Chapter 1

INTRODUCTION

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INTRODUCTION

1.1 ENVIRONMENTAL POLLUTION

All organisms are constantly influenced by their biotic and abiotic surroundings i.e. environment. No organism is independent of its environment. Pollution is, degradation of water or land and provides deleterious effect on human health, plants, animals and materials. Air pollution is presence in air of chemical elements or compounds in sufficient quantity to cause injury to organisms and materials. Man breaths nearly 22,000 times a day where he needs 14 kg. of air and only 2 kg of water and 1 kg of foodstuffs per day (Singh, 1985, Misra and Tiwari 1990).

1.2 HISTORY OF AIR POLLUTION

In the earlier periods wood was the prime source of energy for cooking and industrial processes. From the beginning of the fourteen century to the early part of the twentieth century, air pollution by fossil fuel and wood burning has caused smoke nuisance and occupied the central stage especially in many industrialised areas of the world (Meetham, et al.,1981).

British Parliament passed an Act, in 1273 on smoke and gases and restricted burning of coal in London.During 1952 a worst episode occurred in London due to SO_2 and solid matter in coal smoke by which 4000 people died within a week and 8000 in other three weeks. This followed the appointment of the Beaver Commission which resulted into Great Britain's Clean Air Act of 1956. The recent episode at Bhopal due to methylisocyanate (MIC) gas leakage, Chernobyl disaster in in U.S.S.R and bursting of tanker carrying liquidified petroleum gas (L.P.G.) near Bombay caused heavy damage to biota and the environment.

1.2.1 Global Problems

Air pollution has become a serious global problem. A few enactments have been enacted by many countries to protect and improve environment.

Western Europe is highly polluted near large cities and major industrial complexes. The phytotoxic air pollutants(SO_2, NO_2 and O_3) are major occupants in Western Europe (Fowler and Cape,1982). In U.K., France and West Germany 1.3 $\times 10^6$ ha of agricultural lands are exposed to annual mean concentration of 0.038 ppm of sulphur dioxide and 0.042 ppm nitrogen dioxide respectively (Bell, 1984). In North America, the air pollutants viz., ozone, sulphur dioxide and nitrogen dioxide showed annual mean concentration of 0.052 - 0.074 ppm and crop loss 2 to 5% (Heck, 1984). The eleven European (OECD) countries estimated annual loss of \$ 5×10^8 to agriculture and the yield of perennial ryegrass. (Bell, 1984). The acid rain is a serious problem in Norway, Europe, Canada and America, where land, lakes and rivers are gradually becoming more acidic due to very low pH. Japan suffered due to environmental pollution for a long time. Now the condition has been improved because of their continuous efforts to minimise the same. Still the serious problem of smog is persisting (Furukawa,1984).

Environmental pollution is resulting in increased global temperature caused by accumulation of CO_2 (50%),chlorofluorocarbons (20%), methane (12%) nitrous oxide (7%) and other traces of gases. This is contributing to the green house effect. It is the most potential pollution effects on the global level (Schneider,1987).

1.2.2 Air Pollution Problems in India

During the past three decades public awareness and public outcry against evils of air pollution has grown considerably. India is the most progressive country among the third world nations in identifying key areas and industries of air pollution and attempting control measures.

The rapid and imbalanced industrialisation and improper urbanisation have resulted in acute pollution problems. Autoexhaust pollution in densely populated cities has added to prevailing pollution conditions. The magnitude of the problem has not been fully assessed due to lack of proper planning of industrialisation.

The attempt was made by Government of India to control air pollution. An expert committee was appointed in 1970, and in pursuance of the recommendations of Stockholm conference in 1972, parliament enacted an independent legislation namely Air Pollution Act, 1981 and Environment Act, 1986 (Chakrabarti,1987).

A National Air Quality Monitoring Network (NAQMN) has been set up by National Environmental Engineering Research Institute (NEERI) Nagpur, in ten Indian cities to monitor major air pollutants viz., sulphur dioxide, nitrogen dioxide and suspended particulate matter. The maximum annual average value of SO_2 was recorded at Calcutta (53.26 ug/m^3) followed by Ahmedabad (41.57 ug/m^3), Bombay and Cochin (33.35 ug/m^3), Delhi (31.14 ug/m^3) Hyderabad (21.8 ug/m^3), Kanpur (15.4 ug/m^3) etc. Jaipur was the cleanest city with least pollution (7.98 ug/m^3) (Dave, 1986).

With increase in economic prosperity the number of motar vehicles increased heavily causing added danger to air pollution. Automobile emissions add high amount of carbon monoxide and also hydrocarbons, particulates and oxides of nitrogen in the atmosphere. The major effect of carbon monoxide depends upon its capacity to impair oxygen transport.

1.2.3 Air pollution problems in Gujarat

Gujarat stands second industrialised and third leading urbanized state of India (Parthasarthy,1984).The ecosystem which is essential for state's environmental health is under great stress and is facing ecological disaster due to unproportional growth of industries. During the last two decades Gujarat has been finding itself on the threshold of an industrial explosion (Aggrawal,1988).

Major air polluting units in Gujarat are nine thermal power stations, fifteen cement plants, six fertilizer plants, eleven pesticide plants, one carbon black plant, an oil refinery, a petrochemical complex, three soda ash plants and two sodium cyanide plants.

Many corporations like GIDC (Gujarat Industrial Development Corporation), GIIC (Gujarat Industrial Investment Corporation), GSIC (Gujarat Small Industries Corporations) and INDETXB (Industrial Extension Bureau), have supported the industrial growth in the state. GIDC among these plays a major role in industrial development. It has now 170 industrial estates in various parts of the state (Gujarat Directory of Manufacturers, 1986).

1.2.4 Air Pollution problems in Baroda & its environs.

Baroda is situated in central Gujarat which is located in western India at 21' & 23" North latitude and 73'0" and 74'30" East longitude and 30 meters above mean sea level. (Parthasarthy, 1984,Vijayan and Bedi, 1986). The river Vishwamitri flows through the city from North to South. Baroda is one of the five most polluted regions in the country.

The industrial era in Baroda started in 1890 when a brick making factory was established. The first chemical industry named "Alembic Chemical Works Company" was started in 1907, at Baroda. In the following decades so many public and private industries and industrial estates with mixed units of chemicals, pharmaceuticals and engineering productions have developed.

The industries in Baroda region can be classified into those located within the Baroda Municipal Corporation limits and those outside it in the periphery of 10 to 15 kilometers. Alembic Chemicals, Sarabhai Chemicals, Bhavana Chemicals Limited, Patel Industrial Estate and a group of small scale industries in industrial estate at Makarpura, Pratapnagar, Gorwa are within the limit of Baroda Municipal Corporation. The chemical industries outside the BMC limits are mostly on the north-west of Baroda city & include Nandesari Industrial Estate (having 369 medium and small scale industries), Indian Petrochemicals Corporation Limited (IPCL),Gujarat State Fertilizer Complex (GSFC), Gujarat Refinery (GR),Gujarat Alkalies Chemicals Limited (GACL), Universal Dye Stuff (Parthasarthy,1984).

These industries are emitting various inorganic and organic pollutants. Inorganic gases include sulphur dioxide, oxides of nitrogen, carbon monoxide, hydrogen sulphide and ammonia. Organic vapour include hydrocarbons, ethylene, ozone, alcohols, ketones, and esters.

The tripple process of population explosion, heavy industrialisation and rapid urbanization has created an acute problem of environmental pollution i.e. Air, Water, Soil and Noise pollution endangering biota.

1.3 SOURCES AND TYPES OF POLLUTANTS

The phytotoxic atmospheric pollutants are grouped into two categories, primary and secondary pollutants (Stern,1977).

1.3.1 Primary Pollutants

These pollutants are from identifiable emission sources e.g. sulphur, halogen, nitrogen compounds and fine particulates less than 2 µg in size. They cause environmental deterioration. Noxious odours of organic sulphur compounds are the result of pulp manufacturing and petrochemical processes. These processes also add number of saturated and unsaturated aromatic hydrocarbons together with variety of oxygenated and halogenated derivatives. The nitrogen compounds including nitric oxide, nitrogen dioxide and carbon monoxide are emitted during combustion of carbonaceous fuels. Inorganic Halogen compounds viz.,Hydrogen fluorides, Hydrochloric acid, Chlorine, Nitric acid,Sulphuric acid fumes having toxic properties, produce lethal effect on vegetation, animals, human beings and all other living organisms.

1.3.2 Secondary Pollutants

The pollutants produced in the air by interaction among two or more primary pollutants with normal atmospheric constituents with or without photoactivation are secondary air pollutants. These include ozone, formaldehyde, organic hydroperoxides, peroxyacetyl nitrate etc. Such secondary gaseous air pollutants are resulting from photochemical reactions. (Fontan and Lopez, 1984).

1.4 GENERAL EFFECTS OF AIR POLLUTANTS

Air pollutants effect on aesthatics, economic viability, safety, personal discomfort and health. Economic losses due to air pollution include the direct effect on agriculture and horticulture, the human health and deterioration of materials. The kind and extent of loss varies with the pollutant and other environmental conditions.

1.4.1 Abiotic Components

1.4.1.1 Climate

The climate is the driving force for the ecosystem. Its variability causes stress. The chemical climate is drastically changed by air pollution (Ulrich, 1984). Emission of carbon dioxide, oxides of nitrogen, chlorofluorocarbons, water vapour, methane and particulate could cause change in global climate i.e. temperature, local effects on cloud seeding, rainfall and seasons (Tucker,1986, Bradley *et al*.,1987).

Acid rain is the result of the air pollutants emitted by various industrial activities. The acid rain is the acid deposition both in dry and in wet forms. The major air pollutants implicated in the acid deposition are sulphur oxides mainly sulphur dioxide, nitrogen oxides, hydrocarbons, or volatile organic compounds and particulate matter which are emitted in various proportions in the atmosphere. A huge loss to forest has been reported by acid rain (Cox, 1984, Bell, 1986).

Ozone is a form of oxygen occurring naturally in the high atmosphere. It protects the life on earth by absorbing ultraviolet radiation from the sun which can cause skin cancer, eye damage and harm,animals, crops and biological processes and materials. A major global environmental issue is caused by depletion of ozone layer due to industrial emissions into the atmosphere. Ozone layer is estimated as 3 percent thinner than it was a decade ago (Thomas, 1988, Misra and Tiwari, 1990). Economic crop plants viz. bean, onion, potato, spinach and tobacco are affected and injured by ozone (Ito et al.,1984).

1.4.1.2 Soil

Soil is contaminated by deposition of pollutants from air, rain, flood, irrigation, living organisms, sea and solid wastes. Such deposition on soil surface slowly percolates and retains pollutants which is available to plant roots alongwith microelements. Therefore contamination of soil is more local and patchy than that of water or air. Decrease in forest growth was observed in soil with high acidic deposition (Malhotra and Blauel, 1977, Misra and Shukla, 1990).

1.4.1.3 Water

Water is of primary necessity and is important for life and major industrial processes. The contamination of drinking water by different pollutants causes many water borne diseases viz., dysentary, cholera, typhoid etc. The toxic substances present in water are the products of modern industry and unhygenic conditions. Irrigation of agricultural lands by polluted water adds to pollution affecting vegetation and other biota.

1.4.1.4 Metals & Materials

Air pollutants, moisture and temperature affect rate of metal corrosion. An air pollution survey showed high corrosion rates when change in weight was used as measure of air pollution, near industrial plants like oil refinery, fertilizer and sulphuric acid manufacturing operations. (Kapoor & Gupta, 1985). Particulate matter is an important factor in the corrosion of metal. Moist atmorphere containing SO_2 with particulate matter accelerates the rusting of Iron (Meetham et al.,1981).

Building materials are corroded and disfigured by air pollution in a number of ways in addition to normal weathering processes.

The historic monuments viz., Taj Mahal, Itmad-ud-Daulah's tomb, Fatehpur Sikri, the Sikandra and Agra Forts are in danger due to air pollutants emitted by local industries (Aggarwal,1988). The long term effect of sulphuric acid on white marble, red sand, stone and other monuments would corrode them (Kumar and Prakash,1978, Rao et al.,1983).

1.4.2 Biotic Components

1.4.2.1 Human Health

Groups of men exposed in their occupation to high concentration of pollutants are suffering from chronic bronchitis and lung cancer. Photochemical pollutants cause irritation to eyes and respiratory tract. Atmospheric carbon monoxide coagulates with the human blood and forms carboxyhaemoglobin, thus reducing the oxygen carrying capacity of RBC. This has generally been reported in the cities having many automobiles (Aggarwal et al.,1978). Man made aerosols are acidic and deeply penetrate into the respiratory system. They act as irritants and cause disruption of the lung epithelium (Goldsmith and Friberg,1977).

1.4.2.2 Effects on Animals

Cattles are susceptible to air pollutants same as human being except sheep and pig. They are more sensitive to fluorine. Animal's teeth get deteriorated and are unable to feed due to accumulation of fluorine in the grass. The most pronounced effect of fluorine accumulation in fodder is fluorosis (teeth decay) in cattles (Singh and Saimbi, 1988).

1.4.2.3 Vegetation

Green plants represent a significant natural sink for a number of air pollutants and help in removing them to some extent. Beyond certain levels (which is pollutant and species specific), pollutants become toxic and injurious effects are reflected. Pollution injury is most commonly classified as visible and invisible (hidden) injury (Kozlowski and Mudd, 1975).

Visible injury

Visible injury is observed mostly on foliar tissues of plants exposed to air pollutants. It may occur in two forms a) Acute and (b) chronic injury

a. Acute injury

Acute injury is associated with rapid absorption of acute levels of pollutant in short span. It results in necrosis i.e. death or mortification of tissue. Collapsed marginal or intercostal leafareas show a water soaked appearance later turn to ivory or brown colour due to absorption of enough gas to kill the tissue. Such injury depends on the nature of toxicant, its concentration, the plant species and other factors (Norby and Luxmoore, 1983, Baker and Fullwood, 1986).

b. Chronic injury

It is associated with injury of long term exposure of plants to sub-acute levels of pollutant. The blanching of the green parts of the plant, where green colour disappears and leaves become pale, green yellow or even ivory white, is chlorosis (Dassler and Bortitz,1988).

Invisible injury

The biochemical and physiological activity of plants exposed to air pollutants are affected. Alteration in growth parameters, premature loss of leaves and fruits, changes in water relationships, smaller fruits and poor growth are found in plants exposed to pollutants without visible injury. This concept was not accepted previously due to lack of research reports (Thomas, 1951), but later on invisible or hidden injury concept has been universally accepted (Khan & Malhotra, 1982).

Pollutants and their symptoms in plants

Plants show different leaf injury symptoms exposed to different pollutants (Table 2).

Various growth, biochemical and yield parameters have been studied in different plant species (Godzik and Krupa,1982).

i. Growth and Productivity

The air pollutants can reduce growth and yield with or without visible symptoms. Significant changes in the pattern of growth result from air pollutants exposure to different plant species. Reduction in various parameters viz.,root length (Singh et al.,1988), shoot length (Raza and Rao 1985), number of leaves (Lorenzini and Panattoni, 1986), number of tillers (Ashenden and Williams, 1980), total leaf area (Boralkar and Chaphekar, 1979), biomass accumulation (Saxe,1983) and yield (Dueck et al.,1986) was observed in plants exposed to air pollutants. C_3 plants showed more sensitivity and reduced growth than C_4 plants when exposed to SO_2 (Carlson and Bazzaz, 1982).Yield reduction was observed in winter wheat (Sharma & Rao 1983,Baker et al.,1986) in lucerne plants (Murray, 1985) and in clover ryegrass, (Murray 1984) in winter barley (Ba ker et al.,1987) exposed to different pollutants.

Visible foliar injury symptoms in form of chlorosis and necrosis were correlated with reduction in yield.(Wong et al.,1977,Baker et al.,1982,Bytnerowicz et al.,1987) and with total leaf area in tomato (Stratigakos & Ormrod, 1985). The combined effect of SO_2 + HF pollutants showed 57% leafarea injury in Phaseolus aureus plants(Sharma & Rao,1985). On the other hand lack of correlation of visible injury symptoms and growth reduction effects were observed in young cuttings of Populus nigra and Populus canadensis exposed to mixture of NO_2 + SO_2 (Andrea and Ormrod, 1986) and in other plants (Crittenden and Read,1978,Bell et al. 1979, Mejstrik,1980). Ozone significantly reduced the net photosynthesis and yield of winter wheat crop (Amundson et al.,1987) and in tree species (Wang et.al.,1986). The combined effect of NO_2 + O_3 on sunflower plants showed reduced leafarea with less yield.

The evaluation of leaf age or of growth stage is very important in determining sensitivity to pollutants. The environmental factors such as temperature,moisture, light etc. play an important role in determining the rate of metabolic activity. Various levels and durations of pollutant exposure have been shown to cause injuries such as foliar chlorosis, necrosis, premature foliar loss, inhibition of growth and eventually plant death. It also results into reduced grain yield, fiber yield and reduced foliar quality and quantity.

ii. Cuticle and stomata

The epidermis being the outermost layer of the plant is fully exposed to the atmospheric pollutants. The epidermal features like size and frequency of epidermal cells, stomata and trichomes, often act as modifiable traits and can be used in determining the type and extent of air pollution (Srivastava and Ahmed,1982). Foliar stomata are the principle sites of pollutants uptake. Outermost layer of leaf,the cuticle, also responds quickly to air pollution in a particular way and plays a significant role as bio-indicator of pollution. Number of stomata and trichomes are higher in plants exposed to air pollutants than in healthy population and permit greater uptake of pollutants in foliar tissues (Godzik and Sassen,1978). During the day 70% of the SO_2 was absorbed by stomata and remaining 30% was absorbed by cuticle in wheat (Fowler and Unsworth, 1974). SO_2 caused wider stomatal opening in *Zea mays* and *Vicia faba* (Unsworth *et al.*,1972).

Once SO_2 enters in, it is transformed into sulfite or bisulfite ions. Stomatal sensitiivity to sulfite is high at low pH (acidic) which reduces growth and biochemical parameters (Smith and Raven,1979,Pfanz and Heber, 1986). Stomata may be induced to remain open in bean plants for longer periods when relative humidity is 40% and suppressed at 32% relative humidity (Jensen and Roberts, 1986). SO_2 concentration from 5 to 50 pphm stimulated stomatal opening in bean and corn at 50 - 60% relative humidity, permitting greater entry of SO_2 in the foliar tissues resulting in decrease in cellular pH and reduction in growth parameters.

iii. Transpiration

Exposure of plants to pollutants may cause wider opening of stomata. Due to widened stomatal opening the rate of transpiration is increased which causes more absorption of pollutants. Such pollutants adversely affect the synthesis of primary metabolites needed by the plants to cope up with stressed conditions (Agrawal *et al.*,1985).

The lower transpiration rate was observed in Zea mays (maize) leaves in response to SO_2. Plants exposed to SO_2 showed 15 to 20% more transpiration which may even exceed upto 100% (Ziegler, 1975). Very high transpiration rate causes wilting and low rates of transpiration may inhibit the normal gaseous exchange. In both the cases growth of the plants is effected.

iv. Photosynthesis

Atmospheric pollutants reduce the rate of photosynthesis (Reich et al.,1987, Greitner and Winner,1989). Reduction in photosynthesis by air pollutants is primarily caused by changes in stomatal aperture or reversible inhibition of enzymes system (Silberstein and Galum,1988). SO_2 increased both photosynthetic suppression and mesophyll resistance to CO_2 at high humidities (88%) in Phaseolus vulgaris L.(Barton et al.,1980). SO_2 reduced the photosynthetic activity in the rice (Matsuoka,1978) and in wheat (Pandey and Rao, 1978). Ozone reduced net photosynthesis which was reflected in reduction in seed weight of wheat plants (Amundson et al.,1987, Atkinson et al.,1987). SO_2 + NO_2 and other mixture of pollutants inhibit the photosynthetic CO_2 exchange of plants (Black, 1982, Carlson,1983).

v. Chlorophyll

The specific response of plant's sensitivity to air pollutants was used as biological indicator from the early period (Aruga and Monsi,1963, Silberstein and Galum,1988). Reduction in chlorophyll and carotenoids was found in the absence of visible injury (Singh et al.,1990b, Vij et al.,1981) and with visible injury in wheat plants (Pandey and

Rao, 1978, Agrawal *et al.* 1982). SO_2 reduced chlorophyll content in exposed plants (Ahmed *et al.*,1986, Vijayan and Bedi, 1989). The correlation between SO_2 concentration and total chlorophyll reduction was established in tree species (Dubey *et al.*,1982, Krishnayya and Bedi 1986[b], Vijayan and Bedi,1988[a]). Chlorophyll *a* was more sensitive than chlorophyll -*b* (Pandya and Bedi, 1986, Ayer and Bedi, 1986). The combined effect of SO_2 + O_3 suppressed chlorophyll formation in rice plants (Banerjee *et al.*,1983) and by other mixture of pollutants (Norby *et al.*,1985, Trities and Bidwell,1987). The damage in chlorophyll is due to the removal of central Mg^{++} ion in acidic medium of chlorophyll molecule. Due to this, chlorophyll is converted into photoinactive pheophytin (LeBlank and Rao, 1973).

vi. Carbohydrate

Invisible effects of gaseous pollutants on a wide variety of plants, confirm alterations of concentration of sugars, organic acid and amino acids, resulting in reduction in growth and yield (Koziol, 1984). In tobacco plants the top (developing) leaves had sugar concentrations about twice those of the lower leaves and were found to be resistant to damage. Resistant plant species possess a greater quantity of carbohydrate. Increasing concentration of gaseous SO_2 resulted in an increase in reducing sugars and considerable drop in non-reducing sugars (Malhotra and Sarkar, 1979). The carbohydrate content of leaves, especially the concentrations of reducing sugars, appears to increase at low level exposures to O_3 or SO_2 and then decreases with higher exposures (Koziol and Jordan 1978, Prasad and Rao, 1981).

vii. Protein and amino acids

Sulphur is necessary for the general metabolism of plants as it is a major component of aminoacids, proteins and some vitamins. The accumulation of HSO_3^{-2} and SO_2^{-2} ions as a result of SO_2 pollution, can have drastic effects on plant metabolism by disrupting the natural balance between incompletely oxidized sulphur compounds and sulphydryl groups present in glutathione and cysteine which are essential for the structural integrity of proteins (Malhotra and Hocking, 1976). Free amino acids and soluble proteins increased in tissues of bean (Phaseolus), Soybean (Glycine) and pea (Pisum) exposed to low concentration of SO_2 but decreased when exposed to a higher dose. (Malhotra and Sarkar, 1979, Zedler et al.,1986). Decreased protein content has been reported in SO_2 treated plants due to an inhibition in the protein biosynthesis or to a stimulation in protein breakdown or both (Khan and Malhotra 1983, Nandi et al.,1990).

viii. Translocation

Sulphur dioxide absorbed by the leaves does not remain fixed in the site of absorption but has a substantial degree of mobility. Translocation of sulphur products has been found mainly at protein accumulation site, in the cambium fruit and seeds (Thomas, 1951). The severe effect of SO_2 is more on meristems when sulphur is translocated as SO_3^{2-} or HSO_3^{--} rather than as SO_4^{2-} (Garsed and Mochrie,1980).The change in the balance between partially oxidized and reduced compounds of sulphur might alternatively inhibit or promote cell division. The translocation was inhibited by 39, 44 and 69 percent in bean, exposed to 0.1, 1.00 and 3.0 ppm of SO_2 respectively for two hours. (Noyes, 1980, Teh and Swanson, 1982).

ix Pollutant accumulation

Plants exposure to atmospheric pollutants results in an increase in the concentration of the constituent elements in plants. The exposure dose, duration of exposure, uptake dose, effective dose, turnover of pollutant derivatives, and environmental factors are responsible for pollutant accumulation in plant system (Amiro and Gillespie,1985). Ozone, peroxyacetyl nitrate and ethylene do not accumulate in plants to any great extent (Garsed, 1984). Fluoride is toxic in cumulative doses and causes irreversible injuries like marginal necrosis and tip burning (Sharma and Rao, 1983). Sulphur accumulation has been reported in plants exposed to SO_2 by many workers (Malhotra and Khan,1984, Bytnerowicz et al.,1987a). Uptake of metabolised pollutants such as sulphur and nitrogen dioxide are related with the rate of plant metabolism and are influenced by plant canopy, plant parts and state of plants. Foliage tissue being most effective sorptive tissue, is capable of filtering some SO_2 from the atmosphere at high concentration of SO_2 site (Roberts and Schnipke,1983). Vegetation is considered to be a global sink for the gas than soil.

1.5 SOME IMPORTANT FACTORS INFLUECING THE POLLUTION EFFECTS

1.5.1 Meteorological Factors

Meteorological factors like wind, temperature, humidity, radiation, precipitation have their proper and distinct role in the operation of the pollution system.

The various climatic features of a place such as wind speed and its direction, atmospheric temperature stability, topographical features and surface roughness affect the dispersion of pollutants (Agrawal and Mathur, 1983). Transport of a pollutant from its source to the vicinity of a receptor is controlled by meteorological variables, viz., wind,temperature,precipitation pattern and turbulence.(Hosker and Lindberg,1982).

Presence of water vapour and humidity in air are important factors to know the effect of air contamination. Increase in humidity enhances the pollution effect. Stomatal movement and pollutant uptake are also regularised by temperature and humidity (Norby and kozlowski,1982, Jensen and Roberts, 1986).

1.5.2 Cultural Practices

Leaves of green plants indiscriminately absorb many gaseous substances, either as nutrients or as air pollutants. Air pollutants reduce plant yield in most of the cases,relatively few interactions were found beneficial between gaseous pollutants and nutrition treatments.

In sulphur deficient soil,improvement of sulphur supply results in growth promotion and photosynthetic activation. Maize and radish growing in culture solution of 200, 500, 1000 and 1500 ug/SO_2 m^3showed increase in yield (Cowling and Koziol,1982). Plants exposed to low levels of SO_2 for a long period of time caused an increase in yield (Cowling _et al_.,1973). The higher level of nitrogen showed an ameliorating effect on growth reduction (Ayazloo _et al_.,1980). The incidence and severity of leaf fleck were greatest with low nitrogen and declined as its supply increased (Singh and Rao, 1985). The interaction between sulphur and nitrogen nutrition and the effect of SO_2 on rye grass showed increase in yield (Cowling and Lockyer,1978).

1.5.3 Relative Sensitivity or Tolerence of Species

Plants provide an enormous leaf area of adsorption and accumulation of air pollutants and help to reduce the pollutant level in the atmosphere. Degree of sensitivity of a plant depends on its developmental stage,nutritional status and environmental factors viz. light temperature and humidity. Different plant species show variation in their responses to air pollutants in different ways (Singh et al.,1990). SO_2 induced H_2S emission in plants is related to the tolerance process.The young leaves of cucurbits, which are more efficient in emitting H_2S in response to SO_2 are more tolerant than mature leaves (Sekiya et al.,1982). The rapid metabolism of HSO_3/SO_3^{-2} derived from SO_2 is the principle biochemical mechanism responsible for the resistance of plants to SO_2. Pisum sativum exposed to SO_2 showed increase in glutathione which protected the photosynthetic apparatus and inducted H_2O_2 accumulation in tolerant cultivars (Alscher et al.,1987). Reduction or increase in levels of certain plant metabolites and enzymes under pollution stress has been related with plant tolerance to SO_2 (Tanaka et al.,1988) viz., Ascorbic acid (Lee et al.,1984, Krishnayya and Bedi 1988),Chlorophyll (Bytnerowicz et al.,1987) Peroxidase activity (Khan and Malhotra,1982, Varshney and Varshney 1984), Superoxide dismutase activity (Castillo et al.,1984, Matters and Scandalios, 1987).

1.6 MITIGATION OF POLLUTION EFFECT

Vegetation represents a significant natural sink for a number of air pollutants. They serve as receptor for substances that may be biologically toxic or life supporting. Although the deleterious effects of pollutants on vegetation cannot be avoided completely, some efforts have been made to reduce the injury by various means. Attempts have been made to mitigate pollution injury or to develop resistance in plants and increase crop yield. Foliar supply of urea enhanced the growth and development of wheat plants. Nitrogen supply effected the protein metabolism and provided resistance to the plant (Pandey,1982). Ascorbic acid acts as a strong reductant and is considered to be responsible for photoreduction of photochlorophyllide. The ascorbic acid spray on foliar tissues of trees and crops exposed to SO_2 pollutant showed reduction in plant damage and greater tolerance (Vijayan and Bedi,1988[b], Varshney and Varshney,1984). Calcium hydroxide and potassium ascorbate act as an antidote of SO_2 on foliar tissues (Nandi et al.1981, 1985) to mitigate the pollutant effect. In vitro studies,it is revealed that chlorophyll breakdown in SO_2 exposed plants can be checked by using sodium benzoate as a scavenger of cytotoxic hydroxyl radicals (Shimazaki et al.,1980).

1.7 PRESENT INVESTIGATION

1.7.1 Objectives of the Study

The objectives of the present experimental work were to determine the impact of air pollutants on some cereal crops.

- General vegetation survey was conducted in high,medium and least polluted zones to observe the damaging symptoms and extent of damage in different plant species.

- Certain crop plants were selected to find out their sensitivity and tolerance to air pollution. For this in potted plants, field exposure study was conducted. All cultural practices like soil, water, fertilizer, insecticides except the air were uniformly maintained to avoid the above mentioned variables at different sites.

- Same crops were subjected to artificial fumigation experiments in laboratory keeping all factors uniformly similar as in the field to observe the impact of single air pollutant in simulated conditions.

- Mitigation studies were conducted to minimise the pollution damage by applying different doses of nutrients in vitro and in vivo conditions.

1.8 APPROACH

The present investigation was conducted in the following four stages and the material selected were as following:

i. General field survey

Important economic cash and cereal crops viz., Potato, Pigeon pea, Tobacco, Miller? Maize, Paddy and Wheat were studied growing in the farmer's fields.

ii. Pot exposures

Potted cereal crops viz, Paddy, wheat and maize in different pollution zones were exposed to ambient air to know the ambient air pollution impact.

iii. Artificial fumigation exposures

To study the impact of single air pllutant under known duration and concentration of SO_2, the crops were exposed in specially designed fumigation chamber.

iv. Mitigation study

It was conducted by foliar spray of different chemicals viz., urea and ascorbic acid in the field and in the laboratory to minimise the pollution damage.