal tragedy is a worst industrial disaster which occured due to the neglect of several safety factors and operating instructions resulting in leakage of highly poisonous gas (Methyl Isocyanate). The toll of death could have been reduced with proper timely instructions and remedial measures.

The rapid increase in human population of India, its increasing demands and per capita consumption has resulted into rapid industrialization and urbanization, resulting in decline in natural vegetation and forest cover. One out of ten flowering plants are under threat of extinction, 80% of the fresh water is polluted and nonpotable and most of the cities are suffering from increased load of air pollution (Singh, 1985).

A National Air Quality Monitoring Net Work (NAQMN) has been set up by National Environmental Engineering Research Institute (NEERI) in ten Indian cities. SO_2, NO_2 and SPM levels in these cities were monitored. Annual mean concentration of SO_2 exceeded 60 μgm^{-3} in Ahmedabad and Calcutta. Many times the values recorded were more than 80 μgm^{-3} for Bombay and 300 μgm^{-3} for Calcutta, Delhi, Jaipur, Kanpur and Hyderabad (Aggarwal and Sharma, 1985). In metropolitan cities autoexhaust pollution problems are serious, emission of carbon monoxide in Calcutta during rush hour is at par with that on New York, Chicago or London even though it has far fewer automobiles (Vakil, 1978). Recently ozone injury to vegetation has also been recorded at Jalandhar (Bambawale, 1986).

In order to prevent further deterioration of the environment, efforts are being made for the abatement of pollution in India. In October 1970 Government of India constituted an environmental protection committee for prevention and control of pollution. The water act in 1974 and the Air act in 1981 were passed by the Indian Parliament. In constitution of India specific provisions for protection of environment have been incorporated by constitution's 42nd ammendment act 1976 (Singh, 1985). In Environment (Protection) Act passed in 1986 various aspects have been considered viz. (1) precise standards (2) cost benefit of implication & (3) setting of local bodies to identify and measure the pollution levels locally (Pachauri, 1986). Under a legislation all the states have constituted **Air Pollution Control Boards** even with the pre-existing **Water Pollution Control Boards.** Ambient air quality standards have been formulated in the Air Act 1981. There are 49 central laws and 19 state laws that have a direct or indirect bearing on the protection of environment (Chakrabarti, 1987). Public awareness is slowly increasing, general public and various NGO agencies have started demanding pollution free environment for healthy survival.

1.7.3 State

At present Gujarat ranks second in the country in terms of industrial growth and development. Since its formation in 1960, when it was at eighth position it has made significant progress. Various government promoted and private corporations have supported the promotion and growth of industrial status in the state. GIDC (Gujarat Industrial Development Corporation), GIIC (Gujarat Industrial Investment Corporation), GSIC (Gujarat Small Industries Corporation), Industrial Extension Bureau (INDETXB) etc. are some of such corporations out of which GIDC has played a major role. It started as a small organisation with two to three estates at Naroda and presently has 170 estates spread all over the state like at Ankleshwar, Vapi, Naroda, Vatva, Halol, and in Baroda at Nandesari, Makarpura and Gorva, Kadi, Odhav, Umbergam, etc (Gujarat Directory of Manufacturers, 1986). The rapid industrialization has resulted in drastic changes in environmental conditions of the area. Ahmedabad has been reported to have serious air pollution problems. Autoexhaust pollution has caused severe health hazards in this city.

1.7.4 Baroda

Baroda has witnessed a rapid industrializaion during last three decades. Previously only a few industries like Alembic Chemicals (1907), Shri Yamuna Cotton Mills (1920), Jyoti Ltd. and Sarabhai Ltd. (1943) were present. A close net work of numerous industries was established after the discovery of oil and natural gas in 1960's at Ankleshwar, Khambat (Cambay) and Kalol near Baroda. Establishment of Gujarat Refinery (GR), Gujarat State Fertilizer Company (GSFC) in 1965, Indian Petrochemicals Ltd. (1968), Gujarat Alkalies and Chemicals Ltd. (1978) and Petrofils (1980) with three GIDC estates resulted in deterioration of environmental quality through discharge of various pollutants. The three GIDC estates are : (1). Nandesari Industrial Estate on the north-west of Baroda city and is a giant estate having 369 medium and small scale chemical industries, (2).Gorwa Industrial Estate in the north-western part of the city, (3). Makarpura Industrial Estate on southern boundary of the city having many engineering industries.

The varied industries are discharging various organic and inorganic pollutants deteriorating air, water and soil producing deleterious effects. Most of the major industries are situated on north west of the city, on a very fertile agricultural land. The area was once famous for its fruit orchards good crops and healthy vegetation. High pollution levels in this area has caused heavy damage to crops, fruit orchards and general vegetation (Patel *et al.*, 1977; Bell & Bedi, 1985).

The review of literature presented provides a good knowledge about types and effects of pollutants. Various reductions reported indicate the impact of air pollutants on plant productivity. Biochemical changes reveal the subtle effects. Various explanations were given for the differential response of plants to air pollutants in yield losses, tolerance mechanism and scavenging capacity. These studies have been taken as bases for the present investigation.

1.8 PRESENT INVESTIGATION

1.8.1 Objectives Of The Work

The present study was conducted to know the effect of different air pollutants on some common local vegetables and cash crops. In field fluctuation in concentration of pollutants greatly modifies the effects. The main aim of the study was to know the effect of combination of pollutants in field conditions and to investigate long-term effects of such conditions on plant's productivity.

Attempt was done to select more tolerant species as well as to compare the scavenging capacity of different species. To find out the higher susceptibility age of plants was also another objective of the work.

To study the effect of single pollutant under simulated conditions.

Reduction of pollutant injury is an important aspect in improving plant's ability to cope up with the stress conditions. Attempt was made to know role of some chemicals in minimizing the pollutant injury in field and simulated conditions.

1.8.2 Plan of The Work

The work was completed in following phases.

1. General survey of field grown crops was done to know the pollution status of different localities.

2. Pot exposure study was conducted to know the effect of pollutants on some selected species. Identical cultural practices were maintained at all the sites and the effects were depicted in various growth and biochemical parameters. The impact on yield of plants was also determined.

3. Effect of sulphur dioxide alone was determined by exposing plants under simulated conditions.

4. Minimization of pollution injury was attempted by using some chemicals both in field and laboratory conditions.