# EFFECT OF PARTICULATE MATTER (PM) ON PLANTS, CLIMATE, ECOSYSTEM AND HUMAN HEALTH

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## ABSTRACT

Particulate matter (PM) is a complex mixture of solid and liquid particles that are suspended in air. These particles typically consist of a mixture of inorganic and organic chemicals, including carbon, sulfates, nitrates, metals, acids, and semi-volatile compounds. The size of PM in air ranges from approximately 0.005 to 100 micrometers (µm) in diameter -- the size of just a few atoms to about the thickness of a human hair. Researchers have defined size categories for these particles differently. PM is defined by three general categories commonly used by the U.S. Environmental Protection Agency (U.S. EPA): coarse (10 to 2.5 µm), fine (2.5 µm or smaller), and ultrafine (0.1 µm or smaller). Research suggests that particle size is an important factor that influences how particles deposit in the respiratory tract and affect human health. Coarse particles are deposited almost exclusively in the nose and throat; whereas, fine and ultrafine particles generally are able to penetrate to deep areas of the lung. Fine and ultrafine particles are present in greater numbers and have greater surface area than larger particles of the same mass, and they are generally considered to be more toxic. Most countries contribute to aiborne particulate matter pollution in other countries. In the past couple of years particulate matter has recieved media attention, concequential to the discovery of thousand of people dying young of particulate matter introduced health effects. This includes both short-term and long-term effects. Particulate matter does not only cause health effects, it also plays a role in the green house effect and global warming because of its contribution to cloud formation. Particulate matter is released from natural sources, such as volcanic eruptions, sea salt, or soils. Anthropogenic sources, such as car exhausts, industry, shipping and coal and ore fabrication, cause increases in airborne particulate matter concentrations on many locations. Deposition of these particulate matters on vegetated surfaces depend on the size distribution of these particles and effects of particulate matter on vegetation may be associated with the reduction in light required for photosynthesis and increase in leaf temperature due to changed surface optical properties.

**Keywords - Particulate Matters; Deposition Processes; Climate Effect; Health Effect; Effect On Ecosystem, Effect On Plants; Greenhouse Effect And Global Warming; Control Technology**

## I. INTRODUCTION

Three separate groups of particulate matter are distinguished, according to particle size: - $PM_{10}$: diameter 2.5-10 µm (road dust and particles from worn out engines and breaks)- $PM_{2.5}$: diameter <2.5 µm (from diesel engine exhausts)- Diameter <0.1 µm (EC; elementary carbon) A distinction is also made between primary and secundary partciles. The distinction depends upon the formation of particles in air. Primary particles are formed by friction, wind or fossil fuel burning. Secundary particles are formed during chemical reactions in air of acid substances to salts. Primary particles may adsorb to secundary particles. According to the EPA only $PM_{2.5}$ is harmful to human health, because larger fractions attach to small hairs in the respirational tract, and are subsequently released upon clearing one's throat. Consequently, standards for particulate matter size 2.5 and smaller are stricter than for larger particles. In the past 20 years particulate matters emissions in industry decreased after implementation of dust and soot filters. However, the decrease was partly annulled by increasing emissions in other sectors. Standards for particulate matter are relatively strict, because of the health hazard. Particulate matter is regulated by the Environmental Protection Agency (EPA). Two separate standards for fine particles are included in the Clean Air Act. Primary standards are based upon health effects caused by specific partciles, whereas secundary standards are based upon welfare impact of particulate matter, preventing visibility impairment, and damage to crops, animals and buildings. This year, the 24-hour standard for $PM_{2.5}$ was decreased from 65 to 35 micrograms per cubic meter, and the standard for $PM_{10}$ was set to 150 micrograms per cubic meter. In Europe standards for particulate matter are regulated by the World Health Organization (WHO), and are set to 40 micrograms per cubic meter for $PM_{2.5}$. By 2010 this will be decreased to 20 micrograms per cubin meter. Atmospheric particulate matters are tiny pieces of solid or liquid matter associated with the Earth's atmosphere. They are suspended in the atmosphere as atmospheric aerosol, a term which refers to the particulate/air mixture, as opposed to the particulate matter alone. However, it is common to use the term aerosol to refer to the particulate component alone. Sources of particulate matter can be manmade or natural. They can adversely affect human health and also have impacts on climate and precipitation. Subtypes of atmospheric particle matter include *suspended particulate matter* (*SPM*), *respirable suspended particle* (*RSP*; particles with diameter of 10 micrometers or less), *fine particles* (diameter of 2.5 micrometres or less), *ultrafine particles*, and *soot*. The IARC and WHO designates particulates a Group 1 carcinogen. Particulates are the deadliest form of air pollution due to its ability to penetrate deep into the lungs and blood streams unfiltered, causing permanent DNA mutations, heart attacks and premature death. In 2013, a Danish study involving 312,944 people in nine European countries revealed that there was no safe level of particulates and that for every increase of 10 μg/m3 in $PM_{10}$, the lung cancer rate rose 22%. The smaller $PM_{2.5}$ were particularly deadly, with a 36% increase in lung cancer per 10 $\mu g/m^3$ as it can penetrate deeper into the lungs.

Sources of atmospheric particulate matterSome particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of particulates. Coal combustion in developing countries is the primary method for heating homes and supplying energy. Because salt spray over the oceans is the overwhelmingly most common form of particulate in the atmosphere, *anthropogenic* aerosols—those made by human activities—currently account for about 10 percent of the total mass of aerosols in our atmosphere. Particulate matter is released from natural sources, such as volcanic eruptions, seasalt, or soils. Anthropogenic sources, such as car exhausts, industry, shipping and coal and ore fabrication, cause increases in airborne particluate matter concentrations on many locations. Power plants add to emissions of particulate matter. Emissions from private houses stem from fire places and barbecues. Dutch epidemiologists state that emissions from traffic, particularly from diesel engines, are most damaging to human health.

## II. DEPOSITION PROCESSES

In general, the smaller and lighter a particle is, the longer it will stay in the air. Larger particles (greater than 10 micrometers in diameter) tend to settle to the ground by gravity in a matter of hours whereas the smallest particles (less than 1 micrometer) can stay in the atmosphere for weeks and are mostly removed by precipitation. Diesel particulate matter is highest near the source of emission. Any info regarding DPM and the atmosphere, flora, height, and distance from major sources would be useful to determine health effects.

**Table 1** Types and determinants of particulate deposition and impact to vegetation (Grantz et al., 2003)

| Type of deposition | Determinant of deposition | Quantifiable factors |
|---|---|---|
| Dry deposition | Ambient concentration | Distance from source, Emission strength |
| | Atmospheric condition | Wind speed, Stability, Mixing height Temperature, Humidity, Dew formation |
| | Aerosol properties | Chemical reactivity, Particle solubility Aerodynamic diameter, Biological availability, Hygroscopicity |
| | Surface roughness | Terrain discontinuity, Leaf pubescence Leaf shape, Plant density, Branch spacing Tissue flexibility |
| | Vegetation condition | Surface wetness, Salt exudates, Organic exudates, Insect excreta |
| Wet deposition | Ambient concentration | Distance from source, Emission strength |
| | Atmospheric condition | Mixing height, Timing of precipitation, Intensity of precipitation, Duration of precipitation |
| | Aerosol properties | Chemical reactivity, Particle solubility, Biological availability |
| | Surface roughness | Terrain discontinuity, Leaf pubescence Leaf area index, Nature of exposed, bark and stem |
| Occult deposition | As above | Combination of above factors |

Although the rate of dry deposition of atmospheric particles to plant and soil is a much slower as compared wet or occult deposition, nevertheless it acts nearly continuously and affects all exposed surfaces (Hicks, 1986). Important physical properties of dusts which determine the particle weight and potential transport distance from a source are specific gravity and particle size. Gravitational sedimentation is the main depositional process, for particles >1 µm diameter, whilst for particles < 0.001 µm diameter i.e. respiratory suspended particulate matter inertial properties become increasingly important in determining their impact onto surfaces (Chamberlain, 1986; Fowler et al., 1989; Wesely and Hicks, 2000; Raupach et al., 2001). Dry deposition of organic materials (e.g., dioxins, dibenzofurans, and polycyclic aromatics) to vegetated surfaces is often dominated by coarse PM, even though mass loading in this size fraction may be small (Lin et al., 1993) relative to fine PM. Leaf orientation, age, roughness and wettability of the leaf surface influences dust interception and thus retention (Neinhuis and Barthlott, 1998; Beckett et al., 2000).The strength and constancy of wind, the porosity of the vegetation with respect to air movement also affect dust retention (Raupach et al., 2001). It is difficult to estimate the rate of loss of dust from vegetation surfaces under dry conditions. Krishnamurthy and Rajachidambaram (1974) reported similar cement dust load and its deposition rate (3.7 g $m^{-2}$ $d^{-1}$) on coconut and tamarind leaves. Deposition velocities for fine particles to forest surfaces have been reported in the range of 1–15 cm $s^{-1}$ (Smith, 1990a). The rates of decrease in surface dust load with increasing distance from Highways were exponential (Walker and Everett, 1987). Keller and Lamprecht (1995) reported that dust levels near the Dalton Highway in Alaska were relatively invariable over much of the summer growing season and that over 85% of the dust falling on vegetation surfaces may be removed.

Gaseous pollutant species may dissolve in the suspended water droplets of fog and clouds. Aqueous condensation may occur onto preexisting fine particles and such particles may coalesce or dissolve in fog or cloud droplets. Fog formation influences both the total atmospheric burden and deposition of particulate matter (Pandis and Seinfeld, 1989) by accreting and removing particles from the air, by helping particle growth through aqueous oxidation reactions, and by increasing deposition. Low altitude radiation fogs have unlikeformation and deposition characteristics than high elevation clouds or coastal fogs. Substantially greater concentration of key polluting species (e.g., $NO_3^{\ -}$, $SO_4^{\ 2-}$, and organics) occurs in smaller than in larger droplets in these fogs (Collett et al., 1999). Clouds can contain high concentrations of acids and other ions, particularly and in decreasing order of concentration, sulfate ($SO_4^{\ 2-}$), hydrogen ($H^+$), ammonium ($NH_4^+$), and nitrate ($NO_3^{\ -}$). Acidic cloud water deposition has been linked with forest decline in industrialized areas (Anderson et al., 1999). Concentrations of particulate derived materials are often many-fold higher in cloud or fog water than in precipitation or ambient air in the same area. Fog and cloud water deliver PM to foliar surfaces in a hydrated and therefore bio-available form.

## IV. CONTROL TECHNOLOGIES

Dust collector Particulate matter emissions are highly regulated in most industrialized countries. Due to environmental concerns, most industries are required to operate some kind of dust collection system to control particulate emissions. These systems include inertial collectors (cyclone collectors), fabric filter collectors (baghouses), wet scrubbers, and electrostatic precipitators.

Cyclone collectors are useful for removing large, coarse particles and are often employed as a first step or "pre-cleaner" to other more efficient collectors. Fabric filters or baghouses are the most commonly employed in general industry. They work by forcing dust laden air through a bag shaped fabric filter leaving the particulate to collect on the outer surface of the bag and allowing the now clean air to pass through to either be exhausted into the atmosphere or in some cases recirculated into the facility. Common fabrics include polyester and fiberglass and common fabric coatings include PTFE (commonly known as Teflon©). The excess dust buildup is then cleaned from the bags and removed from the collector. Wet scrubbers pass the dirty air through a scrubbing solution (usually a mixture of water and other compounds) allowing the particulate to attach to the liquid molecules. Electrostatic precipitators electrically charge the dirty air as it passes through. The now charged air then passes by large electromagnetic plates which attract the charged particle in the airstream collecting them and leaving the now clean air to be exhausted or recirculated.

## V. CLIMATE EFFECTS

Atmospheric aerosols affect the climate of the earth by changing the amount of incoming solar radiation and outgoing terrestrial long wave radiation retained in the earth's system. This occurs through several distinct mechanisms which are split into direct and indirect effects. The aerosol climate effects are the biggest source of uncertainty in future climate predictions The Intergovernmental Panel on Climate Change, Third Assessment Report, says: While the radiative forcing due to greenhouse gases may be determined to a reasonably high degree of accuracy. the uncertainties relating to aerosol radiative forcings remain large, and rely to a large extent on the estimates from global modelling studies that are difficult to verify at the present time.The average monthly aerosol amounts around the world based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. Satellite measurements of aerosols, called aerosol optical thickness, are based on the fact that the particles change the way the atmosphere reflects and absorbs visible and infrared light. An optical thickness of less than 0.1, indicates a crystal clear sky with maximum visibility, whereas a value of 1, indicates very hazy conditions.

## VI. DIRECT EFFECT

The Direct aerosol effect consists of any direct interaction of radiation with atmospheric aerosol, such as absorption or scattering. It affects both short and longwave radiation to produce a net negative radiative forcing. The magnitude of the resultant radiative forcing due to the direct effect of an aerosol is dependent on the albedo of the underlying surface, as this affects the net amount of radiation absorbed or scattered to space. e.g. if a highly scattering aerosol is above a surface of low albedo it has a greater radiative forcing than if it was above a surface of high albedo. The converse is true of absorbing aerosol, with the greatest radiative forcing arising from a highly absorbing aerosol over a surface of high albedo. The Direct aerosol effect is a first order effect and is therefore classified as a radiative forcing by the IPCC(Intergovernmental panel on climate change). The interaction of an aerosol with radiation is quantified by the Single Scattering Albedo (SSA), the ratio of scattering alone to scattering plus absorption (*extinction*) of radiation by a particle. The SSA tends to unity if scattering dominates, with relatively little absorption, and decreases as absorption increases, becoming zero for infinite absorption. For example, sea-salt aerosol has an SSA of 1, as a sea-salt particle only scatters, whereas soot has an SSA of 0.23, showing that it is a major atmospheric aerosol absorber.

## VII. INDIRECT EFFECT

The Indirect aerosol effect consists of any change to the earth's radiative budget due to the modification of clouds by atmospheric aerosols, and consists of several distinct effects. Cloud droplets form onto pre-existing aerosol particles, known as cloud condensation nuclei (CCN).For any given meteorological conditions, an increase in CCN leads to an increase in the number of cloud droplets. This leads to more scattering of shortwave radiation i.e. an increase in the albedo of the cloud, known as the Cloud albedo effect, First indirect effect or Twomey effect. Evidence supporting the cloud albedo effect has been observed from the effects of ship exhaust plumes and biomass burning on cloud albedo compared to ambient clouds. The Cloud albedo aerosol effect is a first order effect and therefore classified as a radiative forcing by the IPCC An increase in cloud droplet number due to the introduction of aerosol acts to reduce the cloud droplet size, as the same amount of water is divided between more droplets. This has the effect of suppressing precipitation, increasing the cloud lifetime, known as the cloud lifetime aerosol effect, second indirect effect or Albrecht effect. This has been observed as the suppression of drizzle in ship exhaust plume compared to ambient clouds, and inhibited precipitation in biomass burning plumes. This cloud lifetime effect is classified as a climate feedback (rather than a radiative forcing) by the IPCC due to the interdependence between it and the hydrological cycle However, it has previously been classified as a negative radiative forcing.

Effect of PM on Human health ; Health effects According to the EPA only PM2.5 is harmful to human health, because larger fractions attach to small hairs in the respirational tract, and are subsequently released upon clearing one's throat. Increased levels of fine particles in the air as a result of *anthropogenic* particulate air pollution "is consistently and independently related to the most serious effects, including lung cancer and other cardiopulmonary mortality." The large number of deaths and other health problems associated with particulate pollution was first demonstrated in the early 1970s and has been reproduced many times since. PM pollution is estimated to cause 22,000-52,000 deaths per year in the United States (from 2000) and contributed to ~370,000 premature deaths in Europe during 2005.The effects of inhaling particulate matter that have been widely studied in humans and animals now include asthma, lung cancer, cardiovascular issues, respiratory diseases, birth defects, and premature death. The size of the particle is a main determinant of where in the respiratory tract the particle will come to rest when inhaled. Because of their small size, particles on the order of ~10 micrometers or less ($PM_{10}$) can penetrate the deepest part of the lungs such as the bronchioles or alveoli. Larger particles are generally filtered in the nose and throat via cilia and mucus, but particulate matter smaller than about 10 micrometers, referred to as $PM_{10}$, can settle in the bronchi and lungs and cause health problems. The 10 micrometer size does not represent a strict boundary between respirable and non respirable particles, but has been agreed upon for monitoring of airborne particulate matter by most regulatory agencies. Similarly, particles smaller than 2.5 micrometers, $PM_{2.5}$, tend to penetrate into the gas exchange regions of the lung, and very small particles (< 100 nanometers) may pass through the lungs to affect other organs. Penetration of particles is not wholly dependent on their size; shape and chemical composition also play a part. To avoid this complication, simple nomenclature is used to indicate the different degrees of relative penetration of a PM particle into the cardiovascular system. Inhalable particles penetrate no further than the bronchi as they are filtered out by the cilia, Thoracic particles can penetrate right into terminal bronchioles whereas PM which can penetrate to alveoli and hence the circulatory system are termed respirable particles.A study published in the Journal of the American Medical Association indicates that $PM_{2.5}$ leads to high plaque deposits in arteries, causing vascular inflammation and atherosclerosis — a hardening of the arteries that reduces elasticity, which can lead to heart attacks and other cardiovascular problems. In addition, a new study published January 21, 2014 in the *British Medical Journal* reported that long term exposure to ambient air pollution (particulate matter) is linked with incidence of coronary events. The study design was prospective cohort studies and meta-analysis of the results, and it was done in 11 cohorts participating in the European Study of Cohorts for Air Pollution Effects (ESCAPE). 100,166 participants were enrolled and were followed for an average of 11.5 years. According to the study result, an increase in estimated annual exposure to PM 2.5 of just 5 µg/m3 was linked with a 13% increased risk of heart attacks. The World Health Organization (WHO) estimates that "... fine particulate air pollution (PM(2.5)), causes about 3% of mortality from cardiopulmonary disease, about 5% of mortality from cancer of the trachea, bronchus, and lung, and about 1% of mortality from acute respiratory infections in children under 5 yr, worldwide." Researchers suggest that even short-term exposure at elevated concentrations could significantly contribute to heart disease. A study in *The Lancet* concluded that traffic exhaust is the single most serious preventable cause of heart attack in the general public, the cause of 7.4% of all attacks.The smallest particles, less than 100 nanometers (nanoparticles), may be even more damaging to the cardiovascular system.There is evidence that particles smaller than 100 nanometers can pass through cell membranes and migrate into other organs, including the brain. It has been suggested that particulate matter can cause similar brain damage as that found in Alzheimer patients. Particles emitted from modern diesel engines (commonly referred to as Diesel Particulate Matter, or DPM) are typically in the size range of 100 nanometers (0.1 micrometer). In addition, these soot particles also carry carcinogenic components like benzopyrenes adsorbed on their surface. It is becoming increasingly clear that the legislative limits for engines, which are in terms of emitted mass, are not a proper measure of the health hazard. One particle of 10 µm diameter has approximately the same mass as 1 million particles of 100 nm diameter, but it is clearly much less hazardous, as it probably never enters the human body — and if it does, it is quickly removed. Proposals for new regulations exist in some countries, with suggestions to limit the particle *surface area* or the *particle count* (numerical quantity)A further complexity that is not entirely documented is how the shape of PM can affect health. Of course the dangerous needle-like shape of asbestos is widely recognised to lodge itself in the lungs with often dire consequences. Geometrically angular shapes have more surface area than rounder shapes, which in turn affects the binding capacity of the particle to other, possibly more dangerous substances. The inhalable dust fraction is the fraction of dust that enters the nose and mouth and may be deposited anywhere in the respiratory tract. The thoracic fraction is the fraction that enters the thorax and is deposited within the lung airways and the gas-exchange regions. The respiratory fraction is what is deposited in the gas exchange regions (alveoli).The site and extent of absorption of inhaled gases and vapors are determined by their solubility in water. Absorption is also dependent upon air flow rates and the partial pressure of the gases in the inspired air. The fate of a specific contaminant is dependent upon the form in which it exists (aerosol or particulate). Inhalation also depends upon the breathing rate of the subject. Researchers at the Johns Hopkins Bloomberg School of Public Health have conducted the largest nationwide study on the acute health effects of coarse particle pollution. Coarse particles are airborne pollutants that fall between 2.5 and 10 micrometers in diameter. The study, published in the May 14, 2008, edition of JAMA, found evidence of an association with hospital admissions for cardiovascular diseases but no evidence of an association with the number of hospital admissions for respiratory diseases. After taking into account fine particle levels, the association with coarse particles remained but was no longer statistically significant. Particulate matter studies in Bangkok Thailand indicated a 1.9% increased risk of dying from cardiovascular disease, and 1.0% risk of all disease for every 10 micrograms per cubic meter. Levels averaged 65 in 1996, 68 in 2002, and 52 in 2004. Decreasing levels may be attributed to conversions of diesel to natural gas combustion as well as improved regulations. The Mongolian government agency has recorded a 45% increase in the rate of respiratory illness in the past five years. Bronchial asthma, chronic obstructive pulmonary disease and interstitial pneumonia are the most common ailments treated by area hospitals. Levels of premature death, chronic bronchitis, and cardiovascular disease are increasing at a rapid rate.. Particulate matter does not only cause health effects, it also plays a role in the green house effect and global warming because of its contribution to cloud formation.

## VIII. EFFECTS OF PARTICULATE MATTER ON PLANTS

Exposure to a given mass concentration of airborne PM may lead to widely differing phytotoxic responses, depending on the particular mixture of deposited particles. Particulate deposition and effects on vegetation unavoidably include (1) nitrate and sulfate and their associations in the form of acidic and acidifying deposition and (2) trace elements and heavy metals, including lead. While size is related to mode and magnitude of deposition, and may be a useful substitute for chemical composition (Whitby, 1978). Mineral dusts in general are less soluble and less reactive than the anthropogenic acid-forming sulfate and nitrate particles (Fowler et al., 1989; Grantz et al., 2003). Dusts with pH values of ≥ 9, may cause direct injury to leaf tissues on which they are deposited (Vardak et al., 1995) or indirectly through alteration of soil pH (Hope et al., 1991; Auerbach et al., 1997) and dusts that carry toxic soluble salts will also have adverse effects on plants (Prajapati and Tripathi, 2008a-d).Energy exchange between vegetation and atmosphere involves the absorption and conversion of short-wave radiation and the emission of long-wave radiation (Monteith and Unsworth, 1990). Dust deposited on leaf surface alters its optical properties, particularly the surface reflectance in the visible and short wave infrared radiation range (Eller 1977; Hope et al., 1991; Keller and Lamprecht 1995), and the amount of light available for photosynthesis. When dusts alter optical properties of snow-covered surfaces it can lead to vegetation surface temperatures 4 to 11.5 $^{o}$C above ambient environments (Spatt and Miller 1981; Spencer and Tinnin, 1997), changes in structure and composition of plant community (Auerbach et al., 1997; Spencer and Tinnin, 1997), and change in grazing patterns of animals (Walker and Everett 1987). In desert environment, road dust loads of 40 g $m^{-2}$ increases leaf temperatures by 2 to 3 $^{o}$C (Sharifi et al., 1997).Dust accumulating on leaf surfaces may interfere with gas diffusion between the leaf and air. Sedimentation of coarse particles affects the upper surfaces of leaves more (Thompson et al., 1984; Kim et al., 2000) while finer particles affects lower surfaces (Ricks and Williams 1974; Krajickova and Me Fowler et al., 1989; Beckett at al. 2000). In dusty environments species having stomata in grooves, covering of wax on stomata might be affected less than species in which the stomata are located at the outer surface of the leaf.

## IX. PARTICULATES STRESS ON ECOSYSTEM

Response against particulates stress begins with changes in the population of sensitive individual organisms at single or multiple trophic levels (Bazzaz, 1996). As a minimum three levels of biological interaction are involved between plants and particulates: (a) the individual plant and its environment, (b) the population and its environment, and (c) the biological community and its environment (Billings, 1978). The response of individual organisms against stress is based on its genotype, stage of growth, existing resources, and microhabitat (Levin, 1998). Competition among individuals and species during ecological succession may improve ecosystem tolerance to the challenge of particulates deposition .Succession in unpolluted (favorable) environment is progressive while, under harsh conditions, due to intermittent natural disturbance, energy is diverted from growth and reproduction to maintenance, and return succession to an earlier stage . Such disturbances disrupt normal physiology and biochemistry of plants, the determinants of energy flow and nutrient cycling, food chain structure, and nutrient inventory (Odum, 1993). These disturbances, nevertheless, sets the stage for revival, which permits the disturbed ecosystem to acclimatize to changing environments. Therefore, these perturbations may yield a temporary setback and recovery can be rapid (Odum, 1969). On the contrary, anthropogenic stresses, such as those due to particulate matter and other anthropogenic deposition, may be more harsh and devastating, with stressed ecosystems recuperating less readily and often undergoing further degradation (Odum, 1969; Rapport and Whitford, 1999), e.g. presence of heavy metal exposure causes tree injury and contributes to forest decline in the northeastern United States (Gawel et al., 1996). Particulate deposition reduces growth, yield, flowering, and reproduction of plants (Saunders and Godzik, 1986). Tolerant individuals, present in low frequencies in populations when growing in undisturbed areas, have been selected for tolerance at both the seedling and adult stages when exposed to trace metal or nitrate deposition (Ormrod, 1984; U.S. Environmental Protection Agency, 1993). Tolerant individuals within a plant population exhibit a wide range of sensitivity that is the basis for the natural selection of tolerant individuals. The rapid evolution of certain populations of tolerant species, at sites with heavy trace element and nitrate deposition, has been observed (Saunders and Godzik, 1986). Chronic pollutant injury to a forest community may result in the loss of susceptible species, loss of tree canopy, and safeguarding of a residual cover of pollutant-tolerant herbs or shrubs that are recognized as successional species (Smith, 1974; Miller and McBride, 1999).

The effects of dust deposited on plant surfaces are more likely to be linked with their chemistry rather than simply with the mass of deposited particles (Farmer, 1993). Alkaline particles may injure plant surfaces, such as limestone particles (Brandt and Rhoades, 1972, 1973). There has been reduction in growth of the dominant trees owing to crust formation on leaves which reduces photosynthesis and bringing premature leaf fall and destruction of leaf tissues (Brandt and Rhoades, 1973). Alkaline dust containing high levels of MgO deposited on leaf surfaces disrupted the epicuticular waxes (Bermadinger et al., 1988). Cement dust on hydration liberates calcium hydroxide which can raise leaf surface alkalinity in some cases to pH 12. This level of alkalinity can hydrolyze lipid and wax components, penetrate the cuticle, and denature proteins plasmolyzing the leaf (Guderian, 1986; Czaja, 1960, 1961, 1962). Limestone dust coating of lichen thallus damaged its photosynthetic apparatus (Arianoutsou et al., 1993). All this leads to change in community structure and function.It is reported that deposition of particulate matter affects the microbial community living in the phyllosphere. This microbial community plays an important role in decomposition of litter fall (Miller et al., 1982; Jensen, 1974; Millar, 1974). Since fungi are important decompose, changing the fungal community on the needles finally weakens the decomposer community, decrease the rate of litter decomposition. All these processes alter nutrient cycling (Bruhn, 1980). Slowly decomposing litter influences nutrient availability within the ecosystem because of accumulation of carbohydrates and mineral nutrients (Cotrufo et al., 1995). Epiphytic lichens and mosses, because of their nutritional dependence upon and continued contact to particulate deposition, are at risk. There is various indirect and significant effect of particulate matter on ecosystem. Indirect plant responses of greatest interest are chiefly soil-mediated and depend primarily on the chemical composition of the individual elements present in particulate matter. Changes in the soil may not be observed until accumulation of the pollutant has occurred for 10 or more years, except in the severely polluted areas around industrialized point sources (Saunders and Godzik, 1986). The soil environment is an active site of poorly characterized biological interactions (Wall and Moore, 1999). Rhizosphere organisms play a crucial role in creating chemical and biological transformations, decomposing organic matter and making inorganic minerals available for plant uptake (Wall and Moore, 1999).

## X. CONCLUSIONS

Environmental pollution is often invisible and its consequences are hard to predict. One clear result is that and particulate matter causes more deaths than airborne carcinogenic substances**.** Some environmental norms are clear and strict. A carcinogenic substance may not cause more than one in a million cancer cases per year, for example. But the environmental norms for particulate matter are quite different. 'The norm for particulate matter has more to do with economic, political and technical feasibility than with health. It's a compromise.' The main objective of air quality guidelines and standards is the protection of human health. Since fine particulates (PM10) are more likely to causes adverse health effects than coarse particulates, guidelines and standards referring to fine particulate concentrations are preferred to those referring to TSP, which includes coarse particulate concentrations. Scientific studies provide sample evidence of the relationship between exposure to short-term and long-term ambient particulate concentrations and human mortality and morbidity effects. However, the dose-response mechanism is not yet fully understood. Furthermore, according to WHO (1987), there is no safe threshold level below which health damage does not occur. Therefore, policy makers may have to consider acceptable risk rather than try to achieve absolute safety when setting ambient particulate concentration standards. Furthermore, ambient guide-lines can become an effective part of the environmental management system only if implementation is feasible and the enforcement of other policy instruments ensures their attainment. Consideration should therefore be given to the technical feasibility and the costs of attainment. Another difficulty is that airborne particulates are rarely homogeneous: They vary greatly in size and shape, and their chemical composition is determined by factors specific to the source and location of the emissions. The combined effects and interactions of various substances mixed with particulates have not yet been established (except for sulfur dioxide), but they are believed to be significant, especially where long-term exposure occurs. Measurement techniques and the205Airborne Particulate Matter reliability may vary across regions and countries and so may other factors, such as diet, life style and physical fitness, that influence the human health effects of exposure to particulates Deposition of dust 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 vigor, competitive viability, and reproductive fitness of individual plants. Large-leaved species may provide effective dust barriers close to the source of coarse dusts (e.g. roads or quarries), but less effective barriers against finer dusts that travel greater distances. Dusts effects on vegetation may be connected with the decrease in light available for photosynthetic, an increase in leaf temperature due to changed surface optical properties, and interference with the diffusion of gases into and out of leaves. It is clear that dust particle size has important and predictable effects on energy exchange properties of vegetation. Alkaline particulate matter may exert direct effects on leaf surfaces; however, the effects hardly ever reach the ecosystem level because it is difficult to identify a widespread threat to ecosystem function due to un speculated particulate matter.

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