Studies on the effects of vehicular pollutants on road side plants of Puducherry

Project report submitted to

Department of Science, Technology and Environment.

By

Dr. V. Ramasammy

Principal, Perunthalaivar Kamarajar Arts College,

Kalitheerthalkuppam, Puducherry.

Present address:

Head of the Department of Botany,

Kanchi Mamunivar Centre for Post Graduate Studies,

Puducherry 605 008.

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INTRODUCTION

Clean air can no longer be taken for granted. Today the air in most large Indian cities is severely polluted and this pollution has a tremendous impact on the health of the population. Industrialization, the growth in number of vehicles in urban areas and the burning of bio-fuels in rural households have lead to a rapid deterioration of indoor and outdoor air quality. Out of the 23 metro- and mega cities, Delhi is the most polluted followed by Mumbai, Calcutta, Bangalore, Chennai, Kanpur, Ahmadabad and Nagpur in India. They have severe air pollution problems with the average levels of suspended particulate matter levels much higher than the prescribed standards.

Clean air has so far been treated as an unlimited and free natural resource. Only now as the health costs of polluted air are mounting, people are beginning to realize that clean air is valuable. The health impact of pollution is considerable. Premature deaths due to respiratory and cardio-vascular diseases and illness due to chronic respiratory diseases like asthma and bronchitis have increased. According to a world bank study, in 1995 air pollution might have accounted for some 40,350 premature deaths and 19,805 thousand hospital admissions, and 1201 million minor illnesses. In the last 4 years the numbers of premature deaths have increased by 28% and the number of sickness and hospital admissions by 30%. Another study estimates that 4,10,000 to 5,70,000 women and young children die prematurely every year because of indoor air pollution caused by the burning of bio- fuels in poor ventilated homes.

Urban air pollution is growing due to increasing power consumption, industrialization and vehicle use. In urban centers studied by the Central Pollution Control Board, the suspended particulate matter (SPM) in residential area exceeds critical limits set by the board in many cities. These studies revealed that it is not necessary that the larger cities are the more polluted ones. Kanpur, for instance has more particulate matter in the air than Mumbai, Calcutta or Delhi.

In India surprisingly neither industries nor vehicles are the main source of air pollution. Burning of unprocessed cooking fuels in homes causes the most pollution. Pollutants released indoors, due to their proximity to humans are far more dangerous than those released outdoors. (Anonymous, 2001)

Sources of air pollutants

Air pollutants enter into the atmosphere by various natural and man-made activities such as dust, storm, volcanic eruptions, and industrial pollution etc. They may be present in any form viz. solid, liquid and gas (Raju, 1998) based on the mode of generation of pollutants, the sources are classified as (i) Natural and (ii) man-made sources.

Natural sources

(a) Forest Fires – In the areas of tropical region or areas of high temperature throughout the year forest fire is a common feature. Very large quantities of smoke and particulate matter are liberated during their breakout.

(b) Volcanic eruptions – During the eruption of volcano, lava is produced along with release of minute solid particles, gases and radiation.

(c) Dust storms – They are caused due to the movement of hot winds around the earth and are concentrated in certain places at a particular time.

(d) Pollen grains – The pollution is also caused by the production of large amount of pollens in the spring season. They are mainly responsible for causing allergy.

Man made sources

(a) Domestic pollution– The use of insecticides in homes for cleaning and burning of fuel in home for cooking purpose are the primary source of pollution in domestic area.

(b) Industrial pollution – The industrial activities are primarily responsible for the pollution in India. The various industrial activities ranging from chemical industry, cement plants, paper mills to tanneries are major sources of pollution. The pollutants emitted also have vast difference in their properties. Trace elements are released into the atmosphere along with gaseous pollutant like SO_2, oxides of nitrogen and particulate matter.

Based on the shape of entry of pollutants into the atmosphere, the sources are classified as (i) point source (ii) Line source (iii) Area volume source. They may be of 2 types viz, Instantaneous and continuous.

(a) Point source – It can be defined, as the entry of pollutants into the atmosphere through a single point. Stack of power plant is a continuous source of emission. Instantaneous source is the point through which the emission of pollutant is not continuous eg.Volcanic eruption.

(b) Line source – It can be defined as the entry of pollutants into the atmosphere through a source of line shape eg. Exhaust pollution from vehicles and emission of pollutants through chimneys are continuous source of emissions. Instantaneous line source of pollution is a line shape source through which the emission of pollutants is not continuous eg. Pesticides spray by aeroplane.

(c) Area volume source – It can be defined, as the entry of pollutants into the atmosphere through an area/volume source eg. center of an industrial city is a continuous source of pollution. Instantaneous area volume source through which the emission of pollutants is not continuous eg. blasting of poisonous gas tank.

Based on the origin of pollutants, they are classified as,

(a) Primary pollutants– They are the pollutants which are directly emitted into the atmosphere from the various polluting sources eg. Smoke release from burning of coal.

(b) Secondary pollutants – They are the pollutants, which are formed by chemical reaction of 2 or more primary pollutants. The photochemical reactions are responsible for the formation of secondary pollutants for the formation of PAN (Peroxy acetyl nitrate).

Based on the chemical composition of pollutants, they are classified as

(a) Organic pollutants – The pollutants, which are composed of organic elements and also show the characteristics of organic compounds, are known as organic pollutants eg. PAN, hydrocarbons.

(b) Inorganic pollutants – The pollutants, which composed of elements whose compounds show the characteristics of inorganic compounds, are known as inorganic pollutants eg. CO_2, SO_2 and NO_x.

Based on the state of matter in which they exist in the atmosphere, they are classified as,

(a) Particulate matter – They are finely divided into solid and liquid particles present in the atmosphere, which are generated as a result of combustion and their size varies from 500 microns to 0.0002 micron. They are highly reactive in chemical properties and are mostly carried through the smoke, dust etc.

(b) Gaseous pollutants – Pollutants, which are present in the form of gases are known as gaseous pollutants e.g. CO_2, SO_2 etc.

Particulate matter (Rao, 1997) can be classified as.

1. Aerosols – They are air suspensions have particles of dust, smoke and fume. These particles may be solid liquid or gas depending upon the state of matter in which they exist and are finally dispersed in the atmosphere.
2. Dust – They are mixture of irregular shaped particles which are generated as a result of various manual and natural operations e.g. grinding, blasting and rock disintegration. They remain suspended in the air from a period of some days to few months. Their size varies from 1 micron to 200 microns.
3. Smoke – It is a suspension of very fine carbon particles having size from 0.5 to 1 microns resulting from incomplete combustion of coal wood etc.
4. Soot – It is a suspension carbon particles resulting from incomplete combustion of wood impregnated with tar and their size vary from 1-10 microns.
5. Fumes – They are particles of size range 0.03 to 1 micron formed by the condensation of gaseous pollutants.
6. Mist -- It is a suspension liquid droplet formed after the condensation of vapour. Their size varies from 40 to 500 microns.
7. Smog – It is a suspension of particles of smoke and condensed liquid droplets, which is formed by the photochemical reaction between particulate matter and water molecules.
8. Haze – It is an air pollution condition formed due to presence of very fine dust in the atmosphere. It is expressed as coefficient of Haze (COH). COH = 100 $(\log)_{10}$ {100% transmittance} (Khitoliya, 2004).

In urban areas the transport sector causes the most pollution, producing 74% of the CO_2 and all the lead emitted. The number of vehicles in India has been steadily increasing, leading to a concurrent increase in pollution. In the last 25 years the number of registered vehicles increased over 10 times from a mere 2.1 million in 1973 to 25.2 million in 1993. In the next 5-7 years, the number of vehicles is expected to double. All vehicles burn petrol or diesel. Often this fuel is of poor quality due to illegal contamination and engines of Indian vehicles are not very efficient, leading to increased pollution. The vehicular emission load in 1994 was estimated at 3596.8 tones/day in 12 major Indian cities, which was a significant part of total air pollution load in these cities.

Industry, power plants and the burning of solid waste also add to the pollution load. Some 1,551 medium and large industrial units in the country in 17 highly polluting industrial sectors have been identified as polluting by the Central Pollution Control Board (CPCB). Of these about 77% are predominantly water polluting and 15% are predominantly air polluting and 8% are both air and water polluting industries. Industrial chemicals, rubber, textiles, iron and steel, non-metal products, food products, paper, printing – publishing, metal products and leather industries are among the most polluting. The industrial sector in 1995 contributed 2 million metric tones of pollutants.

The uncontrolled burning of solid waste in urban and semi urban areas is another major cause of air pollution. Mumbai city with a resident population of about 10 million people, produces more than 5,000 tons of garbage every day. According to a NEERI, case study, both the formal and informal sectors burn 100 tones of this garbage every day at Deonar in Mumbai. An 1GIDR study estimates that burning of one tone of garbage produces 0.098 tons of suspended particulate matter, 0.072 tones of SO_2, 0.136 tones of volatile organic chemicals, 0.018 tones of nitrogen dioxide, and 0.38 tones of CO. Conservative estimates based on studies indicate that by 2005, 1.18 million tones of pollutants will be released annually due to burning of waste generated by 307 million inhabitants of 3,696 cities and towns in India. If the emissions produced by burning waste in rural areas also included, total emissions by waste burning would be equivalent to or more than the 2 million metric tons.

Impact of air pollution

Air pollution may cause several health problems. Its impacts economic productivity, reduces agricultural productivity, damages property and causes ecological changes that increase the risk of environmental disasters. Flight schedules are routinely disrupted in winter due to smog in Delhi and other cities, when airports are shutdown for the lack of visibility. According to a study by the National Environmental Engineering Research Institute, the health costs due to air pollution in the National Capital Territory (NCT), Delhi are as much as Rs.117 crore per year.(Anonymous, 2001)

Total suspended particulate matter, especially those particles that are less than 10 microns in diameter (PM 10) and which can easily penetrate the lungs, cause death from both respiratory illness and cardio-vascular diseases. Continuous exposure can cause chronic obstructive lung diseases like bronchitis, and upper and lower respiratory tract infections. Ozone causes asthma, eye irritation, and heart disease. High levels of atmospheric lead contribute to both hypertension and neurological damage, including the loss of intelligence quotient (IQ) in children. CO reduces the amount oxygen carried by the blood, but dissipates rapidly in the environment and its effects are reversible.

Exposure to indoor air pollutants also causes serious health problems like acute respiratory infections, chronic obstructive lung disease, lung cancer and possibly blindness and heart disease in women, children less than 5 years of age, and senior citizens who spend long periods indoors are particularly susceptible.

SUBSTANCE	SOURCE	HEALTH EFFECTS	ENVIRONMENTAL EFFECTS
CO	Mainly from petrol emissions	Fatal in large doses, aggravates heart disorders, affects central nervous system, impairs O_2 carrying capacity of blood, reflexes and causes drowsiness.	Contributes to global warming by removing hydroxyl radical from the air.
Oxides of Nitrogen	Vehicle emissions both petrol and diesel.	Irritation of respiratory tract, reduces lung function, makes a person prone to viral infections.	Acid rain, contributes to global warming, helps to form ground level Ozone (smog).
Ozone	Interactions of hydrocarbons and oxides of nitrogen.	Eye, nose and throat irritation, risks to asthmatics, children and those involved in heavy exercise.	Damage to vegetation crops, contributes to global warming.
Lead	Petrol additive	Affects nervous system and blood, impairs mental development of children, causes hypertension.	Remains in soil, from which it reaches the food chain, inhaled directly into blood stream.
Hydrocarbon	Mainly from unburnt petrol.	Drowsiness, eye irritation, coughing.	Contributes to global warming by forming ground level Ozone.
Benzene	Vehicle emissions, evaporative petrol losses, coke oven, cigarette smoking.	Causes cancer.	None identified to date.
Polycyclic aromatic hydrocarbons.	Mainly from diesel fuel.	Causes cancer.	None identified to date.
SO_2	Mainly from diesel fuel.	Irritation of respiratory tract, large doses can cause laryngo-tracheal and pulmonary oedema, heart & lung diseases.	Source of acid rain, Damages monuments and buildings.
Particulates	Mainly from	Irritation of the respiratory	None identified to date.

	diesel fuel.	tract causes cancer, reduced lung function.	

Components of Vehicular Pollution and their effects on Human & Environment

Anonymous, 2001

EFFECTS OF POLLUTANTS ON PLANTS

1. Effects on vegetative morphological features

Air pollution has an adverse effect on plants. Recently methyl isocyanate gas has also destroyed the vegetation at Bhopal in 2-3 km vicinity from the factory. Responses of Phaseous aureus to SO_2 and HF(hydrogen fluoride) pollutants were carried by Sharma and Rao(1985). It is evident that SO_2 and HF hamper plant growth and suppress the yield in various ways. The seeds collected from the pollutants exposed plants were inferior to control ones. The effects of pollutants on leaves included chlorosis and necrosis, which caused reduction in photosynthetic leaf area. It is known that SO_2 induced foliar injury; later developing into necrotic lesions hampers growth and decreases the net assimilation rate of plants (Katz, 1949; Thomas, 1951; Weinstein and Mc Cune, 1970).

In fumigation studies of NO_2 on populations of 10 annual and perennial weeds of United States were tested to serve as indicators of plant injury caused by air pollutants. Two types of leaf markings developed: (i) a discoloration associated with cell collapsed , necrosis and (ii) a general overall waxy appearance of the leaf (Benedict and Breen ,1955).

Ammonia is present in the atmosphere of metropolitan areas generally escaped from refrigerators, precooling systems of cold storage rooms and anhydrous ammonia used as fertilizer or escaped during its manufacture (Treshow, 1970). Though ammonia is a minor air pollutant with respect to plant damage (Leone, 1979), yet it has caused necrotic and chlorotic interveinal streaking at considerable distances from an accidental release (Taylor, 1973).

In a field study, Dubey et al., (1984) noted reduction in leaf area of plants growing in polluted atmosphere. The maximum reduction was in *Azadirachta indica* followed by *Mangifera indica* while *Clerodendrum indicum* showed little change. Such reduction in leaf area and growth under stressed environmental conditions have been reported earlier (Mc Cune et al., 1967; Pawar et al.,1978).

Leaf surface temperature and leaf absorption in visible and infra – red regions were observed in *Medicago sativa*, *Triticum aestivam* and *Zea mays* which were exposed to different air pollutants. It has been noticed that fly ash exposed plants had high leaf surface temperatures and high light absorption, as compared to plants exposed in field and artificially to SO_2 (Varshney and Garg,1980) .

The effects of vehicular pollution density on leaf anatomy of *Cassia siamea,* a road side plant, showed that plants growing around polluted sites showed leaf injury symptoms, reduction in thickness of leaf lamina, reduction in thickness of xylem cells and phloem cells and number of palisade and spongy cells per unit area (Pretti Bala, 2001).

2. Effects on reproductive morphology

The seedlings of *Spinacea oleracea*, *Abelmoschus esculentus* var. pusa Savni; *Amaranthus viridis* and *Phaseolus areus* var. Vaishakee were fumigated with SO_2 under static conditions, at the ages of 10, 20 and 30 days from sowing. It is seen from the results that 10-days old age plant is more susceptible to SO_2 and the susceptibility decreases with an increase in the age of the plants. The SO_2 exposure results in the reduction of phytomass which may adversely affect the competitive ability and weakening of the plants. Such plants produced less photosynthate as also smaller number of seeds from fewer flowers (Boralkar and Chaphekar, 1989).

3. Effects on micromorphological characters

Wagoner (1975) observed several leaf cuticular and morphological variations in plants of Plantago lanceolata collected from air polluted and non-polluted areas. She noted that the stomatal frequency on the upper surface of leaves from the polluted areas was higher than that of non-polluted areas. Similarly, trichome density and trichome length were correlated with high environmental pollution. However, stomatal size range and number of subsidiary cells remained the same in all populations. SEM studies Godzik and Sassen (1978) on the surface structure of *Aesculus hippocastanum* leaves found to show that small folds present in the outer epidermal cell walls of normal leaves were absent in the leaves of air polluted areas and further stomata of leaves from polluted areas had an abnormal appearance.

A comparative study of the epidermal traits of one polluted and nine healthy populations of *Psidium guajava* was made. Leaves of guava collected from the polluted environment of a cement factory, showed higher stomata and trichome density and smaller epidermal cells and trichome size as compared to those of leaves collected from the unpolluted areas. (Yunus and Ahmad, 1980).

Studies of *Jasminum sambac* with respect to foliar epidermal features brought out by conspicuous decrease in size of epidermal cells and stomata, and increase in epidermal cell, stomatal and trichome frequency in plants of polluted population. These modifications of epidermal triats could be indicative of environmental pollution and could, therefore be used as bio-indicators of air pollution (Kulshreshtha , 1980).

Studies of the modifications of foliar surface traits in response to air pollution were conducted on *Ipomoea fistulosa* collected from polluted environment of Churk and Renukoot showed increased stomatal, trichomes and epidermal cell density; relatively bigger stomata ,larger trichomes and small epidermal cells which on comparison with healthy populations collected from Lucknow environments. SEM studies of the leaf surface revealed wider stomatal openings , disorganization of cuticular striation patterns and dissolution of cell walls in polluted populations. It is further suggested that these changes in the cuticular and epidermal traits in this taxon can be used as markers of the air pollution. The epidermal cell frequency values both in upper and lower epidermides, have increased considerably in polluted populations as compared to the healthy populations. In contrast to the above epidermal cells of polluted populations are much smaller in size than those healthy populations. (Yunus et al.,1982)

4. Effects on wood

Effect of air pollution on wood formation in *Tectona grandis* was studied by Ghouse et al., (1984). They observed that annual loss in wood formation amounting to 26% in its average for the last 6 years.

5. Effects on physiology of plants

Hill and Bennett (1970) compared the effects of NO and NO_2 on the rate of apparent photosynthesis of *Alfa alfa* and oats. A threshold concentration of about 0.6ppm of each gas was required to reduce CO_2 assimilation and combination of two gases gave an additive effect. NO produced a more rapid reduction in apparent photosynthesis, than NO_2 and recovery was more rapid when fumigation was stopped.

Thompson et al., (1970) fumigated navel orange trees continuously with fine levels of NO_2 at 1.00, 0.5, 0.25, 0.12 and 0.06 ppm. After 35 days the 2 highest levels (1.00 and 0.05 ppm) had caused chlorosis of leaves, extensive defoliation and reduced yield.

Oxides of nitrogen are major air pollutants in urbanized and industrial areas. Exposure to NO_2 bought out a decrease in root-shoot length, fresh and dry weights, photosynthetic pigments and ascorbic acid levels were recorded in *Mimusops elengi* (Tiwari and Bansal, 1993). Out of various photosynthetic pigments, chlorophll-a appears to be more sensitive than chlorophyll-b and carotenoids which has also been observed in other plants (Jamrick, 1968; Hill Bennett 1970; Dubery Pawar, 1985; Bansal, 1988; Tiwari, 1991).

Response to ammonia (25% specific gravity 0.91) pollution was very serious which killed the plants of black gram T-9. The damaged leaves of black gram resulting in the reduction of total chlorophyll even when the plants were 30 inches away from the spot of its exposure. Diluted concentration of ammonia with prolonged duration of exposure also had shown deleterious effects on the length of the plant, biomass, root nodule, fruit and seed production capacity of the plants representing the sensitivity of black gram T-9 to ammonia pollution (Raga and Lulekha, 1981).

Dubey et al., (1982) found increment in dry weight and chlorophyll content in leaves of *Maduca indica*, and *Butea monosperma* sprayed with different rates of fly ash. The SO_2 and vapours of herbicides individually have been reported to damage both the pollens and pigments (Dubey, 1977;Shevade and Dubey,1983)

The cement dust released emitted from the operation of a cement factory hampers the growth and development of the plants in its vicinity. The studies made in this connection at three successive developmental stages revealed that chlorophyll concentration and biomass of the plants at polluted sites were reduced, as compared to that at control site. (Singh,1983)

While studying the uptake of NO & NO_2 and their effects on photosynthesis, respiration and transpiration of 8 potted cultivars,(Saxe,1987) brought to light certain interesting aspects. The NO exposure reduced photosynthesis (20%), transpiration (18%) but did not affect respiration. NO_2 rarely had any significant effects. All the effects of the gases on photosynthesis and transpiration were reversible and had independent mechanism.

Two tree species *Dalbergia sissoo* and *Azadirachta indica* were studied as the bioassay material against air pollution around a steel industry of Ujjain by Kumawat and Dubey (1988). A decrease in chlorophyll pigments, Carotenoids and leaf pH, but increase in leaf injury index, leaf area / dry weight ratio , conductivity of leaf disc water ,sulphate (SO_4) content, and total chlorophyll / SO_4 were observed.

The phytoxicity of SO_2 is manifested by various morphological, physiological, biochemical responses including disruption in various metabolic processes and cellular functions affecting photosynthesis and respiration in *Cicer arietinum* (Ferguson et al., 1978). The study demonstrates dual role of SO_2 at its low concentration was promoting growth whereas it was found toxic at higher concentration. Visible injury symptoms such as chlorosis and necrosis where observed in sprouting seedlings after long term exposure. (Saxena et al., 2001).

Therefore, all the above studies clearly establish the adverse effects of air pollutants on plant communities. In the recent past, Pondicherry has witnessed a very rapid increase in the vehicular traffic and during certain times it appears to be unmanageable. Hence, the air pollution due to exhaust pollutants is also on the rise in this peaceful city. Inorder to study the level of air pollution mainly due to vehicles and its impacts on plant characteristics which considered as biological indicators of environmental pollution, the present work has been taken up.

MATERIALS AND METHODS

Study Area

Certain roads in Pondicherry town are always seen with heavy vehicular traffic. The Tindivanam-Pondicherry road from JIPMER to Pondicherry bus stand always shows a very heavy vehicular traffic. Similarly the segments between Villanour to Puducherry bus stand and Ariankuppam to Puducherry bus stand are highly polluted due to heavy vehicular and industrial emissions. In these areas many plants grow in wild and are also planted for beauty. These plants are constantly exposed to tremendous vehicular pollutants. As these segments consist of many important signal areas, lots of vehicles parked for road signals, therefore the plants are morning to night constantly exposed to the exhaust smoke pollutants of vehicles.

First a thorough survey of number of vehicles passing through a segment (between Rajiv Gandhi Square and Indira Gandhi Square) was calculated every hour during the month of March-May 2005 on different days as case study. The average number of vehicles passing through this segment under different categories viz, two wheelers, four wheelers (cars & medium vehicles), and heavy vehicles were calculated.

The following plants were chosen from the above site, which are under constant stress of vehicular pollutants.

Sl. No	Species	Family	Habit & Habitat
1	*Azadirachta indica* A. Juss	Meliaceae	Mesophytic tree
2	*Boerhaavia diffusa* Linn.	Nyctaginaceae	Mesophytic diffuse procumbent
3	*Bougainvillea spectabilis* willd	Nyctaginaceae	Mesophytic shrub
4	*Calotropis gigantea* (L.) Ait.f	Asclepiadaceae	Xerophytic shrub
5	*Catharanthus roseus* (L.)Don (*Vinca rosea* (Linn.))	Apocynaceae	Herb
6	*Duranta repens* (L.)	Verbenaceae	Small tree
7	*Eclipta alba* L.	Asteraceae	Mesophytic herb
8	*Nerium odorum* Soland	Apocynaceae	Shrub
9	*Tecoma stans* (L.)Kunth (Stemalobium stans (L.) seemann)	Bignoniaceae	Shrub
10	*Tridax procumbens* Linn	Asteraceae	Herb

The above ten species were also collected from non-polluted sites from the centre campus, Kurumampet near Oosuderi (Oosudu) lake and other parts of unpolluted regions.

The morphological parameters such as size of internodes, length, breadth and colour of leaves, leaf injury, flowering behaviour with reference to abundance of flowers, were compared between the plants growing in polluted and non-polluted sites. Morphological and anatomical features of leaf, stem and petiole were studied for all the speices except *Azadirachta indica*. In this species wood and bark characteristics alone were compared between plants growing in polluted and non-polluted sites.

The plant parts such as bits of leaves, petioles, stem were fixed in FAA (Farmalin, Acetic acid and 70% ethyl alcohol = 5ml : 5ml : 90ml) (Johansen, 1940) immediately after collection. Epidermal peels were obtained from fresh as well as fixed materials for all the species except *Azadirachta indica*. The peels were obtained by mechanical means using a sharp razor and forceps. Some were also cleared using sodium hydroxide (5%) and chloral hydrate (saturated) successively. After clearing, the leaf bits were thoroughly washed in water (Ramassamy,1991). For the preparation of peels in *Calotropis gigantea* and Nerium book method (Mohan Ram & Nayyar 1974) was followed. In this method fresh leaves were cut into fragments of desired sizes with one edge of lamina left untrimmed. These fragments were boiled in 5-10% aqueous cupric sulphate ($CuSO_4$: 5 H_2O) for 1-2 minutes. Then 4ml of conc.hydrochloric acid was added to the cupric sulphate and the material was again boiled in the mixture for 1-2 minutes. During the treatments, mesophyll tissue between adaxial and abaxial epidermides disintegrates. Being in contact along the untrimmed margin, the adaxial and abaxial epidermal layers can be opened out like a book after removing the mesophyll tissue. Epidermal peels were placed in the slide with the outer side facing the cover slip.

Peels obtained by mechanical, book methods and cleared leaf bits were stained with 1% aqueous saffranin. They were mounted in 50% glycerine and sealed with DPX.The leaf peels were observed under high power (X 400) using Getner trinocular microscope.

The quantitative values of epidermis such as

[1] Cuticular striations

[2] Frequency and size of epidermal cells

[3] Frequency and size of stomata

[4] Percentage of types of stomata

[5] Stomatal abnormalities

[6] Types of trichomes

[7] Frequency of trichomes

[8] Size of trichomes and

[9] Occurrence of idioblasts were recorded.

Hand sections of fixed leaves, stem and petiole were taken for observing, the anatomical characters such as

Leaf

(i) Thickness of leaf

(ii) Thickness of epidermis

(iii) Arrangement of palisade and spongy parenchyma

(iv) Other characteristics such as occurrence of styloids, idioblast, etc.,

Petiole

(i) Epidermis

(ii) Cortex

(iii) Variation in vasculature

Stem

(i) Epidermis

(ii) Hypodermis

(iii) Cortex

(iv) Vascular bundle number and pattern

(v) Idioblasts

Wood and bark samples were taken from *Azadirachta indica* of polluted and non-polluted site. The bark samples, measuring about 5cm square were chiseled out from the trunk, of the tree at the chest level. They were fixed on the spot in FAA. Wood portions were removed from the bark without damaging the phloem part of the bark. The wood samples were pickled in glycerine – alcohol (in equal volumes) which served both as preservative and softening fluid.

The bark samples were dehydrated slowly through upgraded series of tertiary butyl alcohol and ethyl alcohols following the schedule suggested by Saas (1940). Dehydration was followed by paraffin wax infiltration (BDH Wax, 58-60°C melting point). Materials embedded in wax were subjected to microtomy. Section of 10-12 μm thick were prepared with the Rotary microtome and the sections were affixed on the slides using Haup't adhesive (Johansen, 1940). This was prepared by dissolving 1gm granular or sheet gelatin in 100ml water at 35°C. Add 0.5gm sodium benzoate or 2gm phenol. Apply the adhesive by means of a tooth pick or slender glass rod. Bark sections were stained with 0.25 aqueous Toluidine blue (0' Brien et al.,1964). The metachromatic property of the stain gave satisfactory result for the bark .

Metachromacy is a phenomenon in which the colours of tissues and cell inclusion are different from the colour of the stain used. Stain–ions are bound in clusters to the strongly charged binding sites upon the cell components. In metachromatically stained components, these binding sites are so patterned that the stain-ions are placed close enough to interact among themselves through hydrogen bonding. This interaction is optically manifested as a change in the spectral absorption curve of the stain, producing metachromacy. Toluidine blue O stains lignified cells blue, cellulose walls purple, protein – bodies blue, tannins dark green, suberin blue, mucilage pink and callose blue (Vijayarahavan and Shukla, 1990).

The wood specimens were sectioned with sledge microtome to the thickness of 15-20 μm the sections were taken along transverse, tangential longitudinal and radial longitudinal planes. Sections were stained with 0.5% aqueous solution of saffranin and 0.25% aqueous toluidine blue individually. The sections were dehydrated through alcohol –xylol series and mounted in DPX.

For description of the bark structure, the technical terms proposed by Trockenbrot (1990) and Junikka (1994) and for description of wood anatomy, terminology recommended by IAWA multilingual glossary (1964) were adopted. The following parameters were analysed for Bark and wood characteristics:

I. Periderm characters
II. Wood characters
III. Secondary phloem
IV. Length of tracheids
V. Length of vessels
VI. Length of fibres

For studying individual components of the wood and bark, the specimens were macerated employing Jeffrey's maceration fluid.

Quantitative microscopy:

The histomorphological measurements were taken with the help of linear micrometer in a weswox calibrated Binocular microscope. For the quantitative values,the numbers of the cells were determined with reference to the field under higher magnification these readings were brought to one square millimeter.

For calibration of microscope the eye piece was removed from the microscope, the lens was unscrewed and in the ridge the eyepiece micrometer was placed. The lens was then replaced. The stage micrometer was then placed on the stage of the microscope and focused with the eyepiece scale superimposed. The division of eyepiece, which coincides with the division of stage micrometer, was noted. The calibration factor was calculated using the formula.

$$\text{Each division of eye piece micrometer} = \frac{\text{No. of divisions of stage micrometer}}{\text{No. of divisions of eyepiece micrometer}} \text{ X } 10$$

The readings for quantitative values such as size (length and breadth) and number of epidermal cells/sq.mm size (length and breadth) of stomata , stomatal number, stomatal index, % of stomatal types, size and number of hairs, both abaxial and adaxial surfaces, were taken at the base, middle and tip of the leaves and readings were taken. Mean values and values of standard deviation for each character were calculated from these readings and tabulated. Model tables are presented only for four species to reduce the volume of the report.

A. Epidermal cell number and size

Epidermal cell number is the average number of epidermal cells / sq.mm. For calculation the number of epidermal cells, the subsidiary cells were also counted. The length and breadth of epidermal cells were measured at different regions of epidermis.

B. Stomatal morphology

(i) Stomatal number (frequency) and size

Stomatal number is the average number of stomata / sq.mm of epidermis of the leaf (Evans, 1996). The size of stomata (length and breadth) were also measured

(ii) Stomatal index

Stomatal index is the percentage, which the numbers of stomata form to the total number of epidermal cells, each stoma being counted as one cell. Stomatal index is calculated by using the following equation,

$$SI = \frac{S}{E + S} X\ 100$$

Where, SI = Stomatal index , S = Number of stomata per unit area, I = Number of epidermal cells in the same unit area (Salisbury, 1927).

(iii)_Stomatal types

The percentage of destribution of various stomatal types was calculated at different regions of abaxial and adaxial surfaces of leaves and the average for each type has been worked out.

C. Hair frequency and size.

Hair frequency is the average number of hairs / sq. mm. The length and breadth of hairs were measured at different regions of epidermis.

D. Length of internodes

The length of internodes of the plants were calculated at different regions from the 3^{rd} and 7^{th} node in each branch and the average for each plant has been worked out.

E. Leaf size

The length and breadth of each leaf was calculated from the 3^{rd} to 7^{th} and the average for each plant has been worked out.

F. Reproductive Morphology

Reproductive deformations were also recorded with reference to size of inflorescence, number of flowers per inflorescence, size of flowers etc.,

G. Photomicrography

Photomicrography of peels and free hand sections of leaf , petiole and stem were taken using Olympic Nikon (Japan) Automatic camera attached.

Estimation of Photosynthetic Pigments

Biochemical tests were carried out for the two species viz, *Bouganivillea spectabilis* and *Boerhaavia diffusa*. Chlorophyll content of the leaves was estimated by the method of Shoaf and Lium (1976). Fresh leaves were collected from the 5^{th} and 6^{th} node of polluted and non-polluted sites for the above two species. Fresh leaves of 0.25 mg were cut into small pieces and added to 7 ml of DMSO (dimethyl sulphoxide) in a test tube. The pigments were extracted into the fluid without homogenizing, but by incubating the same in dark at 65^{O} C for an hour till the tissues become pale, indicating the complete extraction of pigments into the fluid. The test tubes were covered with aluminium foil to avoid photo- destruction of the extracted pigments. The pigment extract thus obtained were read at 480nm, 645nm, 663nm, against a DMSO blank in a Shimadzu-UV- visible spectrophotometer UV-160. The chlorophyll content of the extract was determined as per the formula

$$\text{Total chlorophyll} = \frac{(20.2A_{645}) + (8.02A_{663})}{aX1000Xw} \text{ X } \text{ V (mg/g/fw)}$$

$$\text{Chlorophyll 'a'} = \frac{(12.7A_{663}) - (2.69A_{645})}{aX1000Xw} \text{ X } \text{ V (mg/g/fw)}$$

$$\text{Chlorophyll 'b'} = \frac{(22.9A_{645}) - (4.68A_{663})}{aX1000Xw} \text{ X } \text{ V (mg/g/fw)}$$

Where,

A= absorbance at specific wavelength

V= volume of the solution taken

A= length of light path in the cell

W= fresh weight of sample in gram

OBSERVATION

Boerhaavia diffusa Linn

Morphological Characters

Unpolluted (Plate 1A, B)

Diffuse herb; leaves green, ovate to (sub) cordiform, 2.5–2.9x1.9–2.3cm thick, chartaceous, glabrous or glaucous below, base truncate to (sub) cordate, apex obtuse to acute; stem thin, internodes to 5.65cm; petiole to 1.5cm; inflorescence axillary and terminal, 3-7 flowered, pedicel to 0.3cm; perianth tube 4mm, lower part prominently 5-ribbed, upper part deep pink, 4mm across; stamens 2 or 8, filaments 3mm, anthers 0.5mm; ovary 0.6mm; style 3mm; anthocarp club-shaped, glandular-hairy, top rounded(Matthew, 1983).

Polluted (Plate 2C, D)

Plants growing in the polluted site show the following features. Leaves small (1.1-1.5x0.8-1.4cm), pale green; petiole short to 0.8cm; stem thick compared to the plants of unpolluted site; internode short (2.2cm average); inflorescences few (Table 1).

Micromorphological Characters

Unpolluted

Adaxial (Plate 2A, B)

Costal regions

Cells distinct over midrib only, narrow axially elongated, rectangular to fusiform; hairs uniseriate, glandular, multicellular, uniseriate, terminal glandular cell is glandular assumes various shapes, viz., spherical, clavate, straight or curved.

Non-Costal regions

Cells larger isodiametric, rarely anisodiametric, spherical to ellipsoidal; walls thin, straight to arched (Table 2); stomata slightly smaller frequent, irregularly distributed, spherical to ellipsoidal (Tables 3, 5); of the three types of stomata namely tetra-, aniso- and anomocytic, tetracytic ones frequent (Table 4), stomatal polymorphism seen, knob like thickenings at both poles of most stomata seen; hairs frequent (Table7), glandular, uniseriate, measures 22-48µm in length, cells 2-5; the terminal cell is of various shapes and size, in all the cells nucleus is so prominent especially in lower cells; crystalliferous idioblast frequent.

Abaxial (Plate 3A, B)

Costal regions

Cells distinct over midrib only, similar to those of adaxial; hairs infrequent, uniseriate, glandular similar to those of adaxial.

Non-Costal regions

Cells mostly isodiametric, rarely anisodiametric, smaller than adaxial somewhat spherical with granular content, larger cells seen along with smaller cells; walls thin, arched; stomata frequent, irregularly distributed, mostly oval in shape, of the three types of stomata tetracytic ones dominant, anomocytic ones rare (Table 4) ; hairs infrequent, similar to those of adaxial with variously shaped glandular terminal cell (Table 7)

Polluted

Adaxial (Plate 2C, D)

Costal regions

Cells distinct over midrib, narrow, axially elongated, rectangular to fusiform; walls straight, slightly thick; hairs infrequent, similar to those of unpolluted but collapsed (Table7)

Non-Costal regions

Cells smaller than unpolluted, various shapes, (Table 2) isodiametric, mostly spherical; walls thin, straight to arched; stomata larger than unpolluted (Table 3), spherical, almost uniform sizes; of the three types of stomata tetracytic ones dominant (Table 4), polar thickenings faint; hairs frequent, similar to those of unpolluted, but highly collapsed, head cell buldged than unpolluted; crystalliferous idioblasts rare (Tables 7, 6).

Abaxial (Plate 3C, D)

Costal regions

Cells distinct over midrib only, similar to those of abaxial unpolluted; hairs infrequent, glandular, similar to those of abaxial unpolluted (Table 7)

Non-costal regions

Cells various shapes, irregularly oriented, more of anisodiametric, larger than unpolluted, almost uniform sizes (Table 2); walls thin, sinuous; stomata slightly less frequent, spherical, uniform in size, larger than unpolluted; of the three types, tetracytic ones frequent (Table 4); hairs frequent, highly collapsed(Tables 7, 9) crystalliferous idioblasts rare.

Leaf transection

Unpolluted (Plate 4 A)

Midrib consists of single, large, slightly flattened vascular bundle; sclerenchyma on the adaxial and abaxial side of the vascular strands; hypodermis 2 layered, thick walled; large, spherical, parenchymatous cells with raphides; lamina thickeness 462.5 μm (Table 9); both the epidermides single layered, cells barrel shaped with curved outer walls; cells of adaxial epidermis larger and deeper than abaxial epidermis; over the midrib cells small, slightly vertically elongated, pappilose, cuticle corrugated with crystalline granules; hairs infrequently seen; mesophyll differentiated into 3 regions; single layered palisade cells with frequent crystal containing idioblasts which sometimes protrude into the inner regions, middle smaller, spherical cells with chloroplasts, and 3-4 layered loosely arranged spongy cells with triangular, truncate, fusiform or hammer shaped cells, vascular strands possess few xylem tissues on the adaxial side and phloem beneath .

Polluted (Plate 4 B)

Midrib consists of 4-5 discontinuous vascular strands forming a ring; sclerenchyma on the adaxial and abaxial sides of the vascular strands, hypodermis 2 layered, thick walled, large, spherical parenchymatous cells with more raphides in midrib and mesophyll; lamina thickness 275 μm (Table 9); both the epidermides single layered, cells barrel shaped with curved outer walls, smaller than unpolluted; cuticle corrugated with crystalline granules; hairs frequent, head cell buldged, mesophyll differentiated into 3 regions similar to those of unpolluted; vascular strands possess few xylem tissues on the adaxial side and phloem beneath.

Petiole transection

Unpolluted (Plate 5A)

Petiole is hemispherical with a shallow central groove on the adaxial side; epidermial cells small, isodiametric to spherical, outer wall thick stained pink with saffranin and thin radial walls; cuticle heavily deposited with crystalline granules; hypodermis 2-3 layered, cells spherical to oval, collenchymatous, cells of ground tissue large, circular to polygonal; walls thin, parenchymatous, a few cells in the ground tissue show cluster of acicular calcium oxalate crystals in cavities; 5-7 vascular strands occur discontinuously in a curved fashion, in the center of the petiole, these strands flanked on both the adaxial and abaxial sides by 5-8 layers of sclerenchymatous cells, xylem is found on the adaxial side beneath of which phloem tissues occurs; xylem vessels are arranged in radial rows accompanied by trachieds, xylem fibres and xylem parenchyma; sclerenchyma cells are narrow, long and thick walled; hairs infrequent, similar to leaf.

Polluted (Plate 5B)

Epidermal cells and cuticle similar to those of unpolluted but often found to contain crystals frequently; cell size slightly decreased. hairs frequent, collapsed, with buldged head; vascular bundles similar to those of unpolluted, small with few radial rows of xylem and with more sclerenchyma; cells of ground tissue slightly smaller than the unpolluted. a few cells in the ground tissue occupied by crystals.

Stem transection

Unpolluted (Plate 6A)

Cuticle thick lamellar; epidermal cells small, rectangular with outer curved walls; hairs infrequent; hypodermis – a few layers of collenchyma in patches with intervening parenchyma followed by cortex; cortex parenchymatous with distinct intercellular spaces. 16 vascular bundles in 3 rings, 2 large bundles at the center surrounded by smaller ones forming an outermost loose ring beneath the pericycle; vascular bundles not surrounded by sclerenchyma, the central bundles collateral, open but cambial activity remains confined to individual bundles; secondary increase in thickness is due firstly to the formation of a continuous cambium cylinder in the outer ring; the newly formed bundles remain embedded in hard lignified conjunctive tissue; secondary phloem scanty formed outside opposite to the xylem vessels; crystals infrequent in cortical cells, more number of broad vessels; pith cells larger.

Polluted (Plate 6B)

Cuticle thick, lamellar; epidermal cells small, rectangular with outer curved walls; hairs frequent, collapsed; 12 – 13 vascular bundles in 3 rings, more of sclerenchyma; calcium oxalate crystals frequent in cortical cells; vessels less and narrow; Phloem slightly narrow; pith cells smaller crystalliferous idioblasts seen in the pith cells.

Content of chlorophyll was estimated in plants growing unpolluted and polluted sites.The results are given below.

No	Pigment(mg/g fr. weight)	Unpolluted site	Polluted site
1.	Chlorophyll A	1.84	1.46
2.	Chlorophyll B	0.27	0.19
3.	Total chlorophyll	2.12	1.66

Bougainvillea spectabilis **willd**

Morphological Characters

Unpolluted (Plate 7A, Plate 8B)

An arborescent shrub climbing over large trees and through other vegetation by means of the curved spines on the stem and branches; bark pale and corky, cracking into rectangular plates; branches and shoots hairy, very hairy when young; spines woody axillary, 1-2 inches long, more or less curved; leaves green, petioled to 1.3cm (average) lamina ovate or even rotundate in shape, obtuse or shortly acuminate, entire, memberanous to somewhat leathery in texture, (L)6.3 x (B)4.6cm (average) sparsely hairy above, hairy to hirsute below; internodes to 5.8cm (average) stem thick; flower heads terminal or axillary, seated on peduncles and more or less gathered into branched panicled inflorescence, peduncles simple or sometimes divided, each flower head consists of 3 bracts arranged as an involucre carrying the flower, bracts purple or rosy purple, ovate in shape, 1.5 in. long, 1.2 in. wide, obtuse at the tip, cordate at the base, memberanous in texture, articulately nerved; the flowers adnate to the median nerves of the subtending bracts, perianth tubular, corolla – like, hairy, 1 in. long, ending above in a 5 – lobed narrow mouth, fruit club-shaped, 5-ribbed, glabrous or pubescent (Bor & Raizada, 1982).

Polluted (Plate 7B, 8A)

Plants growing in the polluted site showed certain modifications such as stem thin with short spines; leaves pale green, small to (L)5.4 x (B)3.6cm (average), short petiole to 0.8cm (average); short internodes to 3.3cm (average); flowers a few pale pink in colour (Table 10).

Micromorphological Characters

Unpolluted

Adaxial (Plate 9 A, B)

Costal regions

Cells distinct over midrib and major veins only. Cells narrow, long, rectangular, fusiform; walls straight, thick; hairs uniseriate, long, 6-10 celled, glandular, cells brick shaped, terminal cell club shaped; walls thick, straight often curved.

Non-Costal regions

Cells medium sized, granular, mostly isodiametric polygonal; walls straight, thick(Table 11); stomata very infrequent, large, spherical, irregularly distributed to all directions, subsidiary cells strickingly different from other epidermal cells often containing oil globules (Tables12, 14), of the two types of stomata viz. tetra- and anomocytic, anomocytic ones dominant (Table 13); hairs infrequent, shorter than hairs of midrib, mostly 4 celled, terminal cell club shaped showed prominent nuclei, hair bases surrounded by radiating cells (Table 16).

Abaxial (Plate 10 A, B)

Costal regions

Cells distinct over midrib and lateral major veins; cells similar to those of adaxial; hairs similar to those of adaxial.

Non-Costal regions

Cells medium sized, various shapes, isodiametric, sometimes anisodiametric, rectangular, polygonal, narrow; walls thick, straight to arched; stomata frequent, similar to those of adaxial; of the 2 types of stomata, anomocytic dominant (Table 13); a few stomata are exceptionally larger having more than 5 subsidiaries (giant stomata) stomatal index 18.82 (Table 15); hairs frequent, similar to those of adaxial.

Polluted

Adaxial (Plate 9 C, D)

Costal regions

Cells narrow, similar to those of unpolluted.

Non-Costal regions

Cells small, polygonal containing one or more oil globules (Table 11); walls thick, straight, stomata very rare, both tetra- and anomocytic types present equally; hairs very infrequent, collapsed (Table 16).

Abaxial (Plate 10 C, D)

Costal regions

Cells similar to those of unpolluted, very narrow; hairs similar to those unpolluted, shorter, 4-5 celled.

Non-costal regions

Cells much smaller than unpolluted (Table 11), isodiametric polygonal; walls thick, almost all the cells contain oil globules; stomata more frequent and smaller than unpolluted, spherical (Tables 12, 15), of the two types of stomata, anomocytic ones dominant, stomatal index 12.88 (Table 15); hairs frequent than unpolluted (Table 16), most of the hairs collapsed, structure similar to those of unpolluted abaxial but narrow.

Leaf transection

Unpolluted (Plate 11 A)

Epidermides single layered, cells barrel shaped, horizontally elongated, cells of upper epidermis large and deep; cells of lower epidermis small and narrow; cuticle thick, lamellar; lamina thickness reduced 212.5 μm (Table 9) hairs present on both surfaces similar to abaxial leaf surface; palisade parenchyma single layered, cells long, narrow, compactly arranged; spongy parenchyma irregular with lot of intercellular spaces; large raphides (styloids) frequent, mostly lying perpendicular to both the epidermides; some styloids extend between upper and lower epidermis; epidermal cells of midrib region narrow, vertically elongated, often showing papilla like structure; hypodermis collenchymatous; ground tissue parenchymatous with unevenly thickwalled cells; vascular bundles 6 in number arranged in a semicircular fashion; each vascular bundle on its lower side surrounded by sclerenchyma cells; vessels very large thick walled.

Polluted (Plate 11 B)

Epidermides single layered, cells tabular; smaller than unpolluted on both epidermides, however cells are deeper than abaxial but less deep than unpolluted; cuticle thick lamellar; thickness of lamina increased 262.5 μm(Table 9); palisade cells single layered cells shorter than unpolluted; spongy parenchyma irregular, narrow; styloids similar to those of unpolluted; frequent and smaller; in mid-rib region hypodermis, cortical cells, and vascular bundles similar to those of unpolluted. However the vascular bundles mostly 7 but smaller; vessels not only reduced in number and also in size; the ground tissue cells containing idioblasts filled with sand crystals which are absent in unpolluted.

Petiole transection

Unpolluted (Plate 12 A)

Petiole abaxial side circular adaxial side flat; epidermis consists of thick walled narrow cells, vertically placed; cuticle thick, lamellar; hair infrequent, similar to those of unpolluted abaxial; vascular bundles 5-6 forming a eccentric ring; of the two central vascular bundles, one is bigger than the other; vessels irregularly placed; base of the vascular bundles surrounded by thick walled sclerenchyma; hypodermis collenchymatous; cortex cells thick walled, parenchymatous; crystelliferous idioblasts absent.

Polluted (Plate 12 B)

Shape similar to unpolluted; epidermis similar to unpolluted; cuticle thick, lamellar; hypodermis similar to those of unpolluted; cortical cells smaller in size but similar to unpolluted; the ground tissue similar to unpolluted but consists of idioblast containing sand crystals; vascular bundles eight in number forming a eccentric ring, but smaller in size; vessels number less than unpolluted; base of the vascular bundles surrounded by sclerenchymatous cells; however only a single large median bundle present instead of two in unpolluted.

Stem transection

Unpolluted (Plate 13 A)

Epidermis single layered cells tabular granular; walls thick, cuticle lamellar, thick. hairs infrequent similar to those of leaf; hypodermis consists of a row of vertically elonglated cells and almost like brick shaped; inner to this a ring of collenchyma 5-6 celled thick; inner to the collenchyma 5-7 layered paranchymatous cortex, cells large slightly thick walled; discontinuous ring of sclerieds distributed in the ground tissue, cells polygonal, various sizes with very thick lamellations, lumen very narrow; vascular bundles forming a continuous cylinder, showing included phloem; vessels large and broad; bundles on its lower side surrounded by broad, sclerenchymatous zone; pith consists of mostly large thin walled cells, in this ground tissue several pith bundles seen embedded; bundles similar to those of leaf as described earlier.

Polluted (Plate 13 B)

Epidermis similar to those of unpolluted, cells more thicker than unpolluted; cuticle thick; hairs rare; hypodermis, cortex, sclerieds are similar to those of unpolluted, however the collenchymatous region appears to be broader; the parenchymatous cortex becoming narrow; vascular bundles form a continuous ring similar to those of unpolluted, however vessels fewer in number and narrow; vascular bundles surrounded by more of sclerenchyma; pith bundles similar to unpolluted but the cells of ground tissue contain large amount of accumulation of starch grains.

Content of chlorophyll was estimated in plants growing in unpolluted and polluted sites. The results are given below.

No	Biochemical parameters(mg/g fr. weight)	Unpolluted	Polluted
1.	Chlorophyll A	1.68	1.54
2.	Chlorophyll B	0.45	0.28
3.	Total chlorophyll	2.12	1.82

Calotropis gigantea (L.) Ait. f

Morphological characters

Unpolluted (Plate 14 A, B)

A much branched, hardy, erect, woolly shrub, 1-5m in height;stems woody, round, tender ones covered with soft, loosely appressed, whitish, waxy or sometimes powdery pubescence; bark thick, light yellow or ash grey, soft, corky, deeply fissured; internodes to 8.2cm;leaves green, fleshy, cuneate-obovate, or obovate-oblong with a narrow cordate or often amplexicaule base smooth above, cottony below of, 14.3 x 8.6cm (average);flower lilac or pale rose or purple , rarely light ,greenish ,yellow or white , in simple or compound cymose – corymbs . (Anonymous, 1992)

Polluted (Plate 14 C, D)

Plants growing in polluted site are small in height 1-3m, herbaceous , leaves small with 10.4 x 6.7 cm (average), pale green in colour , short internodes to 6.3cm (average) (Table18).

Micromorphological characters

Unpolluted

Adaxial (Plate 15 A, B)

Costal region

Cells distinct over midrib and major veins only,cells axially elongated rectangular to fusiform ; walls thick, straight.

Non- costal region

Cells mostly isodiametric, various shapes viz.,polygonal, rectangular and of various sizes,walls thin; stomata frequent, large, ellipsoidal (Tables 19,20),of the four types of stomata viz., para-, aniso-, tetra- and anomocytic, paracytic ones dominant (Table 21), incompletely amphicyclic (dicyclic, tricyclic), gaint stomata infrequent; cuticular striations rarely seen, running from the outer surface of the guard cells in parallel bundles to a short distance then becomes obscure; hairs infrequent, large, unicellular, filiform (Table 24).

Abaxial (Plate 16 A, B)

Costal region

Cells similar to those of adaxial.

Non-costal region

Cells large(58x26.5μm), mostly anisodiametric, various shapes viz, rectangular, trapezoidal, irregularly distributed, walls curved, thin (Table 19); stomata elliptical, large, irregularly distributed in all directions ,of the four types of stomata,paracytic one dominant (Table 21), lateral subsidiaries often seen radially divided making the stomata aniso- or tetracytic,some stomata incompletely amphicyclic (dicyclic rarely tricyclic); some stomata of large sizes surrounded by five or more subsidiaries infrequently seen (30X20μ); cuticular striations frequent, running from the outer surface of the guard cells in parallel bundles to a short distance then becomes obscure; hairs frequent, uniseriate, filiform, non-glandular hairs (Table 24), hair bases single or in pairs surrounded by rosette of cells.

Polluted

Adaxial (Plate 15 C, D)

Costal regions

Cells small , similar to those of adaxial unpolluted.

Non-costal regions

Cells various shapes and size, similar to adaxial unpolluted, walls thin, straight; stomata more frequent, smaller (Table 20), of the four types of stomata paracytic ones dominant (Table 21), tetracytic and anomocytic types frequent than adaxial unpolluted, gaint stomata infrequent; cuticular striations infrequent; hair bases single or in pairs, more frequent than unpolluted.

Abaxial (Plate 16 C, D)

Costal region

Cells distinct over midrib and major veins only , cells axially elongated rectangular to fusiform; walls thick, straight.

Non-costal regions

Cells similar to those of abaxial unpolluted but smaller, more frequent (Table 23), various shapes viz, polygonal, rectangular, trapezoidal; walls thin, straight to slightly sinuous;stomata more frequent, size slightly smaller (Table 20), of the four types of stomata, paracytic one is dominant (Table 21); large sized giant stomata frequent with more number of subsidiary cells, stomata incompletely amphicyclic rarely dicyclic; cuticular striations more frequent running in parellel bundles from the outer surface of the hair bases to a short distance, but becomes faint; hairs more frequent hair bases single or in pairs, hair cells thin walled with prominent nuclei.

Leaf transection

Unpolluted (Plate 17 A, B)

Both the epidermides single layered ;cells in the lower epidermis smaller, thin walled, tabular, less deep,cells in the upper epidermis rectangular, deep;guard cells fleshed with epidermis, but appears to be sunken because of thick cuticle, striated on the adaxial epidermis, thicker than lower epidermis; palisade 3 – layered, compact, spongy parenchyma broad, irregular cells; latex vessls in the mesophyll tissue frequent; in midrib region epidermial cells small slighty vertically elongated; below the upper epidermis and above the lower epidermis many layered collechyma cells; vascular bundles cresent shaped embedded in the ground parenchyma tissue; latex vessels many in the parenchyma tissue; xylem not dense; lamina thickness 1042 μm (Table 9)

Polluted (Plate17 C, D)

Epidermis similar to those of unpolluted, however the cells become smaller, the adaxial cells are deeper than abaxial; cuticle thick, striated; palisade distinctly four layered; compact with more number of chlorolplast, cells narrow and longer than unpolluted, spongy parenchyma narrow irregular, similar to those of unpolluted; lamina thickness increased 275μm (Table 37); collenchymatous hypodermis similar to unpolluted, but less in lower epidermis; vascular bundles cresent shaped with dense xylem; latex cells more frequent.

Stem transection

Unpolluted (Plate18 A)

Epidermis single layered, cells small, thickwalled, cells more or less vertically elongated; cuticle thick, slightly striated; hairs frequent similar to leaf, thin walled; hypodermis collenchymatous, well developed; cortex parenchymatous, thick walled; vascular bundles forming ring, endodermis indistinct, xylem in vertical rows, not dense; laticiferous tissue associated with vascular bundles of both cortex and pith; pith parenchymatous; crystalliferous idioblasts infrequent in pith and cortex.

Polluted (Plate 18 B)

Epidermis single layered similar to unpolluted; hairs frequent; cuticle similar to unpolluted; hypodermis collenchymatous poorly developed; cortex parenchymatous, cell slightly smaller than unpolluted; xylem dense than unpolluted; lactiferous cells both outer and inner forming a ring in the cortex and well developed; pith parenchymatous; crystalliferous idioblasts more frequent in both pith and cortex.

Catharanthus roseus (l.) Don.

Morphological Characters

Unpolluted (Plate- 19 A)

An erect handsome, herbaceous, annual, leaves deep green, oval oblong or obovate, glossy; inter node length is 3.13 flowers in cymose axially clusters, with or deep rose-coloured, corolla gamopetalous, usually rotate; lobes 5, spreading, contorted; stamen 5, inserted on the corolla-tube. Filament usually short; anthers liner – oblong; ovary one celled with axial placenta; fruits pairs of follicles.

Polluted (PLATE- 19 B)

Plants growing in polluted site show the following differences in their morphological features. Leaves small (3.7-4.5x 1.1-1.7 cm); stem thick compare to the plants of unpolluted site; internodes length is (1.68) short. The number of flowers per inflorescence (20 averages)

Micromorphological Characters

Unpolluted

Adaxial

Costal regions

Cells distinct over midrib and major lateral veins, narrow axially elongated, rectangular to fisiform, rhomboidal; walls straight thick; hairs unicellular, non-glandular ,warty ,conical type , base slightly broader cuticular striation arising from the hair base runs for the short distance in parallel bundles; stomata absent .

Non-Coastal regions

Cells small, polygonal some times oval to spherical, walls thin straight to arched; stomata small irregularly distributed , oval mostky anisocytic and tetracytic, size 25.75 µm × 20 µm; hairs frequent similarto the coastal region size 93.75 µm × 43 µm.

Abaxial (Plate-21 A)

Coastal region

Cells distinct over midrib and major lateral veins , axially elongated , rectangular to fusiform, rhomboidal; walls straight, thick, hairs unicellular, non-glandular warty, conical type , base slightly broader ,size (25.25 µm × 21.25 µm), stomata absent.

Non-Coastal regions

Cells anisodiametric , longer than broad elongated , some time spherical , walls thin arched to slightly serious , stomata frequent irregular distributed(Table-3). Oval to spherical small mostly anisocytic and tetracytic size 25.25 µm × 21.25 µm,cuticular straiation arising from the margin of the guard cells of some of the large stomata (gaint stomata), straiations run for a short distance in parallel bundles , hairs unicellular, non glandular(Table-4) becomind broader at the base, cuticular straiation arising from the hair base runs for the short distance in parallel bundles, size 168 µm × 20.5 µm.

Polluted

Adaxial

Costal region

Cells distinct over midrib and major lateral veins , axially elongated , rectangular to fusiform ,rhomboidal; hairs absent or in some places hair bases of the fallen hairs seen; stomata abnormalities rare, stomata frequent increase compare to the unpolluted region(166.98 mm.sq).

Non Coastal Region

Cells smaller than unpolluted, polygonal, sometimes spherical, isodiametric, sometimes anisodiametric, walls thin, straight to arched; stomata frequent (166.98/mm.sq), spherical uniform size 30 µm × 22.5 µm hairs absent or in some places hair bases of the fallen hairs seen; stomatal abnormalities rare.

Abaxial (Plate 21 B)

Coastal region

Cells distinct over midrib and major lateral venis, axially elongated, rectangular fusiform rhomboidal, walls straight, thin, sinuous; hairs absent or in some places the hairs bases of the fallen hairs seen. The stomatal frequent large(488.4/mm.sq)compareto the unpolluted region.

Non Coastal Region

Cells smaller than unpolluted; stomata more frequent longer than unpolluted walls sinuous; stomata spherical uniform in size 30 μm × 20.75 μm ; hairs absent appears to the papillous, hypodermis 2-3 layer cholenchymatous, cartex parenchymatous cells large thin walled vascular bundles cresent shaped with many layers of xylem, hairs non glandulor , conical uniseriate 3-4 celled gradually taperony tip bland walls thick.

Leaf Transection

Unpolluted (Plate 23 A)

Epidermis single layered on both surface, cells rectangular, tabular thin walled those of abaxial epidermis, cuticle slightly thick, lamellar thickness is 302.18 μm ; Hairs unicellular, conical type, non glandular with thick warty walls, palisade cells, elongated slightly broader one sometimes 2 rows with full of chloroplast, spongy Parenchyma many celled thick slightly irregular with lot of chloroplast , xylem cresent shaped with several rows of xylem.

Polluted (Plate 23 B)

Cuticle appears to be slightly thicker, palisade cells more compact much elongated narrow, the number of chloroplast reduced, spongy parenchymata irregular , midrib region recent shaped but with several rows of smaller vessels . Bundles arranged in cresent shaped, parenchymatous cell small a few layers of cholenchymatous hypodermis .

Petiole Transection

Unpolluted (Plate 22 A)

Semicircle out layer, Epidermis single layered cells vertically elongated in some region appears to the papillous; cuticle slightly thick; hypodermis 2-3 layer cholenchymatous; cortex parenchymatous, cells large, thin walled; vascular dundle crescent shaped with many layers of xylem; hairs non glandular conical, uniseriate 3-4 celled gradually taperong tip blond walls thick.

Polluted (Plate 22 B)

Semicircle, epidermal single layered, cells vertical elongated, more of papillous an adaxial side, cuticle thick, hypodermis several layered, cholenchymatous cell small cresent shaped bundle many rows of xylem with smaller vessels.

Stem Transection.

Unpolluted (Plate 24 A)

Circular in outline, epidermis single layered, cell small, vertically elongated, cells appear papillous, cuticle thick lamellar, hypodermis 2-3 layered Cholenchymatous; inner cortex parenchymatous cells large spiracle; xylem circular with several rows of xylem; pith parenchymatous crystals rarely seen

Polluted (Plate 24 B)

Circular in outline; epidermis single layers, cells small, vertically elongated, papillous rarely seen cuticle thick lamellar hypodermis cholenchymatous 2-3 layered ; inner cortex parenchymatous similar to unpolluted. Xylem form a ring with several rows of xylem vessels are narrow diameter compare to unpolluted; pith crystals absentees

Root Transection

Unpolluted (Plate 25 A)

Circular in outline; epidermis single layered highly distorted because of secondary growth given very early stage, secondary growth in the cortical regions also same; the cells of cart uniformly arrange with distinct phellogen; secondary xylem with laxer (loosely) rows of vessels, the larger in diameter.

Polluted (Plate 25 B)

Circular in outline; epidermis single layered highly distorted because of secondary growth given very early stage, secondary growth in the cortical regions also same; the cells of cart uniformly arrange with distinct phellogen; secondary xylem with laxer (loosely) rows of vessels, the larger in diameter, xylem vessels so crowd and profuse then plants of unpolluted site.

Duranta repens L.

Morphological Characters

Unpolluted (Plate 26 A)

A small tree to 6 m; occasionally spiny and with dropping 7- angled branches; ovate 6.6cm of leaf in length; Breadth of the leaf is 3.2 cm (average) Therefore leaf size 6.6 × 3.2 cm ; length of the internode 3.5 cm average. Petiole length km (average); Twig length 57 cm (average); leaf colour dark green; small flowers with cylindrical corolla and spreading luinb lilac – blue; flowers abundant 26 numbers per twig (average) followed by orange yellow berries tropical; fruit weight for 10 numbers (average) is 2.139 gm; Androecuim 4 in number of variable size; of the four, too long, too short are seen; stamens epipetalous; anthers 2-celled; dithecous, saggitate, filaments long with longer staminal hairs with higher frequency containing glandular head. Gynoecium with style long, stigma simple globuse. The plant is found in (Florida, West Indies,, Mexico to Brizil) 'Pigeon berry'; staminal hair size (87×9) cm.

Polluted (Plate 26 B)

Plants growing in polluted site are small in height of 4cm ; leaves smaller in size of 4.5 cm in length and 1.9 in breadth; therefore size is (4.5×1.9) cm; size of internode 2.2 cm; petiole length 0.6 cm (average); twigh length 40 cm average; internode size lesser than unpoluted, leaf colour pall green; flower pale blue in colour; flowers less 19 numbers per twig (average); followed by pall orange yellow berries; fruit weight for 10 numbers (average) is 1.408 gm Androecium smaller than unpolluted; filaments short with, short staminal hairs of lesser freavency containing glandular head; Gynoecium with very short style; stigma simple globuse; staminal hair size (55×7) cm.

Micro morphological characters (Plates 30 A-D)

Unpolluted

Adaxial side

Costal region

Epidermal cells very distinct; rectangular; cynouse and walls undulated; hairs uniseriate; 3-celled sickle shaped; non-glandular hairs; terminal part of the hair pointed or àpering or sharp.

Non-costal region

Cells distinct; large isodiametric; walls thin; unclulated; stomata absent; hairs frequent; glandular; uniseriate; terminal part tapering and pointed.

Unpolluted

Abaxial side

Costal region

Epidermal cells district; rectangular; aynouse and walls undulated; hairs infrequent uniseriate; non-glandular hair similar to those of adaxial side.

Non-costal region

Cells distinct; large isodiaunetric in its nature; especially cells are suraller than adaxial size, walls very thin, stomata frequent irregularly distributed mostly oval in its shape; of the two types of stomata Anisocytic and Anomocytic, anomocytic one is dominant, Anisocytic one is rare in distribution; hairs infrequent; similar to those of adaxial 3- celled, sickle shaped hairs are present with tapering or pointed terminal cell.

Polluted

Adaxial side

Costal region

Cels distinct; rectangular; walls very straight, thin and fragile, glandular hairs 3-celled sickle shaped but reduced in its size and frequency.

Non-costal region

Cells smaller than unpolluted; various shapes isodiametic, walls thin and fragile; straight walled; glandular hairs infrequent, hairs shiverled and collapsed; hair size small and reduced; staminal hair size is also reduced stomata absent.

Polluted

Abaxial region

Costal region

Cells distinct, rectangular, walls very straight, thin, hairs infreuent, glandular in nature.

Non-costal region

Cells smaller than unpolluted; isodiametic; walls thin; very straight stomata more frequent; elliptical; unforum in size; smaller than unpolluted; of the types of stomata anisocytic and anounocytic; Anounocytic one are frequent; hairs infrequent;

Leaf transaction

Unpolluted (Plates 29 C)

Midrib consists of single large vascular bundle selerenchyna on the adaxial and abaxial side of vascular strands; hypodermis double layered; thick walled; spherical in shape; lamina thickness 520.5 cm both the epidermis single layered; cells barrel shaped cells of adaxial epiderunis smaller than abaxial epideriums. Over the unid-rib, cells are large spherical; cuticle with crystalline granules; hairs frequently seen; unesophyll cells large; chlorenchyn alous; cyleisdrical cells with numrous cloroplasts and 3-4 layered tightly arranged without intercellular spaces in the spongy cells spherical in its shape; vascular stands possess xylem tissues on the adaxial side and phloem beneath xylem.

Polluted (Plates 29 D)

Midrib consists of single smaller vaseular bundle, sclerenchgunatous cells on the adaxial and abaxial side of the vascular strands; hypodermis double layered; thick walled; spherical in shape; lamina thickness 475 cm.

Both epidermis are single layered; cells barrel shaped; cells of adaxial epidermis smaller than abaxial epidermis; over the inidrib cells are large; spherical; cuticle with crystalline granules; hairs absent. Mesophylth cells small. chlorenchynaths; cylindrical cells with numerous chloroplasts and 3-4 layered tightly arranged spongy cells without intercellular spaces, spherical; vascular strands possess xylem tissues on the ada-xial side and phloem beneath the xylem.

Petiole transactions

Unpolluted (Plates 29 A)

Epidermal cells are small, isodiametric to spherical with this radial walls; article deposited with crystalline granulls; hypoderunis 3 layered; cells spherical to oval, collenchymaltous; large ground tissue; circular, walls thin parenchymatous; few cells in ground tissue show darkly stained clusters of calcium oxalate crystals in cavities; vascular strand occur contentiously like a crescent in the centre of the petiole; xylem is found on the adaxial side beneath of which phloem tissues occurs; xylem vessels are arranged in radial rones accompanied by trachieds. Xylen fibres and Xylem parencheyma; hairs more frequent; End of the petiole curved like hook.

Polluted (Plates 29 B)

Epiermal cells and cuticle similar to those of unpolluted; cell size slightly decreased hairs frequent; with tapering end; vascular bundle similar to those of unpolluted small with continuously arranged cresent shaped one present; cells of ground tissue slightly smaller than the unpolluted; a few cells in the ground tissue occupied by crystals.

Stem Transection

Unpolluted (Plates 28 A)

Cuticle thick lanellar; epidermal cells single layered small with rectangular shape; hairs frequent; hypodermis consists of 5-6 called thick collenchefunatous cells which are rectangular. Inner to the collenchefunatous cells 3-4 layered parenchyunatous cortex with a ring of patches of cells. Cells large slightly thick walled; Mascular bundle forming ring; endodermis distinct; xylem in vertical rows; with parenchymatous; crystalliferous idioblasts infrequent in cortex.

Polluted (Plates 28 B)

Cuticle thick lanellar; epidermal cells single layered small rectangular hairs frequent, hypodermis collenchymatous, smaller than unpolluted; cortex Paranchymatous with a right a patches of cells; patch size smaller than unpolluted. Xylem dense; laticiferous cells in cortex well developed, Pik Parenchymatous; Crystalliferous idioblast infrequent in cortex.

Chlorophyll Estimation of *Duranta Repens*

Content of Chlorophyll was estimated in plants growing in unpolluted and polluted sites. The results are given below

Sl.No.	Samples	Chlorophyll 'a'	Chlorophyll 'b'	Total Chlorophyll	Carotenoid
1.	*Duranta repens* Unpolluted	3.35	6.64	9.98	0.06
2.	*Duranta repens* Polluted	3.29	6.46	9.75	0.02

Eclipta alba (L.) HASSK

Morphological Characters

Unpolluted (Plate 31 A)

Herb with ascending branches to 50(75)cm, often with short, axillary branchlets; stem thin, slender, green, internode 4.9cm (average); leaves green, opposite, simple, lanceolate, 7x2.5cm (average), chartaceous, hirsute above and below, base cuneate, decurrent, margin irregularly serrate – dentate, apex acute, subsessile; capitula 1-3, axillary or terminal, stalked, heterogamous, involucre companulate; phyllaries
2 – seriate, outer florets (sub) biseriate; inner pappus of 2, minute, acute, connate scales; style 1.5 mm; achenes oblong or 3 – quetrous, hairy above (Matthew, 1983).

Polluted (Plate 31 B)

The plants of polluted site showed stem thick, hard, brownish, heavily strigose; internodes short 3.9cm (average), leaves broader and shorter, 6x2 cm (average), dark green, tip burns frequent. (Table 25).

Micromorphological Characters

Unpolluted

Adaxial (Plate 32 C, E)

Costal regions

Cells distinct over midrib and lateral veins, axially elongated rectangular to fusiform; walls thick and straight, cells of minor veins rectangular; walls thin and sinuous; hairs frequent uniseriate, non-glandular, conical, uniformly distributed towards tip of the leaf, base bulbous, broad, raised on the epidermis, body generally two celled, rarely three, the lower cells long with thick encrusted wall, the upper cell small beak like with a dense content inside, tip pointed.

Non-costal regions

Cells small, iso-, or anisodiametric irregularly oriented (Table 26); walls thin, sinuous, sinuous mostly 'U' shaped; stomata large (Table 27), oval to ellipsoidal, frequent, irregularly oriented; of the two types of stomata, tetracytic ones slightly more than anisocytic (Table 28); hairs two types, non-glandular, uniseriate conical hairs with bulbous base similar to those of costal region, frequent (Table 32), cells around the bulbous base is characteristically radiating; the other type uniseriate, glandular hairs with thin walls, infrequent, base slightly bulbous, body 4-5 celled almost equal in length (Table 33).

Abaxial (Plate 33 A, B)

Costal regions

Cells distinct over midrib and lateral veins, axially elongated, trapezoidal, rectangular to fusiform; walls straight, thick; hairs similar to those of adaxial.

Non-costal regions

Cells large, irregular, anisodiametric, various shapes (Table 26); walls thin, sinuous, sinuous mostly 'U' shaped; stomata frequent, slightly smaller than adaxial, ellipsoidal, irregularly oriented in all directions (Tables 27, 29), of the two types of stomata tetracytic ones more frequent (Table 28); hairs two types similar to those of adaxial.

Polluted

Adaxial (Plate 32 D, F)

Costal regions

Cells distinct over midrib only, rarely distinct in lateral veins, similar to those of adaxial unpolluted; frequency of the hairs increased; hairs two types similar to those of adaxial non-polluted, length of both the hairs become reduced (Tables 32, 33).

Non-costal regions

Cells larger than adaxial unpolluted, elongated, various shapes, irregularly oriented; walls thin, mostly arched to slightly sinuous; hairs two types similar to those of adaxial unpolluted (Tables 32, 33).

Abaxial (Plate 33 C, D)

Costal regions

Cells distinct only over midrib, rarely over minor veins, narrow, rectangular longer than broad, sometimes fusiform; walls slightly thick, straight; hairs similar to those of abaxial unpolluted; length of both the hairs decreased over abaxial unpolluted (Tables 32, 33), however the wall of the non-glandular conical hair become very thick than unpolluted, frequency of these two types of hairs has increased (Table 31).

Non-costal regions

Cells slightly larger and more frequent than abaxial unpolluted, anisodiametric, irregularly oriented (Table 26); walls thin, slightly sinuous to arched; stomata small mostly spherical, ellipsoidal, more frequent than unpolluted (Table 27), of the two types of stomata anisocytic one more frequent than tetracytic (Table 28), a reverse condition is seen as that of unpolluted; hairs two types, similar to those of abaxial unpolluted, however the size of the hairs come down with a very thickened wall (Tables 32, 33).

Leaf transection

Unpolluted (Plate 34 A)

Midrib consists a main large central bundle and four small lateral bundles, arranged crescent shaped; crystalliferous idioblasts infrequent in the cortical region of midrib, lamina thickness 1510.9 µm (Table 9); upper epidermis single layered cells large deep, tabular; cuticle lamellar, thick; palisade cells elongated, mostly single layered; lower epidermis single layered, cells small, not deep; cuticle thin, lamellar; hairs infrequent.

Polluted (Plate 34 B)

Midrib consists of single vascular bundle with five small vascular bundles three on one side and two on other side; vessel elements size slighty reduced however number increased; crystelliferous idioblasts absent; the size of the cortical parenchyma cells also decreased; upper and lower epidermis similar to unpolluted; however the cell size of the adaxial epidermis increased; palisade cells single layered, cells narrow and shorter; the amount of spongy parenchyma increased; the thickness of lamina decreased 937.8 µm (Table 9).

Stem transection

Unpolluted (Plate 35 A)

Epidermis single layered, cells small, narrow, tabular; cuticle slightly thick lamellar; cortex parenchymatous often showing small air spaces; vascular bundles many in a ring each with rows of vessels and fibres, bundle cap small; pith parenchymatous, cell large, walls thin; crystals absent; hypodermis mostly two layered, thick walled parenchymatous.

Polluted (Plate 35 B)

Epidermis similar to those of unpolluted; cuticle thick, lamellar; hypodermis four layered; air spaces in the cortex appear to be larger; bundle cap larger; vascular bundle with more number of larger vessels with more fibres; pith cells large, thin walled, crystals absent.

Nerium odorum **Soland.**

Morphological Characters

Unpolluted (Plate 36 A, C)

A large glabrous evergreen shrub with milky juice. leaves usually in whorls of three narrow, coriaceous (17.5-21.2 cm x 1.6-2.4 cm), linear, lanceolate, acuminate, tapering into the short petiole (1 cm), dark green and shining above, midrib stout; nerves numerous spreading horizontally; internode (1.5 - 2.5 cm), flowers red rose coloured, average of flowers per inflorescence 9.5, fragrant; calyx - lobes lanceolate; corolla 3.8 cm diameter, lobes rounded. corolla 5, gamopetalous, funnel - shaped lobes spreading, twisted slightly scented. corona - appendage lancinate into numerous irregular segments; stamens 5, epipetalous inserted near the top of corolla tub anthers sagittate, conniving arand and adhering to the stigma, produced in the long twisted appendages; gynoeciun bicarpellary, ovaries united, placentation parietal, ovules many per carpel; Follicles 15-23 cm long, rigid, at length separating long follicles with brown coma to the seeds.

Polluted (Plate 36 B, D)

Plants growing in the polluted site show the following differences in their morphological features. Leaves small (6.5 - 10.1 cm x 0.5 - 1.3 cm), pale green; petiole short (0.4 cm); stem thick compared to the plants of unpolluted site; internode short (1.1 - 2.1 cm), the number of flowers per inflorescence (4.2) (Table 34).

Micromorphological Characters

Unpolluted (Adaxial) (Plate 37 A)

Costal Regions:-

Cells distinct over midrib only, cells axially elongated, rectangular to fusiform; walls thick, straight, hairs and stomata are absent.

Non-Costal Region

Cells small, isodiametric, polygonal, trapesoidal, rectangular; cell wall slightly thick, straight to arched; stomata absent, hairs infrequent, 7.3 µm. small, unicellular, non-glandular conical hairs with pointed tip.

Abaxial

Costal Region

Cells distinct over midrib only; cells similar to those of adaxial.

Non-Costal Region

Cells mostly isodiametric, elongated, narrow longer than broad, walls straight, slightly thick; stomata confined to crypts(80.6 µm. average diameter); the crypts are circular to oval shape, sometimes irregular, many crypts occur as one islet. sometimes they are very close to each other, each islet consists of 5-8 crypts, the crypts densely clothed with unicellular, non-glandular conical hairs, such a hairs also seen between the islet of non-stomatiferous region infrequently (Table 35-36).

Polluted (Plate 37 B)

(Adaxial)

Costal Region

Cells small, similar to those of adaxial unpolluted. cell wall thick, straight; hairs and stomata absent.

Non-Costal Region

Cells small but slightly larger than unpolluted, polygonal, trapesoidal, retangular; cell wall thick, straight to arched; hairs infrequent (12.3 µm), often sclereid like thick walled cells rare frequently found. non-glandular unicellular conical type with pointed tip.

Abaxial

Costal Region

Cells distinct over midrib only; cells similar to those of adaxial.

Non-Costal Region

Cells mostly isodiametric, elongated, narrow but slightly appear to be larger than unpolluted, longer than broad, walls thick, straight; stomata confined to crypts (53.8 µm. average diameter); crypts appear to be smaller than unpolluted, highly distrated, sometimes irregular many crypts occur as one islet, sometimes very close to each other, each islet with of 4-6 crypts. The crypts are densely clothed with unicellular, non- glandular conical hairs, such hairs also seen between the islet of non-stomatiferous region infrequently, the frequency of hairs in non- stomatiferous region have increased, hairs variously bent, thick walled; sclereid like cell are seen frequently.

Leaf Transection

Unpolluted (Plate 38 A, 39 A)

Epidermis 3-4 layered on the adaxial side, 4-6 layered on the abaxial side; cuticle very thick, lamellar; palisade parenchyma 2-3 layered, spongy parenchyma cells small, irregular; stomatal crypts are seen on the abaxial epidermis, densely clothed with unicellular, non-glandular filiform, conical hairs, variously bent; lamina thickness 140 µm; midrib broad, vascular bundle crescent shaped with several rows of xylem; massive collenchymatous hypodermis seen in the midrib region; bundle sheath extension parenchymatous, cells small, roundish and thick walled.

Polluted (Plate 38 B, 39 B)

Epidermis 3-4 layered on the adaxial side, 4-6 layered on the abaxial side; cuticle thick, lamellar; palisade parenchyma 2-3 layered, narrow; spongy parenchyma cells small, irregular; stomatal crypts are seen on the abaxial epidermis densely clothed with unicellular, non-glandular filiform, conical hairs, variously bent; lamina thickness 125 µm; midrib comparatively narrow than unpolluted; vascular bundle crescent shaped, the rows of xylem are less in number; bundle sheath extension parenchymatous, cells small, roundish and thick walled, crystalliferous idoblasts frequently seen.

Petiole

Unpolluted (Plate 40 A)

Oval in shape with a shallow groove on the adaxial side; epidermis single layered, cells small, thick walled; cuticle thick, lamellar; unicellular, non-glandular conical hairs frequently seen all over the surface but more on the shallow grooved region; vascular bundle crescent shaped with rows of xylem, cortex broad; the hypodermis broadly collenchymatous many cells thick, inner cortex parenchymatous, cells uniformly roundish in shape.

Polluted (Plate 40 B)

Oval to spherical shape with shallow groove on the adaxial side, narrower than unpolluted; epidermis single layered, cells small, thick walled; cuticle thick lamellar, unicellular, non-glandular conical hairs frequently seen all over the surface, but more frequent than unpolluted. Vascular bundle crescent shaped, the amount of xylem drastically reduced; cortex broad. the hypodermis broadly collenchymatous, many celled thick, inner cortex parenchymatous, cells uniformly roundish in shape, cortex broad. crystalliferous idioblasts of various sizes so frequently seen.

Content of chlorophyll was estimated in plants growing in unpolluted and polluted sites. The results are given below.

No.	Pigment(mg/g fr.weight)	Unpolluted site	Polluted site
1.	Chlorophyll A	1.68	1.54
2.	Chlorophyll B	0.45	0.28
3.	Total Chlorophyll	2.12	1.82

Tacoma stans (l.) kunth.

Morphological Characters

Unpolluted (Plate 41 A)

An erect, sparingly pubescent or nearly glabrous shrub, 2-4 m high; internode length is 3.75cm(averages); leaves opposite, odd- pinnate, up to 20cm in length; leaf lets 5 or 7, lanceolate to oblong – lanceolate, 6-13cm long and slenderley acuminate base, margins sharply serrate, panicles terminal; flowers racemosely arranged on the few branches; inflorescence averages is 56.6 cm; calyx green 5mm long, 5-toothed, corolla yellow 4-4.5cm long, capsules linear about 15cm long 8mm wide, acuminate.

Polluted (Plate 41 B)

Plants growing in the polluted site show the following differences in their morphological Characters, internode short length 2.15(averages); leaves small (7.7 – 11cm x 1.3 – 3.6 cm) pale green; petiole short 2 cm; stem thick compared to the plants of unpolluted site; inflorescences small size (20cm averages) compared to the plants of unpolluted site.

Morphological Characters

Unpolluted
Adaxial

Costal regions:

Cells distinct over midrib and lateral veins ; cells small axially elongated, narrow ,rectangular to fusiform,longer than broad; walls thick ,straight; hairs rarely seen, which are of non glandular uniseriate conical type.

Non coastal regions:

Cells small isodiametric to anisodiametric ; walls thin slightly sinuous ; stomata absent ; hairs 2 types

1. Uniseriate non glandular conical hairs (size 17.82µm) in frequent.
2. Glandular pellate hairs base one celled, stock one celled,pellate head 10-15 cells radiating, infrequent (size 53.46µm) .

Abaxial (Plate 42 A)

coastal regions

Cells distinct over midrib and lateral veins ; cells small axially elongated, narrow, rectangular to fusiform ; walls thim sinuous mostly 'U' shaped; stomata frequent medium sized;hairs frequent.

Non coastal regions

Cells medium sized isodiametric; walls thin sinuous mostly 'U' shaped; stomata frequent medium sized, oval irregularly distributed, mostly tetracytic; hairs 2 types.

1. Uniseriate non glandular conical hairs mostly 3-4 celled; walls thick ,hairs frequent(64.02µm)
2. Glandular pellate hairs similar to coastal region. Hairs frequent,pellate disc with dense condent.(24.42µm).

Polluted

Adaxial

Costal regions

Cells distinct over midrib and lateral veins ; cells small axially elongated, narrow ,rectangular to fusiform, walls thick ,straight; hairs rarely seen, which are of non glandular uniseriate conical type.

Non coastal regions:

Cells smaller than unpolluted; walls thin slightly sinuous to sinuous; stomata absent,hairs 2 types

1. uniseriate non glandular conical hairs mostly 3-4 celled; walls thick ,hairs frequent(16.56µm).
2. Glandular pellate hairs similar to coastal region. Hairs frequent, pellate disc with dense condent.(42.2µm).

Abaxial (Plate 42 B)

coastal regions:

Cells distinct over midrib and lateral veins ; cells small axially elongated, narrow ,rectangular to fusiform, walls thick ,straight.

Non coastal regions:

Cells medium sized isodiametric; walls thim sinuous mostly 'U' shaped; stomata frequent medium sized ,oval irregularly distributed, mostly tetracytic; hairs 2 types.

1. uniseriate non glandular conical hairs mostly 3-4 celled; walls thick ,hairs more frequent (102.3µm).
2. Glandular pellate hairs similar to coastal region. Hairs morefrequent,pellate disc with dense condent.(27.72µm).

Leaf Transection

Unpolluted (Plate 44 A)

Midrib so brominant circular in outline ;hairs are confine to the adaxial regions;Epidermis single layered cells narrow small; cuticle thin lamellar or strained on the midrib ; vascular bundle in the midrib semicircle shaped; vascular bundles surrounded by schlerenchymatous sheath, bundle sheath extension adaxial side . Lamina size is 137.5µm; epidermis single layered on both surface; cells of adaxial side deeper than abaxial side; cuticle thick lamella ;palisade cells small ,single row cells narrow both hairs of more frequent on on the abaxial side hairs 2 types.

1. uniseriate non glandular conical hairs in frequent.
2. glandular pellate hairs base one celled, stock one celled,pellate head 10-15 cells radiating, infrequent .

Polluted (Plate 44 B)

Midrib so brominant circular in outline ;hairs are confine to the adaxial regions; Epidermis single layered cells narrow small; cuticle thin lamellar or strained on the midrib; palisade cells, narrow hairs frequent on adaxial side, narrow, hairs are seen all round but more on adaxial; hairs 2 types

1. uniseriate non glandular conical hairs frequent.

2. glandular pellate hairs base one celled, stock one celled, pellate head 10-15 cells radiating, frequent.

Lamina thickness 125µm. Schlerenchyma very well developed, the amount of xylem reduced; cells of bundle sheath extension appear to the thick laminar similar to the unpolluted.

Petiole Trans

Unpolluted (Plate 43 A)

Circular in the outer line with a hump on the abaxial side; epidermis single layered; cells very small ; cuticle lamellar thick ; hypodermis chlorenchymatous; inner cortex parenchymatous; inner cortex parenchymatous ;cells large; both type of hairs seen mostly on the flat adaxial side; vascular bundle almost circular, wavy with broad vessels; pith cells large polygonal.

Polluted (Plate 43 B)

Outline similar to unpolluted; epidermis single layered; cells very small cuticle lamellar thick; schlerenchymatous hypodermis well developed; chlorenchymatous; hypodermis well developed pith cells large; polygonal thin walled crystal absent; amount of xylem higher then unpolluted; vessels small is size compare to the unpolluted.

Tridax procumbens Linn.

Morphological Characters

Unpolluted (Plate 45A, C)

Straggling hispid perennial herbs, leaves (4.8 - 5.6 x 2.1 - 3.5 cm) opposite, inciso - dentate or pinnatisect, petiole size (1.2 cm); internode (5.0 - 6.8 cm); heads medium sized, heterogamous, rayed; number of ray - flowers 5.3 perhead, fertile, number of disc-flowers 46.3 perhead, , fertile, involucre companulate, few seriate, outer broad, herbaceous, inner scarious; receptacle flat or convex; paleae membranous; corolla of flowers ligulate or 2 - labiate, the outer lip large 3-lobed, the inner small 2-lobed; flowers tubular, the limb 2-lobed; anther-bases with short acute auricles sengenesious, style-arms hairy, the tips subulate; achenes turbinate or oblong, silky; pappus of short or long aristate feathery bristles.

Polluted (Plate 46 B, D)

Plants growing in the polluted site show the following differences in their morphological features. Leaves small (1.1 - 3.1 x 1.0 - 1.8 cm), pale green; petiole short to (0.5 cm) ; stem thick compared to the plants of unpolluted site; internode short (4.02 cm average) ; inflorescence small, ray florets 3.5 in number; disc florets 38.4 in number.

Micromorphological Characters

Unpolluted (Adaxial)

Costal Regions

Cells distinct over midrib and lateral veins, narrow, axially elongated, rectangular to fusiform; hairs uniseriate, non-glandular, conical hairs, mostly 3 celled basal cell very broad, the upper cells gradually narrowing, tip pointed (25 - 45 x 5 - 8 µm) .

Non - Costal Regions

Cells medium sized isodiametric, rarely anisodiametric spherical to polygonal; walls thin, straight to arched; stomata smaller (21 - 25.5 x 17.5 - 22.5 cm) mostly tetracytic, frequent, irregularly distributed, abnormal stomata rarely seen; hairs frequent, non-glandular similar to the costal region, uniseriate.

Abaxial (Plate 46)

Costal Regions

Cells distinct over midrib and lateral veins, similar to those of adaxial costal; hairs frequent, uniseriate. hairs are of 2 types (i) non-glandular similar to adaxial surface (ii) glandular hair small frequent, 3-4 celled, unseriate, terminal cell glandular, slightly broader.

Non - Costal Regions

Cells mostly isodiametric, rarely anisodiametric, smaller than adaxial. some what spherical, walls thin sinuous; stomata more frequent, small (26-35x20.5-28.5 µm) irregularly distributed, mostly oval in shape, hairs frequent, hairs are of 2 types. (i) non - glandular uniseriate conical hairs similar to those of adaxial surface. (ii) glandualr hair small frequent, 3 - 4 celled, uniseriate terminal cells glandular slightly broader.

Polluted Adaxial

Costal Region

Cells distrinct over midrib and lateral veins. narrow, axially elongated, rectangular to fusiform, hairs uniseriate, non-glandular, conical hairs mostly 3 celled, basal cell very broad, the upper cells gradually narrowing, tip pointed (33-55 x 5-9 µm).

Non - Costal Region

Cells medium sized isodiametric, rarely anisodiametric, spherical to polygonal, walls thin, straight to arched; stomata larger (23.1 - 28.7 µm x 20-28.1 µm) than the unpolluted, mostly tetracytic frequent, irregularly distributed, abnormal stomata rarely seen; hairs frequent, non-glandular similar to the costal region.

Abaxial (Plate 46 B)

Costal Region

Cells distinct over midrib and lateral veins, similar to those of abaxial unpolluted; hairs frequent, hairs are of 2 types (i) non-glandular (ii) glandular similar to those of abaxial unpolluted, size of hairs have become drastically reduced.

Non - Costal Region

Cells smaller than unpolluted, walls thin, sinuous; stomata more frequent larger than unpolluted (28.5 - 37.5 x 19.5 - 30.5 µm),less frequent, spherical, uniform in size; hairs less frequent than unpolluted highly collapsed (25-48 x 5-8 µm) (Table 4).

Leaf Transection

Unpolluted (Plate 48 A)

Epidermis single layered on both surface, cells tabular, the adaxial epidermal cells deeper than abaxial, cuticle thin, lamellar palisade parenchyma columnar, two layered, spongy parenchyma irregular, many layered; midrib consists a main small central bundle, crescent shaped; bundle sheath extension parenchymatous; stomata occur both in the abaxial and adaxial epidermis, guard cells flesh with epidermis; crystalliferous idioblast infrequently seen in the bundle sheath extension, hairs are of 2 types (i) non-glandular (ii) glandular. Non-glandular hairs seen on both surfaces, glandular hairs seen only on the abaxial surface, lamina thickness 132.5 µm.

Polluted (Plate 48 B)

Epidermis similar to those of unpolluted; cells appear more deeper; palisade parenchyma and spongy parenchyma similar to those of unpolluted; lamina thickness 122.5 µm; hairs similar to those of unpolluted, but highly reduced in length, often collapsed; vascular bundle smaller than unpolluted.

Petiole

Unpolluted (Plate 49 A)

Epidermis single layered, cells tabular to barrel shaped; hairs present, petiole crescent shaped with 3 vascular bundles in the form of arc, central are larger, lateral one smaller; stomata infrequently seen similar to those of leaf abaxial epidermis; cortex collenchymatous,hypodermis.

Polluted (Plate 49 B)

Epidermis similar to those of unpolluted; narrow, vascular tissue well developed; crescent shaped with 5 vascular bundles, the central one large, the extreme outer ones are very small, collenchymatous, hypodermis reduced, pith parenchymatous, cells smaller than unpolluted.

Stem

Unpolluted (Plate 50 A)

Stem circular in outline, epidermis single layered, cells barrel shaped; cortex narrow, outer collenchymatous and inner parenchymatous; prominant vascular bundles arranged in a ring, conjoint collateral open; pericycle sclerenchymatous; pith cells larger, thin walled parenchymatous.

Polluted (Plate 50 B)

Stem circular in outline, epidermis single layered; cells narrow, thick walled, barrel shaped, cortex narrow; vascular bundles similar to unpolluted; the size of the bundle decreased than unpolluted; pith cells polygonal, thin walled; parenchymatous, cells slightly smaller than the unpolluted.

Root

Unpolluted (Plate 51 A)

Circular in outline; secondary growth seen; xylem radiated in rows, vessels large, fibers narrow; annual rings absent; secondary phloem well developed; periderm present.

Polluted (Plate 51 B)

Similar to the unpolluted; but the vessels are large more in number, periderm thick. Content of chlorophyll was estimated in plants growing unpolluted and polluted sites.

The results are given below.

No.	Pigment(mg/g fr. weight)	Unpolluted ste	Polluted site
1.	Chlorophyll A	1.84	1.46
2.	Chlorophyll B	0.27	0.19
3.	Total clorophyll	2.12	1.66

Azadirachta indica A. Juss.

The wood structure for the effect of air pollution is studied only in *Azadirachta indica* A. Juss.

Unpolluted (Plates 52-58)

Wood diffuse porous, vessels in long radial multiples, multiples of 2 or 3 cells, vessels moderately small to medium sized; perforation simple; tyloses absent; wood rays homogenous, multiseriate, uniseriate rare; axial parenchyma paratracheal; vasicentric; fibres with simple or moderately bordered pits, septate; scattered fibres of crystalliferous cells seen.

Polluted (Plates 52-58)

Wood of tree growing in polluted site have more number of vessels than normal and also larger in size; secondary phloem copious in polluted and have more of sieve tubes and less in phloem parenchyma.

Much change could not be observed in wood fibres of trees growing in normal and polluted sites. However, bark fibres in polluted is long as well as broad. The sclereids also appear to be larger.

DISCISSION

Air is one of the five essentials (air, water, food, heat and light) for human beings. Man breathes nearly 22000 times a day and inhales approximately 15 kg of air per day. Even though the air is abundantly available over the surface of the earth, but it contains a lot of impurities. In India the problem of air pollution has reached alarming proportions due to concentration of industries in selected areas. Various types of contaminants are entering into the atmosphere of earth by natural and manmade activities, which are taking place on the earth. The various source of air pollution are

TOTAL SOURCES

- Mobile Sources
  - Line Sources
    - Railroad Ioco-motives
    - Channel Vessels
    - Highway Vehicles
  - Area sources
    - Motor vehicles
      - Light duly
      - Medium duty
      - Heavy duty
    - Port vessels
    - Railyard locomotives
    - Aircraft (airports)
    - Miscellaneous
- Stationary Sources
  - Point Sources
    - Power plants
    - Industrial processing
    - Solid waste Disposal
      - Municipal incinerators
      - Open burning
    - Fuel combustion (industrial)
      - Coal
      - Oil
      - Gas
      - Other
    - Miscellaneous
  - Area Sources
    - Residential heating
      - Coal
      - Oil
      - Gas
      - Other
    - Commercial & institutional heating
      - Coal
      - Oil
      - Gas
    - On-site incineration
    - Open burning
    - Evaporative losses
    - Miscellaneous

(Agarwal, 1991).

The tremendous increase in mobilization of human society has resulted in phenomenal rise in vehicular traffic on the major road ways. The vehicles discharge an appreciable amount of exhaust emission which consists of poisonous gases like carbonmonoxide, sulphur-di-oxide, oxides of nitrogen etc. 75% of the air pollution takes place through exhaust gases from automobiles (Chandra Bhora and Arvind Kumar,2004)The emissions from the vehicles cause adverse effects on plants, animals, soil and other environmental constituents. The present study deals with the effect of air pollution in particulars, the vehicular pollution on plants.

In this present study one of the highly polluted areas in Pondicherry city, the segment of road between Rajiv Gandhi square and Indira Gandhi square was selected for this study. The Rajiv Gandhi and Indira Gandhi squares are major signal areas where five and four major roads join respectively and vehicles stop for long time for signals. These squares are situated within a kilometre distance. In this many plants are grown for beauty and many avenue trees are planted on road sides. Hence, this area was selected for the present study. First, number of vehicles passing through this segment was calculated every hour during the month of March to May 2005 on different days and different times. The average number of vehicles passing through this segment under different categories viz two wheelers, four wheelers (cars & medium vehicles) and heavy vehicles were calculated.(Table 34 ;Fig 1)

The readings were taken for 12hrs from 8 AM to 8 PM. The total number of vehicles passing this segment in 12 hrs is 40255, of which two wheelers, four wheelers 29052,(cars and medium vehicles) 6272 and heavy vehicles 5113.An average of vehicles passing through this small segment is 3360 per hour. This clearly indicates that loads of exhaust emissions generated every day (12 hrs only). This will be certainly still more during festival time and marriage days.

The use of plants as indicators of air pollution has long been accepted. Many plants respond quickly to low concentrations of air pollutants in predictable ways. As a result, plants are considered to be more sensitive to air pollutants than are animals and humans as they are constantly exposed to air pollutants. Among various plant organs, leaves by virtue of their location, distribution and structure are the main recipients of pollutants and a number of studies have proved that most obvious effects of air pollution are expressed by foliage than any other part of the plant. Being, the outermost layer, the epidermis is relatively more prone to hazards of air pollutants than another tissue. The significance of stomata in protecting plants against air pollutants has been studied by Mansfield and Majernik (1970), who provided experimental evidence suggesting that stomatal closure helped to protect plants against pollution damage.

Some of the cuticular and epidermal features like size and frequency of epidermal cells, stomata, trichomes, idioblasts and cuticular thickening and striations are the traits which frequently respond to environmental stresses and hence they can also be useful as bio indicators of air pollution (Yunus and Ahmad, 1980).

Ten plant species found growing in these study areas have been employed for the present study. Of these in the nine species the morphological and micro-morphological features of leaves, petioles and stems have been studied and in the last species *Azadirachta indica* only wood anatomy was studied. For the study on effects on physiological parameters such as the content of pigments, only five species have been employed viz. *Boerhaavia diffusa*, *Bougainvillea spectabilis, Nerium odprum, Duranta repens, Tridax procumbens.*

The effect of air pollutants on the macro-morphological features of plants include mainly the leaf injury symptoms such as leaf tip burns, interveinal necrosis in *Mangifera indica* (Pawar, 1982); discolouration (chlorosis) associated with cell collapse and necrosis and a general overall waxy appearance of leaves of some perennial weeds (Benedict and Breen, 1955); reduction in leaf area in *Azadirachta indica* and *Mangifera indica* (Dubey *et al.*, 1984; Mc Cune *et al.*, 1967; Pawar *et al.*, 1978); reduction in thickness of leaf lamina in *Cassia siamea* (Pretti Bala, 2001); chlorosis, necrosis and degenerated cells in *Syzygium cuminii* (Jafri *et al.*, 1979); *Tabernaemontana coronariae* (Srivastava *et al.,* 1980) and *Psiduim guajava* (Yunus and Ahmad, 1980). Vehicular exhaust has been observed to cause the reduction in the average number of pinnules and leaf area of pinnules in three species of Mimosaceae (Anil K Raina *et al.,* 2004) and *Vigna mungo* (Lalman and Singh,1990)

However, the leaves of *Clerodendron indicum* least affected by air pollution in field condition while those of *Azadirachta indica* were severely affected (Dubey *et al.,* 1984). Further it was brough to light fumigation of high doses of SO_2 in *Zea mays* showed decrease in seed germination, seedling growth, root length and dry weight (Subash chand and yadav, 1989).

The present study on ten species belonging to eight unrelated families have shown the following modified macro-morphological features as a result of air pollution in these experimental sites, such as size of leaves, length of petiole and internodes have become considerably reduced in all the species except *Calotropis gigantea* (leaves of *Calotropis gigantea* sessile) which are compared the plants growing in non-polluted sites; leaves became pale green and stem became pale and thin and plants with fewer flowers. However, in *Eclipta alba* leaves became dark green, woody the stem became hard, brownish and heavily strigose (Tables 1, 10, 18, 25).Stunted growth was observed in *Calotropis gigantea* and *Bougainvillea spectabilis.*

Several studies have been carried out on the micro-morphological effects of air pollutants on plants. These studies have unearthed several interesting findings on the effects of air pollution on plants. These effects include

- Small folds present in the outer epidermal cell walls of normal leaves were absent in the leaves of air polluted area and stomata in the leaves of polluted area had an abnormal appearance, revealed from SEM studies of *Aesculus hippocastanum* (Godzik and Sassen, 1978).
- Stomatal frequency, abnormal stomata and idioblasts frequency had increased conspicuously in *Ricinus communis* collected from polluted area. The stomata showed wide openings with elaborate cuticular striations (Yunus *et al.,* 1979).
- A conspicuous decrease in epidermal cell size and increase in frequency of epidermal cells and stomata in polluted population of *Syzygium cuminii* (Jafri *et al.*, 1979), some ferns (Chandra, 1980) and *Jasminum sambac* (Kulshreshtha *et al.*, 1980).
- Higher stomata and trichome density and smaller epidermal cells and trichome size as compared to those of leaves collected from unpolluted area in *Psidium guajava* (Yunus and Ahmad, 1980) and *Ipomoea fistulosa* (Yunus *et al.,* 1982).
- Disorganisation and loss of normal shape and size of stellate trichome, epidermal cell and stomata all over the foliar surface in polluted population of *Croton sparisiflorus* (Srivastava and Ahmad, 1982)

- Small closely packed cuticular striations noted in healthy populations were absent in polluted populations of *Croton sparsiflorus* (Srivastava and Ahmad, 1982).

- Wider stomatal openings, disorganization of cuticular striation pattern and dissolution of cell walls in polluted population of *Ipomea fistulosa* (Yunus *et al.*, 1982).

- The present study on ten species reveals several modified micro-morphological features in plant populations growing in polluted area, hence, these features can profitably be employed as marker characters for the identification of the extent of pollution in an area.

- Epidermal cell size decreased in all the species (except *Boerhaavia diffusa* -abaxial surface) and epidermal cell number has increased in all the nine species presently studied in both adaxial and abaxial surfaces (Tables 2,5,6,11,14,15,19,22,23,26,29,30).

- The nature of epidermal cell wall has been altered in the leaves of plants growing in polluted area in the, all species except *Bougainvillea spectabilis.* Interestingly this feature occurs on the abaxial side only not on the adaxial side.

- A decreasing trend in stomatal size (except both surfaces of *Boerhaavia diffusa* and abaxial surface of *Eclipta alba*) and an increased stomatal frequency in all the species (except *Boerhaavia diffusa* which is decreased) studied in the leaves of plants growing in polluted areas. However, the stomatal types and their percentage of occurrence have not been altered.(Tables 6,12,13,14,15,20,21,22,23,27,28,29,30).

- Stomatal opening was wider in the pollution affected plants leaves presently studied as reported earlier by Rajagopal and Saxe (1988). The enhanced stomatal opening will lead to greater losses of water causing stress especially in plants with limited water supply.

- It is evident from the present study that the stomatal index in pollution affected plants has decreased (except *Eclipta alba* where it is increased). Similar observation have been made in *Acacia nilotica*, *Leucaena leucocephala* (Anil K Raina *et al.*,2004) and *Vigna mungo* (Lalman and Singh, 1990).

- Many stomatal abnormalities could not be observed in the pollution affected leaves of present study except *Eclipta alba*. Where stomatal abnormalities like stoma with single guard cell and contiguous stomata infrequently observed.

- Hair size showed a decreasing pattern (except *Boerhaavia diffusa* which showed an increased trend) and hair frequency has showed an increasing pattern in all four species presently studied. In *Boerhaavia diffusa* and *Bougainvillea spectabilis* the hairs become collapsed however, the terminal glandular cell of uniseriate glandular hairs have become bulged and distorted.(Tables 7,8,16,17,24,31,32,33).
- Crystalliferous idioblasts have become rare in leaves of plants growing in polluted areas.
- The leaf anatomical features also show some interesting pattern of alteration in pollution affected plants which have not been studied by earlier workers.
- In all the species studied the numbers of vascular bundles in the midrib have increased. Except *Calotropis gigantea* in all the species presently studied the vessel number and size (diameter) have shown an decreasing trend.(Plates 4,11,17,22)
- The numbers of palisade layers have increased in *Calotropis gigantea* and generally the palisade cells have become short and narrow in all the species presently studied (Plate 17).
- The latex cells are more frequent in *Calotropis gigantea* in pollution affected leaves.
- The thickness of pollution affected leaves have become reduced in all the species except *Eclipta alba* where lamina thickness has increased over leaves of plants growing in unpolluted site(Table 9).
- Similarly studies on the anatomical responses of petiole and young stem to pollution have been attempted for the first time.
- In petiole and stem the shape has not been altered by pollutants influence.
- Similar to the leaf anatomy, the petiole also showed an increased number of vascular bundles but each with a few rows of xylem compared to petioles not affected by pollution.(Plates 5,12)
    - In petioles affected by pollution the epidermal cell size decreased but the hair frequency has increased. Similar to leaves the hairs have become collapsed as in *Boerhaavia diffusa* and *Bougainvillea spectabilis*. Interestingly the cell size of ground tissue in petioles has come down.

- The stems of pollution affected plants have shown less amount of xylem with narrow vessels but with more of selerenchyma fibres. The bundle cap in *Eclipta alba* is larger in pollution affected stem. The collenchyma in *Bougainvillea spectabilis* stem appears to be broader in pollution affected plants. It shows clearly, the tendency to develop more mechanical tissues over xylem in plants growing in polluted sites over the plants of non-polluted sites. Another significant alternation is the reduction in size of the cortical and pith cells similar to petiole in those stem from plants of polluted sites. Interestingly the pith and cortical cells of *Bougainvillea spectabilis* show more of stored starch grains in pollution affected plants.(Plates 6,13,18,23)
- A few works are available on the effects of air pollutants on the reproductive morphology. The SO_2 exposure resulted in the reduction of biomass which adversely affected the competitive ability and weakening of plants in *Spinacea oleracea, Abelmoschus esculantus* var pusa savani, *Amaranthus viridis* and *Phaseolus aureus* var, vaishakee. Such plants produced less photosynthate and also smaller number of seed from flowers (Boralkar and Chaphekar, 1989). The present study also records the occurrence of the reduced number of flowers per inflorescence in plants collected from polluted sites (Plate 8, 36, 41). Further the pollution affected plants bore small sized flowers. Interestingly the impact of pollution even can be noticed at the level of sex organs – androecium and gynoecium (Plate 27) resulting in decrease in the length of stamens and styles and also the length of the staminal hairs.
- Not much of work is available on the effects of air pollutants on wood of tress except Ghouse et al., (1984). They observed that annual loss of wood formation in *Tectona grandis* amounting to 26% in at average. The present study for the first time brings out the occurrence of interesting alternation in the component of bark and wood of *Azadirachta indica* tree growing in polluted site. In comparison with leaf, petiole and young stem the wood have less number of narrow vessels than wood of tree growing in unpolluted site. This feature further confirms the tendency of pollution affected plants to develop more mechanical tissues over conducting element (xylem). Much alteration could be observed in bark fibres than wood fibres as they are close proximity to air pollutant than wood. The bark fibre in trees of polluted site is long as well as broad. The sclerieds also appear to be larger (Plate 30).

Effects of air pollutants on physiology of plants were brought to light by many workers. These effects mainly consists of

- NO produced more rapid reduction in apparent photosynthesis than NO_2 in *Alba alba* and recovery was more rapid when fumigation was stopped in (Hill and Bennett, 1970) and 5 potted cultivars (Saxe, 1987).
- Interestingly NO2 exposure produced profound effects in *Mimusops elengi* as it brought a decrease in root, shoot length ratio, fresh and dry weight, contents of photosynthetic pigments and ascorbic acid levels (Tiwari and Bansal, 1993)
- Contrast to the above an increment of dry weight and chlorophyll content was noticed in *Maduca indica* and *Butea monosperma* sprayed with fly ash (Dubey *et al.,* 1982).
- Ammonia pollution has severely damaged the leaves of black gram T-9 resulting in the reduction of total chlorophylls and biomass (Raza and Zulekha, 1981). Further the numbers of root nodules / m2 were reduced from 520 to 400 (for 60 minute exposure). Fruit setting and seed production were reduced to almost 44%.

In the present study, only the levels of chlorophyll contents were analysed between plants growing in unpolluted and polluted sites that in two species viz, *Borehaavia diffusa* and *Bougainvillea spectabilis* . The present study clearly established that the reduction in the levels of pigments due to air pollution similar results also obtained in *Mangifera indica* exposed to SO_2 pollution (Pawar, 1982).

Therefore, plants quickly respond to air pollutants and this is brought out by the modifications of various traits in them. Hence they can be utilized as biological indicators of air pollution. The present study on ten species on plants clearly establishes that the experimental sites chosen in this study is highly polluted.

SUMMMARY

The present study brings out the effects of air pollution especially the vehicular pollution on plants in the field condition. The study is first of its kind for this region of Pondicherry.

For the case study for movement of vehicles at a given site between the Rajiv Gandhi square and Indira Gandhi square was selected which is considered as one of the heavily air polluted segments due to heavy vehicular traffic in Pondicherry. The distance inbetween these two points is less than a kilometre. The number of vehicles viz, namely two wheelers, four wheelers (cars and medium vehicles) and heavy vehicles passing through this segment was calculated at different times for 12 hours 8 AM to 8 PM March to May 2005. The total number of vehicles passing through this segment is 40255. An average of vehicle 3360 is estimated to cross this area per hour.

Ten species viz, Juss , *Boerhaavia diffusa* Linn., *Bougainvillea spectabilis* willd ,*Calotropis gigantea* (L.) *Catharanthus roseus* (L.)Don, *Duranta repens* L, *Eclipta alba* L., *Nerium odorum* Soland, *Tecoma stans* (L.), Kunth *Tridax procumbens* Linn and *Azadirachta indica* A. have been selected for this present study. Plant parts of the above species were collected from polluted sites as well as from non-polluted sites.

In the first nine species macro-morphological and micro-morphological features were studied. In the last species *Azadirachta indica*, only wood anatomical features have been studied.

The effects of macromorphological features included in the presently studied four species are (1) considerable reduction in the size of leaves, length of petiole and length of internodes. (2) Leaves became pale green and stem became pale and thin. (3) the plants bore few flowers only.Contrary to this in *Eclipta alba* the leaves became dark green and leaf tip burns were common in this taxon. The stem has became hard, brownish and heavily strigose. Stunted growth was observed in *Calotropis gigantea* and *Bougainvillea spectbilis.*

With reference to micro-morphological features various modifiable traits of leaf epidermis, internal structure of leaf, petiole and stem were studied.

Epidermal cell size is distinctly inversely proportional to the epidermal cell number. Reduction in epidermal cell size and increase in the epidermal cell frequency is a common feature in all the species studied except *Boerhaavia diffusa.*

The nature of epidermal cell wall has been altered in leaves of plants growing in polluted area. In *Boerhaavia diffusa,* C*alotropis gigantea* the arched walls of abaxial epidermis in leaves of unpolluted area has been modified as sinuous in leaves of polluted site. Similarly, in *Eclipta alba* sinuous wall has been altered to arched in leaves of polluted site. It is interesting to note here in all the three species a change has been brought in the abaxial surface.

While, the stomatal types and their percentage of occurrance have not been drastically altered, a decrease in stomatal size and increase in stomatal frequency (except *Boerhaavia diffusa*) in all the species presently studied. The stomata appears to be wide open in the leaves of polluted site.Stomatal abnormalities like stoma with single guard cell and contiguous stomata were observed infrequently only in *Eclipta alba* the other species did not show any abnormalities.

The trichome morphology appears to be severely affected by air pollution .Hair size showed a decreasing trend except *Boerhaavia diffusa* and at the same time the hair frequency showed an increasing trend. In addition the hairs of *Boerhaavia diffusa* and *Bougainvillea spectabilis* became collapsed and the glandular head cell became buldged and distarted in leaves of polluted site.

The lamina thicknesses have become reduced in pollutant affected leaves except *Bougainvillea spectabilis*, in which the lamina-became thicker than normal leaves. The numbers of palisnde layer have increased in leaves of *Calotropis gigantea.* However the palisade cells of all speices of pollution affected leaves become narrow and short.

Anatomy of leaves, petiole, and stem in this present study also brings out some interesting pattern of alteration of traits in pollution affected plants for the first time.

The number of vascular bundles in the petiole and midrib of leaves have become increased and the vessel density has comedown except *Calotropis gigantea.* Interestingly in all the species studied the pollution affected plants, the vessels appears to be narrow.

Hair frequency has increased in the petioles of all the species presently studied with the hairs become collapsed in *Boerhaavia diffusa* and *Bougainvillea spectabilis* similar to leaves.

The frequency of occurrence of latex cells have increased in pollution affected leaves, petiole and stem of *Calotropis gigantea*. Reduction in the cell size of ground tissue is a common feature in petiole and stem of all the species studied.

The pollution affected plants stem showed less amount of xylem with narrow vessels and interestingly have more sclerenchyma tissue developed and even bundle cap has became broader (*Eclipta alba*).Significantly the pith and cortical cells of *Bougainvillea spectabilis* show more of starch grains in pollution affected plants.

The present study also records the occurrence of the reduced number of flowers per inflorescence in plants collected from polluted sites (Plate 8, 36, 41). Further the pollution affected plants bore small sized flowers. Interestingly the impact of pollution even can be noticed at the level of sex organs – androecium and gynoecium (Plate 27) resulting in decrease in the length of stamens and styles and also the length of the staminal hairs.

The present study on wood anatomy of *Azadirachta indica* showed less number of narrow vessels in trees affected by pollutants than the wood of trees growing in unpolluted site. The fibres of bark were very much affected by air pollutants as they are longer and broader than the tree growing in unpolluted site. The anatomical studies on petiole and young stem and wood anatomy confirms the tendency of pollution affected plants to develop more mechanical tissue over conducting elements.

Five species viz. *Boerhaavia diffusa*, *Bougainvillea spectabilis, Nerium odprum, Duranta repens,* and *Tridax procumbens*. have been studied for analyzing the content of chlorophyll pigments which clearly showed that there is a decrease in the content of chlorophyll a, chlorophyll b and total chlorophylls which has very much affected the photosynthetic efficiency of these plants.

The earth is the only object known in the entire universe capable of supporting life. The supporting property of our planet is due to its unique atmosphere. Today there is an overwhelming evidence that various pollutants affect and will continue to affect life on this planet. It has become increasingly evident that air pollution is affecting the vegetation to the same extent as it is affecting human and animal lives.

Because of the differential sensitivity of plant taxa to different air pollutants, it has also been possible to use plants as bio-monitor of air pollution and that has added an entirely a new and hitherto unknown dimension to air pollution studies.

While the air pollution may affect the plants in a variety of ways, the leaves by virtue of their very abundance, location and distribution bear the main burnt of air pollutants. Lately, interest is growing among plant anatomist in the study of effect of air pollution on the foliar epidermal features and their significance as the bio indicators of environmental pollution.

Being outermost layer the epidermis is relatively more exposed to hazards of air pollution than another tissue and some of the epidermal features act as modifiable traits and hence they can be useful in determining the type and extent of air pollution.

Therefore, the present study on various macro- and micro-morphological features of ten species clearly suggests that the segments studied in Pondicherry is very much affected by air (vehicular) pollutants.

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