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An Investigation in to the Impact of Particulate Matter on Vegetation along the National Highway: A Review

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ABSTRACT
Air pollution is a major problem in modern society. These substances include various gases and tiny particles or particles that harm plants, human health and damage the environment. Particulate Matter (PM) is the term for particles found in the air, including dust, soot, dirt, smoke and liquid droplets. Particulates can be suspended in the air for long periods of time. Particulate Matter (PM) is of localized importance near roads, quarries, cement works and other industrial areas. Apart from screening out sunlight, dust on leaf blocks stomata and lowers their conductance to CO_2, simultaneously interfering with photosystem II. Polluting gases such as SO_2 and NO_x enter leaves through stomata, following the same diffusion pathway as CO_2. NO_x dissolves in cells and gives rise to nitrite ions (NO_2^-, toxic at high concentrations) and nitrate ions (NO_3^-) that enter into nitrogen metabolism as if they had been absorbed through the roots. In some cases, exposure to pollutant gases, particularly SO_2, causes stomatal closure which protects the leaf against the further entry of the pollutant but also curtails photosynthesis. In the cells, SO_2 dissolves to give bisulfite and sulfite ions; sulfite is toxic but at low concentrations it is metabolized by chloroplasts to sulfate which is not toxic.

Key words: National highway, particulate matter, vegetation

INTRODUCTION
Air pollution is caused by fumes and smoke from vehicles, factory chimneys and power station. Poisonous gases, such as sulphur dioxide, mix with rain and mist to produce acids. When the acid rain falls, it kills plants over a wide area. Burning fuels also causes a build-up of carbon dioxide. Industrialization is major threat to the environment. Pollution is just one example. Factories discharge harmful chemical into rivers and seas, killing fish and plants.

Environmental stress, such as air pollution, is among the factors most limiting plan productivity and survivorship (Woo *et al.*, 2007). It is a major problem arising mainly from industrialization.

Atmospheric particulate matter is a mixture of diverse elements. Deposition of particulate matter to vegetated surfaces depends on the size distribution of these particles and, to a lesser extent, on the chemistry. Effects of particulate matter on vegetation may be associated with the reduction in light required for photosynthesis and an increase in leaf temperature due to changed surface optical properties. Changes in energy exchange are more important than the diffusion of gases into and out of leaves which is influenced by particulate matter load, colour and particle size. Alkaline particulate materials may cause leaf surface injury while, other materials may be taken up across the cuticle. Interception of particulate matter by vegetation makes an important contribution to the improvement of air quality in the vicinity of vegetation. Although the effect of particulate matter on ecosystem is linked to climate change, there is little threat due to un-speculated particulate matter on a regional scale.

All over the world, especially in developing countries, roads are continuously increasing at a fast rate and roadsides occupy a very broad area of most countries. Ecologically unique roadside communities (NRC, 1997) provide enormous opportunities for investigations (Forman and Alexander, 1998) and roadsides are great frontiers awaiting science and society (Forman and Deblinger, 2000).

Removal of particulate matter by vegetation through interception from the atmosphere enhances air quality in urban areas (Beckett *et al*., 1998, 2000; Freer-Smith *et al*., 2005) and near roadways (Smith, 1971; Freer-Smith *et al*., 1997). Properties of both particles and the vegetation are important in deciding their interactions and consequently the effectiveness of particle removal from atmosphere. Leaves, susceptible and highly exposed parts of a plant, may act as persistent absorbers in a polluted environment (Maiti, 1993). Small vegetation elements are more effective in removing small particles from an air stream than are large elements. They act as pollution receptors and decrease dust concentration of the air. The capability of leaves as dust receptors depends upon their surface geometry, phyllotaxy, epidermal and cuticular features, leaf pubescence and height and canopy of trees (Fowler *et al*., 1989; Nowak, 1994; Beckett *et al*., 2000; Raupach *et al*., 2001). Prajapati and Tripathi (2008a, b) have shown that pollution tolerant tree species can be used for green belt development. A number of recent studies observed that in urban atmospheres the concentrations of PM 10 and PM 2.5 airborne aerosols show good agreement with traffic-related pollutants and other combustion processes (Prajapati and Tripathi, 2007). Whereas, crustal material, resuspended road dust and long-range transport events are mainly identified as sources of the coarse particles (Park and Kim, 2005; Vallius *et al*., 2005).

Deposition of particulate matter on vegetation will be affected by the particle size distribution and the dimensions and density of foliage elements in the dispersion path. The effect of size-segregated rather than chemically speculated particulate matter on ecosystem function is mediated by effects on vigour, competitive viability and reproductive fitness of individual plants. Large-leaved species may provide effective particulate matter barriers close to the source of PM (e.g., roads or quarries) but less effective barriers against finer particulate matter that travel greater distances. The fine particles emitted, specially from diesel vehicles having particulate size diameters of less than 10 μm (Known as the PM10 fraction) are extremely hazardous to human health. Poor quality diesel, old vehicles and overloading are the main reasons for such pollution from motor vehicles.

Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollutant level in air environment, with various extend for different species (Liu and Ding, 2008). The use of plants as monitors of air pollution has long been established as plants are the initial acceptors of air pollution. They act as the scavengers for many air born particulates in the atmosphere (Joshi and Swami, 2007).

A recent study by the Centre for Science and Environment (CSE) has revealed that air pollution has been killing nearly 52,000 people in 36 Indian cities every year pre-maturely while hospitalizing about 26 millions (Pattnaik and Pattnaik, 2000). Matysiak (2001) studied the contents of carotenoid in the needles of Pinus sylvestris growing in polluted areas. Plants having more APTI values are more tolerant to air pollution than those having lower index value (Kulshrestha *et al*., 2003). Pandit and Prajapati (2003) studied accumulation of some trace elements in different species of Acacia like *A. nilotica*, *A. leucophloea* and *A. senegal* in reserved forests near Bhavnagar, Gujarat state and described air pollution tolerance among roadside plants exposed to varying degrees of traffic pollution. Wali *et al.* (2004) studied the effect of air pollution on plant growth, stomatal response and photosynthesis of *Althea officinalis*. Lone *et al.* (2005) studied dust pollution caused by vehicular traffic in Aligarh city Utter Pradesh state. Arya (2009) reviewed effect of air pollution on plants. Seyyednejad *et al.* (2009) have observed significant changes in the morphological and physiological responses Callistemon citrinus in petrochemical zones of South Iran due to air pollution. Agbaire (2009) and Agbaire and Esiefarienrhe (2009) determined air pollution toler- ance indices of some plants around oil exploration and gas plant site in Delta State of Nigeria. Honour *et al.* (2009) investigated responses of herbaceous plants to urban air pollution. Rai *et al.* (2010) noted alteration in leaf surface structure due to particulate pollution in few common plants. While, Koochak and Seyyed Nejad (2010) observed such effect on *Prosopis juliflora*. Kapoor *et al.* (2009a, b), Govindaraju *et al.* (2010) and Bamniya *et al.* (2011a, b) studied the harmful effects of air pollution on physiological activities of few tree species with significant results.

It has been generally accepted that dust originating from unpaved roads can aggravate respiratory ailments, create driving hazards and cause considerable discomfort to those living alongside these roads. However, it has only been recently that studies have been undertaken to establish the nature and extent of the road-dust problem.

The average density of dust present on leaf surfaces, on any dry day, was then calculated. A range of high, medium and low numbers of expected days per month on which road dust could occur, together with the average number of days of dry weather after a rainfall event, with a road drying time difference for winter and summer, was computed to give the accumulated average amount of dust present per unit of ground area per day. A further allowance was made for the amount of leaf area per unit of ground area and the type of leaf surface (i.e., pubescent or glabrous), providing the accumulated average amount of dust present on leaf surfaces per unit of ground area per day.

Magnesium chloride ($MgCl_2$) based dust suppression prod ucts are applied to nonpaved roads during spring and summer months for dust suppression and road stabilization purposes. Chloride-based dust suppressants are used to control erosion and fugitive dust and reduce maintenance costs on nonpaved roads by stabilizing soil and drawing moisture from the atmosphere to keep road surfaces damp (Addo *et al.*, 2004; Piechota *et al.*, 2004). Dust from nonpaved roads can contribute significantly to atmospheric particulate matter which has numerous environmental and human health effects (Sanders *et al.*, 1997; ECHC, 2001; Singh *et al.*, 2003). The U.S. Environmental Protection Agency has established air quality standards for fine particulate matter (PM-10). Municipal road and bridge departments in arid climates can suppress PM-10 emissions on nonpaved roads by applied chemical dust suppression products (Singh *et al.*, 2003).

In Indian cities, airborne particulate matter seems to be a very serious problem (Agarwal *et al.*, 1999). Airborne particulate matter represents a complex mixture of organic and inorganic substances of varying size and may enter an organism or plant in a number of ways. The fine fraction (02.5 mm) of the particulate matter contains most of the acidity (hydrogen ion) and mutagenic activity (Van Houdt, 1990; Beckett *et al.*, 1998). Many plants are very sensitive to air pollutants and pollutants can damage their leaves, impair plant growth and limit primary productivity (Ulrich, 1984).

Various plants are sensitive to air pollutants and pollutants can damage their leaves, impair plant growth and limit primary productivity (Ulrich, 1984). The most obvious damage occurs in the leaves. Growth and reproduction in some plants may be impaired and the population of sensitive species is reduced while tolerant species can thrive and dominate the vegetation. The major damages caused by air pollutants to plants include chlorosis, necrosis and epinasty (Prasad and Choudhury, 1992; Katiyar and Dubey, 2000). Plants may also reduce air quality, particularly through the production of pollens and spores which become airborne (Burge *et al.*, 1982; Owen *et al.*, 1992).

Most of the effects of the dust particles on plants include the potential to block and damage the stomata such that photosynthesis and respiration are affected. Other effects are shading (which may lead to a reduction in photosynthetic capacity) wearing down on the leaf surfaces and cuticle (Iqbal and Shafig, 2001).

Air pollution has been described as an additional stress on plants since they often respond to atmospheric contamination in the same way as they respond to drought and other environment stress. The role of air pollutants causing injury to plants either by direct toxic effect or modifying the host physiology rendering it more susceptible to infection. In severe case of pollution, the injury symptoms were expressed as foliar necrosis or completely disappearance of the plants. Several workers have also previously studied the impact of air pollution on plants with reference to foliar anatomical and biochemical changes by experimenting on various sensitive plants (Samal and Santra, 2002).

In general, tolerant plants in metal contaminated environments are believed to be reliable indicators of pollution and disturbance. In general, tolerant plants in metal contaminated environments are excluders, accumulators. Many investigators expect hyper accumulator species to be present among resilient roadside plants (Okunola *et al.*, 2007; Bakirdere and Yaman, 2008). Phytosociological analysis of natural vegetation is recognized as an efficient and appropriate method to select out useful plant species from natural communities (Katsuno, 1977).

The survey of literature revealed a large number of publications dealing with physical and chemical effects. There are studies on road dust (Keller and Lamprecht, 1995), salinity of motorway soils (Thompson *et al.*, 1986), sand and 14 salt (Oberts, 1986), roadside litter (Andres and Andres, 1995), character and dispersal of motorway run-off (Bellinger *et al.*, 1982), toxicity of sediments contaminated with road run-off (Boxall and Maltby, 1995) and landslides, erosion and sediments (Haigh, *et al.*, 1993). There are studies specific to pollution detention ponds (Yousef *et al.*, 1986).

There seem to have been very few studies of the chemical and physical effects of road dust on nature; some of these few studies relate to specific regions or biomes such as the Tundra and Taiga (Forbes, 1995; Walker and Everett, 1987). Physical effects may include cell destruction and blocked stomata. Chemical effects may arise from elements such as Al, Cr, Fe and Ni deposited in airborne road dust and affecting biota via soil enrichment (Santelmann and Gorham, 1988). A recent literature review by Farmer (1993) described the effects of dust types on crops, grasslands, heathlands, trees, arctic bryophyte and lichen communities. Dust may affect photosynthesis, respiration, transpiration and facilitate affects of gaseous pollutants. Farmer found that Epiphytic lichens, Sphagnum and other mosses were the most sensitive of those studied.

In all the plants collected from polluted environment, the photosynthetic pigments were reduced and the percentage of reduction was studied. Then, *Azadirachta indica, A. Juss*was further taken for the study of rubiso enzyme modifications because of their medicinal importance and aesthetic value. Results of this study shows that there is negative impact on plants by thermal power plant pollution and plant species differ in their response to air pollution. Until now, there is no comparable data on impact of pollution on rubisco enzyme modifications in any other plant species, collected from polluted environment at field level (Govindaraju *et al*., 2010).

MATERIALS AND METHOD

Particulate matter along the high ways is a major concern of environmentalist. Particulate matter is the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.

Vegetation along the high ways is having a lot of importance in terms of temperature, sound absorption and other aesthetic reasons. Impact of particulate matter on the deposition of atmospheric dust on plant leaves varies with the structure, geometry, epidermal and cuticular features and phyllotaxy of leaves, with the height and canopy structure of trees and with the location and height of emission sources. Smaller plants with short petioles and rough leaf surfaces accumulate more dust than larger plants with long petioles and smoother leaf surfaces. In plants, dust particles affect foliar biochemical characteristics, bring about certain morphological symptoms and reduce leaf pigments.

Study area: Dhanbad district lies in the mid eastern part of Jharkhand state. It is connected through NH-2 and NH-32 from state capital and different district headquarters of the state. The district is located between 23° 26’- 24° 01’ North latitude to 86° 10’-86° 48’ East longitude. The area is covered in toposheet no 73I/1, 73I/2, 73I/5, 73I/6, 73I/7 73I/9, 73I/10, 73I/13 and 73I/14 of survey of India (1:50000 scale). The Dhanbad town is spread over an area of 23.39 km^2. It comprises of the following villages: Hirapur, Dhaiya, Saraidhela, Barmasia, Manaitand, Bhuda, Duhatand, Panderpalha and Bishnupur. Dhanbad is the only district in the Jharkhand state where participation in the non-agricultural sector is more than that in the agricultural sector. It is obviously due to availability of the coal resources has prompted extensive mining activity. Less than 8% of the district population is employed in the agricultural sector. Out of the total 0.713 million acres of land in the district, it is estimated that barely. 22.10% of the land is under agriculture. The reflexes of the mining activity on the environment are of great concern. The Dhanbad district consist of 8 blocks of Dhanbad district namely Baghmara, Baliapur, Dhanbad, Govindpur, Jharia, Nirsa, Topchanchi and Tundi. The district comprises of 157 number of panchayats and 1052 no. of villages. The total population of the Dhanbad district as per the 2001 census is 23, 97,102. Rural population is 11, 41,744 and Urban population is 12, 55, 358. The density of population is 1167 person per km^2 (CGWB, 2009).

Present study mainly focus on NH-2 highway in Dhanbad which enters from Barakar River in Dhanbad district and moves towards Gaya via Barwaadda, Raj Nagar and Isri. Numbers of activities are going on both sides of NH-2. Major activities are small towns, commercial activities, agriculture and industries such as coke oven plant and brick making units. Survey of this area will be beneficial to understand the mechanism of harmful effect of industrial pollution and vehicles exhaustion the vegetation diversity present in these particular areas as shown in Fig. 1.

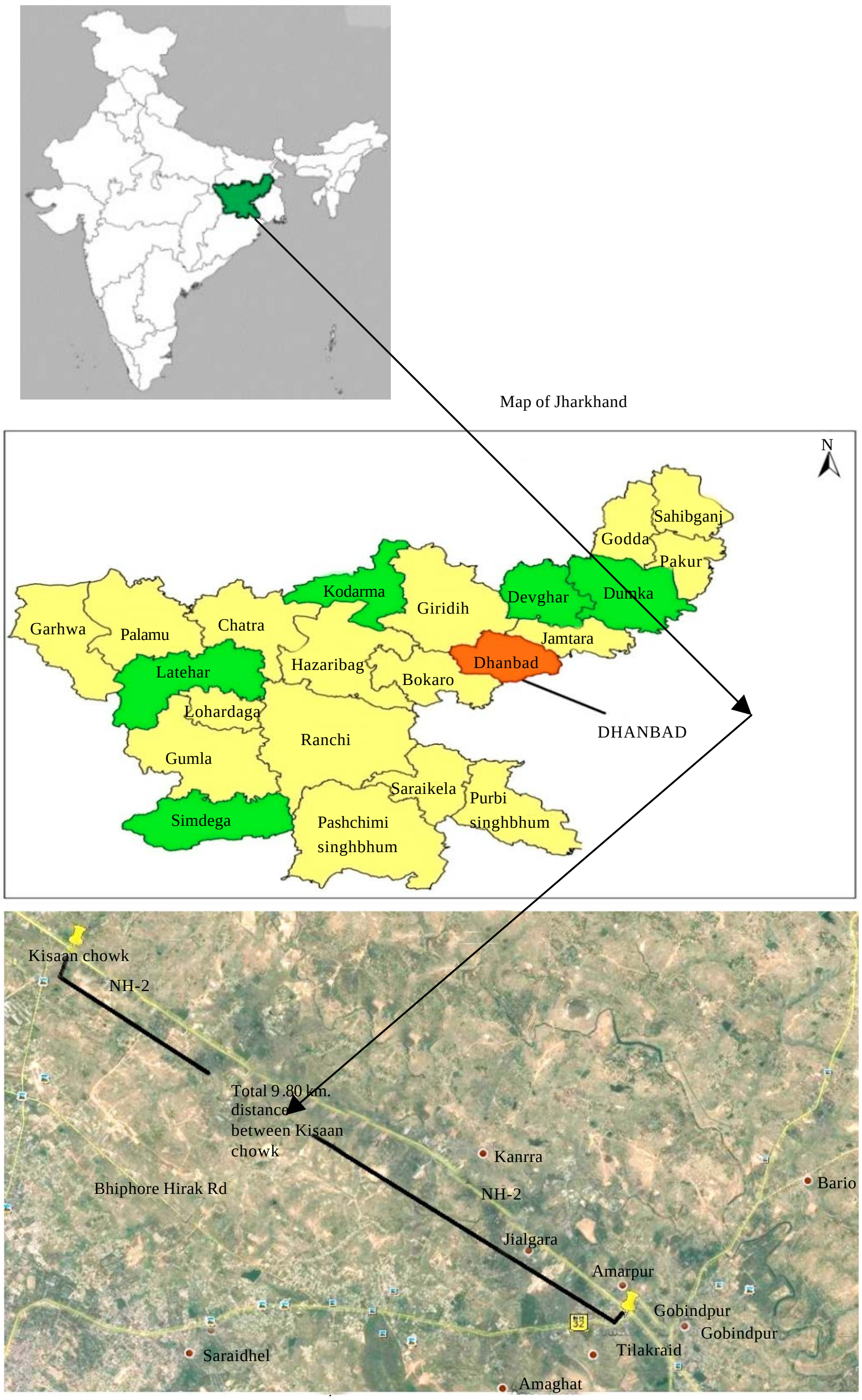

Fig. 1: Map showing India, Jharkhand and the location of the investigation site at Dhanbad City (NH-2)

Climate: Dhanbad district experience sub-tropical climate which is characterized by hot summer from March to May and well distributed rainfall during southwest monsoon from June to September. Winter season in the area is marked by dry and cold weather with intermittent showers during the month of December to February. Dhanbad area is climatically different from neighboring regions. The important climatic elements such as temperature, precipitation, pressure and wind velocity show great variation (CGWB, 2009).

Identification of particulate matter sources in study area: The serious pollution problems of atmosphere, water and land degradation have resulted from the mining activities for nearly the last two centuries, since the mining activity began here. Some of the important large and medium scale units in the region are: A.C.C. Ltd., Sindri, Allied Industries (P) Ltd, Amaghata, Bihar State Super-Phosphate Factory, Sindri, Bokaro Steel Plant, Bokaro, Fertilizer Corporation of India, Sindri, Hindustan General Electrical Ltd., Hindustan Metals and Forging Ltd., Bhuli, Jharia Fire-bricks and Potteries Works, Jharia, The Bararee Coke Co. Ltd., Kusunda and hundreds of Coke oven Plants.

The particulates belong to the class of poorly soluble particles that also encompasses carbon black, coal mine dust and titanium dioxide (Borm *et al.*, 2004; Moller *et al.*, 2008). Measurements of the PM in ambient air are usually reported as the mass of particles with an aerodynamic diameter that is less than 2.5 mm (PM2.5) or 10 mm (PM10) (Zhu *et al.*, 2006).

Identification of floral diversity in study area: Many studies (Harms *et al.*, 2001; Chittibabu and Parthasarathy, 2000; Phillips *et al.*, 2003; Fashing *et al.*, 2004; Proctor *et al.*, 1983) have followed permanent plot sampling technique for floristic diversity analysis. However, the size of permanent plot varied from 1-50 ha. The studies such as Proctor *et al.* (1983) in Gunung Mulu National Park, Sarawak, Parthasarathy and Sethi (1997), Kadavul and Parthasarathy (1999) in Coromandal coast and Eastern Ghats respectively, Aldrich *et al.* (2002) in East central Indiana, Grau *et al.* (1997) in Tucuman, Argentina, Mani and Parthasarathy (2006) in Shevaroys, India, Bhat *et al.* (2000) in Uttara Kannada India have laid less than 10 ha plots to estimate the floristic diversity. Phillips *et al.* (2003) in Amazonian Peru and Pitman *et al.* (2002) in Ecuador and Peru have estimated with greater than 10 ha but less than 50 ha plots. Harms *et al.* (2001) in Barro Colorado, Panama Island, Nath *et al.* (2006) in Mudumalai Wildlife Sanctuary, India and He *et al.* (1996) in Negeri Sembilan, Malaysia have laid 50 ha plots in their studies. Though, these studies have conducted big permanent plot estimation. For convenience, the plots are divided into 10×10 m sub-plots (Chittibabu and Parthasarathy, 2000; Mani and Parthasarathy, 2005; Venkateswaran and Parthasarathy, 2005), 20×20 m plots (Harms *et al.*, 2001; He *et al.*, 1996; Grau *et al.*, 1997), 5×5 m plots (Franklin and Rey, 2007), 2×50 and 6×50 m (Gordon and Newton, 2006a). Occasionally, the plot dimension has also been changed to circular (20 m radius) in Linder *et al.* (1997) and rectangular (10×500 m) in Shankar (2001).

According to random sample technique, plots are laid in the field randomly to represent the entire floristic region in order to avoid bias sampling (Magurran, 1988; Zhang and Wei, 2009; Zhang, 2011). When compared to big permanent plot studies, the random plot studies are very limited in the literature. The size of the plot/quadrat varies from 1×1-20×50 m (Zhang and Barrion, 2006; Zhang *et al.*, 2008). Gordon and Newton (2006b) have conducted random plot analysis in Huatulco, Mexico with 2×50 and 6×50 m size. Knight (1975) has investigated the floristic diversity in Barro Colorado Island, Panama with 10×20 m plots. In Santa Catalina Mountain, Arisona, Whittaker and Niering (1965) and Swamy *et al.* (2000) in Agasthyamalai hills of South India, Sagar and Singh (2006) in Vindhyan dry tropical forest of India have estimated the diversity of forest using 10×10 m plots. Ramanujam and Kadamban (2001) in South eastern coastal of India have used 25 plots of 20×20 m. Huang *et al.* (2002) in the East Usambara Mountains of Eastern Arc Africa and Kalacska *et al.* (2004) in Parque National Santa Rosa in the Province of Guanacaste have conducted floristic studies with 20×50 m random plots. Bazzaz (1975) in Southern Illinois have used 40 plots of 2×1 m size and 25 plots of 4×4 m size in his diversity studies. Rarely, the dimension of plot is circular (Linder *et al.*, 1997) with 20 m radius. However, they have not mentioned the reason for the circular plot and its significance. Gordon and Newton (2006b) have recommended that randomized selection of site for sampling would ideally assess the diversity in any locality. As far as shape of plot is concerned, Condit *et al.* (1996) confirmed that very narrow rectangular plots, 1000×1 m, were more diverse (18-27%) than square plots.

Studies of global patterns of plant species richness are few in number and those published to date have not been made within an explicit geographical framework (Malyshev, 1975; Barthlott *et al.*, 1996, 1999; Mutke and Barthlott, 2005).

RESULTS AND DISCUSSION

Sampling and analysis: Sampling was be done for a complete year covering all types of climatic variations. Particulate matter was be analyzed for PM 10, PM 2.5 and presence of heavy metals. In addition of this, soil samples was also analyzed with respect to its physical and chemical properties along with presence of heavy metals. Samples from vegetation was studied under Floristic study, morphological study, anatomical study. Final effect of dust lading was studied over vegetation.

Impact of dust on plants: Growth and development of plants are functions of the environment including solar radiation, air, water and soil (Scholz *et al.*, 1992; Katiyar and Dubey, 2000). The variation in the pigment (chlorophyll and carotenoid) content in plants is also attributable to the environmental conditions. The development phase of plants influences the type and degree of reaction to environmental factors (Pandey and Agrawal, 1993). Dust deposition on leaf surfaces may also reduce the synthesis of chlorophyll a due to a shading effect (Singh *et al.*, 2002) and photosynthesis (Anthony, 2001).

The photosynthetic efficiency has been reported to be strongly dependent on leaf pH (Liu and Ding, 2008). The photosynthesis was reduced in plants with low leaf pH (Turk and Wirth, 1975). The pH ranged between 4.4 and 8.8 lies in both intermediately tolerant and sensitive plant species (Lakshmi *et al.*, 2009) and thus, all plant species are both intermediately tolerant and sensitive to air pollutants.

Photosynthesis is the process by which energy of sunlight is absorbed through the leaf surfaces of green plants and used to build up complex substances from carbon dioxide and water. This process provides the fuel for plant growth; any reduction in photosynthesis is accompanied by an approximate corresponding percentage loss of plant growth and yield. Dust particles of a size range less than 5 m in diameter can interfere with the mechanism of stomatal pores. These small openings are largely responsible for the basic respiration and transpiration functions of plants.

Morphological changes: Morphological characters of plants are very important in determining plant resistance to air pollution. Characteristics, such as sunken stomata, thick cuticle, small and dense cells and suberised cell walls are in favor of reducing pollutant entry into leaves and cells (Pal *et al.*, 2002). Pollutants also cause erosion of epicuticular wax which protects the entry of pollutants through leaf cuticle by serving as a barrier. Therefore, the structural resistance of epicuticular wax to the erosion effect of air pollutants would be an important factor in providing overall resistance of plants to air pollution (Dixit, 1988; Huttunen, 1994; Bacic *et al.*, 1999). Out of the four plants selected for this study, *Terminalia arjuna* (Roxb.) Wt. and Arn., *Cassia fistula* Linn. and *Polyalthia longifolia* Thw. are trees and *Bougainvillea* 'Mahara' (a bud sport of Bougainvillea X buttiana Holttum and Standley) is a woody, climbing shrub of great ornamental value. The multibracted cultivars with rhodamine purple colour are very attractive and extensively used in the bioaesthetic planning and are planted along the roadsides as dust filters (Sharma *et al.*, 2005; Sharma and Goel, 2006).

The leaves may act as persistent absorbers in the polluted environment and they act as pollution receptors and therefore reduce the dust concentration of the air. This particular capacity of plant leaves as dust receptors reported to be dependent of their surface geometry, phyllotaxy, epidermal and cuticular features, leaf pubescence and height and canopy of trees (Neinhuis and Barthlott, 1998).

Sulfur dioxide enters the leaves mainly through the stomata (microscopic openings) and the resultant injury is classified as either acute or chronic. Acute injury is caused by absorption of high concentrations of sulfur dioxide in a relatively short time. The symptoms appear as 2-sided (bifacial) lesions that usually occur between the veins and occasionally along the margins of the leaves. The colour of the necrotic area can vary from a light tan or near white to an orange-red or brown depending on the time of year, the plant species affected and weather conditions. Recently expanded leaves usually are the most sensitive to acute sulfur dioxide injury, the very youngest and oldest being somewhat more resistant. Different plant species and varieties and even individuals of the same species may vary considerably in their sensitivity to sulfur dioxide. These variations occur because of the differences in geographical location, climate, stage of growth and maturation.

Dust loading by plants: According to Prajapati and Tripathi (2007), dust interception and its accumulation in different plant species not only depends upon the sources and amount of pollutants in the environment but also depends on morphological characters of plants like leaf size, texture, hair, length of petiole and weather condition and wind direction. Analysis of the present investigation shows that in all the three seasons, dust fall on the leaves of all the plants under study was observed very high in polluted areas which was due to more pollutants releasing through industries, congested market area and traffic activities while in controlled area and low polluted region i.e., residential area, dust particles settled down on leaves generally come from the surrounding soils due to high wind speed. Same result of high dust deposition on the leaf surface in urban and industrial area have been reported by Rao and Pal (1979) and Shetye and Chaphekar (1989). It may be concluded that high dust deposition on leaf surface at road side with heavy vehicular traffic may be due to spray of unburnt oil residue of diesel or petrol on the leaf surface.

Bhatnagar *et al.* (1985) reported very high dust fall on the leaves of all the nine plants under study growing in industrial in comparison to those growing in nonindustrial area. Varshney and Mitra (1993) concluded that the row of roadside hedges trapped nearly 40% of particulate matter, most of which arises from the traffic movement. Finally, it can be concluded that high dust fall on the leaves of plants at polluted sites might be due to dense traffic movement, industries, power plant and congested infrastructure and market area.

Different reasons were given by different researchers for the dust holding capacity of plants. Dust interception and retention depends upon leaf orientation, age, roughness and wettability of the leaf surface (Neinhuis and Barthlott, 1998; Beckett *et al.*, 2000). It also depends on the strength and constancy of wind, the porosity of the vegetation with respect to air movement and the amount and intensity of rain according to Raupach *et al.* (2001). The deposition of gaseous pollutants and particulate matter and their interception are greater in woodlands than in shorter vegetation (Fowler *et al.*, 1989; Bunzl *et al.*, 1989). It has been established that leaves and exposed parts of a plant generally act as persistent absorbers in a polluted environment (Samal and Santra, 2002).

CONCLUSION

Air pollution is rapidly becoming an environmental problem of public concern worldwide. Industrialization, population growth and associated increase in energy demands have resulted in a profound deterioration of air quality in developing countries like India. Air pollution comes from many different sources such as factories, power plants, automobiles and even windblown dust. Air pollution is not harmful only for plant, it is also very harmful for all living organism. Air pollution can threaten the health of human beings, plants, lakes, crops and animals. The study also concludes that the plants are very good for air pollution indicator and also very good for dust capturing. Plants which have higher index value are tolerant to air pollution and can be caused as sink to mitigate pollution while plats with low index value show less tolerance and can be used to indicate levels of air pollution.

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