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DUST POLLUTION AND ITS INFLUENCE ON VEGETATION – A CRITICAL ANALYSIS

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Abstract: The major sources of dust pollution include suspension of soil, agriculture-related activities, road dust, vehicular exhaust, power plants, construction activities, open fires, brick kilns, cement factories and volcanoes. Due to this pollution, plants suffer from stomatal closure leading to cell/tissue changes, leaves' necrosis, pigment loses and chlorosis. The first physiological reaction after dust deposition to the vegetation takes place on the leaf with reduced net assimilation efficiency. Moreover, the long-term depositions change the photochemistry leading to retarded leaf growth. Deposits for many years over plants' surface lead to a large-scale reduction in the assimilate balance. Additionally, there are few reports on abrasive effects of dust, especially under high wind speed; supporting secondary effects such as an increase in diseases and pest incidence after the protective leaf cuticle were removed physically. Changes in soil chemistry due to dust deposition in the rhizosphere also lead to a change in soil nutritional values. In this article, we summarized the influences of dust pollution on various parameters of vegetation.

Keywords: Dusts; Air pollution; Photosynthesis; Stomatal closure; Fly ash.

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1. INTRODUCTION

Most developing nations have been influenced by atmospheric pollution, in terms of human health [1], climate change [2] and loss of biodiversity [3]. With urban transport development, traffic-derived pollutants become an increasing problem [4], [5], [6] and have been linked to respiratory and cardiovascular disease, birth and developmental defects, cancer and so on. According to WHO

[7], the life expectancy of urban residents in strongly polluted areas could decrease by over one year, particularly for children and people with lung and heart disease. There are 800000 deaths annually, which could be due to urban air pollutants [8]. The major sources of dust pollution include suspension of soil, agriculture related activities, road dust, vehicular exhaust, power plants, construction activities, brick kilns and cement factories etc. [9], [10]. In addition, transboundary and long range transport also contributes a significant amount of atmospheric dust in the south Asian region [11]. Particulate matter pollutions usually arise from multi-various sources. They can derive from anthropogenic activity as well as from natural sources [12]. They can be released into the environment as primary or secondary particles. Primary particulate matters develop and are produced directly from the sources. While secondary particulate matters are reaction products in the atmosphere. Examples of such reaction products are ammonium sulfates and nitrate of ammonia as well as aldehydes and ketones [13]. These substances adhere to other atmospheric particles easily leading to the formation of nuclei of condensation [14]. Countries like India have high loading of soil derived dust in the atmosphere under prevailing dry weather conditions. The soil derived particulate matter is rich in $CaCO_3$ and acts as an effective scavenger of atmospheric SO_2 forming $CaSO_4$ which is also removed through dust-fall [15], [16], [17]. Deposition of such particulate matter on the foliar may lead to different phytotoxic effects depending on the characteristics of the deposited material. The sulphate, nitrate and heavy metals are the most commonly reported air pollutants responsible for phytotoxic effects [18]. Sulphate and nitrate being acidic species have a higher aqueous affinity which allows these ions to mobilize into the foliar mesophyll cells creating stress [19], [20]. Dust-fall having pH values ≥ 9 might cause direct or indirect injury to the foliar tissues [21], [22]. Deposition of dust on the foliar surface may alter its optical properties, particularly the foliar surface reflectance in the visible and near infrared region [23], [24]. Dust-fall also alters optical properties of snow-cover which can lead to an increase in temperature of vegetation surface [27], [28], changes in grazing patterns of animal [25], [26], [27]. According to Sharifi *et al.*, [28], the deposition of road dust of 40 g m^{-2} can cause the 2-3°C increase in leaf temperature in desert environments. The species having stomata in grooves might be less affected than the species in which the stomata are located at the outer surface of the leaf. Hence, dust-fall on foliar surfaces has significant impacts on the photosynthesis and growth [28], [29]. Trees and shrubs are considered as efficient filters for road dust [30], [31]. In the Indian region, dust is abundant in the atmosphere. Many industrial processes, especially in quarrying causes fine particle matters producing in huge quantities around the world [32]. Other major sources of particle matters are traffic and thermal power plants [33], [34]. The contribution of different sources towards total dust pollution varies from location to location. Even within traffic, the emissions from car vary a lot [35]. Langner [35] used for his calculations of particulate matters filter efficacy rates of urban greens a mean particle matter

emission rate per car of 100 mg km^{-1}. It is not easy to transfer empirically based deposition factors to complex urban situations. Some silica particle matters derived from the rock in inland settings and from shells or algae in coastal areas are relatively inert in nature [36], [37], [38]. Other particulate matters like limestone quarry dust are highly alkaline in nature [39], [40]. Airborne particulates, used as an indicator of heavy metal pollution due to atmospheric deposition, mainly originates from fuel combustion by gasoline/diesel powered vehicles and non-combustion sources including vehicle brake and tire abrasion, gardening, household waste discharge, architectural painting and building structure erosion [41], [42], [43], [44] and it contains a mixture of heavy metals, black carbon, polycyclic aromatic hydrocarbons and other substances suspended in the atmosphere [45]. The roadside soil in Beijing is significantly contaminated by heavy metals [46], of which some are carcinogenic, mutagenic, teratogenic, endocrine disruptors, whereas others cause neurological and behavioral changes, especially in children [47]. Vegetation has been used as an indicator of air pollution [48], [49], as their leaves can effectively adsorb air particulates [50], [51], [52], [53], [54] and reduce air pollutants [55]. Dust can impact plants directly by covering aboveground parts of the vegetation or indirectly over the soil and the root systems. Apart from the pure size of the dust particle the physical and chemical characteristics of the particles are also important for their effect on plants. Plants differ in the ability to collect particulate matter from the air [56], [57] and in their reaction to particulate matters depositions.

Dust deposition on Plants

Generally, dust particles are filtered by plants at a much higher rate than fine particles [35]. The amount of coal dust deposited on plant surfaces varies significantly spatiotemporally. Many of the factors responsible for the coal dust deposition are similar to those governing deposition of other pollutants. Generally greater surface roughness increases deposition rate [58]. This parameter is especially important at greater wind speeds [59]. Chamberlain [59] also describes that wet surfaces can result in higher deposition rates. The plant reaction differs depending on the size of the deposited particles served that chemical interactions of dust with the vegetation surface are impaired by the presence of water. For example, fly ash to a great extent is not water soluble and thus the probability of chemical burn only very small. This may not apply to other types of dust. Pilot experiments on particulate matters which affect plants were conducted by Dugger and Cooley [60] on commercial crops. They compared charcoal, calcium carbonate, and aluminum hydroxide dusts on *Lycopersicon esculentum*. All three dusts increased transpiration, but charcoal reduced growth parameters while the other dusts increased it. Sree Rangaswami and Jambulingam [61] studied in southern India the distribution of plant species around a cement factory that emits dusts. Out of 54 species, they found only nine species were able to grow close to the factory. All of those plant species possessed small leaves, resulting in a reduced dust load. Generally, unpaved roads produce higher dust levels than paved roads [62]. Brown and Berg [40] undertook a detailed study of an unpaved road in Alaska. He found that in the summer about 10 g m^{-2} day^{-1} was a logarithmic decline in deposition away from the road, with deposition still occurring 1 km away. Dusts affect plant physiology at both physically as well as at the chemical and biochemical level. The absolute level of dust deposition might be important for physical effects. Fine dust particles can clog stomatal openings [63], [64], reduce photosynthesis [65], increases leaf temperature [66], [67] and increase transpiration [68].

Dust Effect on Leaf Morphology

Leaf is the most sensitive part to be affected by air pollutants instead of all other plant parts such as stem and roots. The sensitivity rests on the fact that the major portions of the important physiological processes are concerned with leaf. Therefore, the leaf at its various stages of development serves as a good indicator of air pollution. Pollutants came from the auto emission can directly affect the plant by entering into the leaf, destroying individual cells, and reducing the plant ability to produce food. Urban air pollution is a major environmental problem, mainly in the developing countries [69]. The response of the plant to dust accumulation may vary according to different species, as dust deposition fluctuates with plant species due to leaf orientation, leaf surface geometry, phyllotaxy, epidermal and cuticular features, leaf pubescence, height and canopy of roadside plants [30], [70], [71], [72]. With the accumulation of dust, the roadside plant may exhibit adaptive response by changing morphological and physiological attributes. Heavy metals released from automobiles are extremely toxic and reduces plant growth and morphological parameters. Therefore, a study conducted by Ahmad *et al.*, [73] is agreement that the Cadmium had toxicity at 5 mg L^{-1} in case of root and shoot growth. Air pollution due to vehicular emission mostly arises from cars, buses, mini-buses, wagons, rickshaws, motorcycles and trucks. These resources introduce varieties of pollutants (oxides of nitrogen, sulphur, hydrocarbon, ozone, particulate matters, hydrogen fluoride, peroxyacyl nitrates, etc.) into the environment which not only put an adverse effect on the health of human beings, and animals, but seriously treating the trees and crops of such areas. Research studies revealed that plants growing in the urban areas are affected greatly by these pollutants [74]. Pollutants can cause leaf injury, stomatal damage, premature senescence, decrease photosynthetic activity, disturb membrane permeability and reduce growth and yield in sensitive plant species [75]. Reductions in leaf area and leaf number may be due to decreased leaf production rate and enhanced senescence. The reduced leaf area results in reduced absorbed radiations and subsequently in reduced photosynthetic rate [75]. The interactions between plants and different types of pollutants were investigated by many authors: most of the studies on the influence of environmental pollution focusing on physiological and ultrastructural aspects [76], [77]. Studies concerning the anatomy of the vegetative organs under conditions of pollution have been also carried out [78], [79], [80], [81], [82]. Dineva [83] and Tiwari *et al.* [75] recorded a reduction of leaf area and petiole length under pollution stress conditions. Previous researches reported significant reduction in different leaf variables in the polluted environment in comparison with clean atmosphere [84]. In their study on *Platanus acerifolia* showed changes in leaf blade and petiole size in the polluted air. Significant reduction in length and area of leaflets and length of petiole of *Guaiacum officinale* of polluted plants was recorded. Reduction in the dimension of a leaf blade of five tree species in the vicinity of heavy dust and SO_2 pollution was also observed [84]. Significant effects of automobile exhaust on the phenology, periodicity and productivity of roadside tree species was also reported [85]. The decrease in leaf area in drought stress had been observed because of tolerance of water content of tissue possible by the decrease in leaf area [86]. Increase in length, breadth of leaflets and decrease in the area of the leaf had demonstrated in leaves of *Albizia lebbeck* under the stress of air pollution [87], [88]. Moreover, a study on leaves of *Callistemon citrinus* planted in industrial area clears that length, width of leaf and also leaf area decreased [88]. *Cassia siamea* plants growing at two different sites (polluted and non-polluted) on two important roads of Agra city exhibited significant differences in their flowering phonology and floral morphology [89]. Researchers showed that stimulation of photosynthetic rates in elevated CO_2 was nullified by decreased total leaf area [90]. Totally describe of air pollution is related to the morphology of area of leaf visible damage including a reduction of leaf area, changes in morphology as compare to unpolluted condition, necrosis and chlorosis. Naido and Chricot [91] showed that by the effect of air pollutant exchange of gases on the area of a leaf of *Avicenia marina* decreased. One way to increase tolerance in contrast with stress is to balance the water content of tissue by decrease the leaf area [86]. It seems that these species use this way as a defense mechanism.

Dust Effect on photosynthesis through deposition

The substantial effect of coal dust deposition on plant leaf surfaces probably lies thereby in a reduction of the photosynthetic product [91], [92]. Krajickova and Mejstrik [93] found that particulate matters from a coal-fired power plant affected photosynthesis of *Calamagrostis epigejos* and *Hypericum perforatum* but the stomata were rarely blocked. They suggested that the dust might act directly on the guard cells, though the mechanisms for this effect remain uncertain until now. After dust deposition on the leaves, *Rhododendron catawbiense* exhibited an increased absorption in the infrared spectrum and a reduced reflection and transmission of radiation [94]. Deposition of smaller particle sizes leads to stranger reduction of photosynthesis than with coarse particles [95]. This effect is presumably due to the closer lining of dust particles on leaf surface resulting in a greater shading effect of photosynthetically active radiation. In experiments, where the dust of different particle sizes were applied electrostatically to *Brassica* plant leaves, no difference in the photosynthetic efficiency of the plant was found. This may be due to uniform particle distribution and a very thin layer of dust deposition. Plant reactions due to dust deposition are species dependent. For example, the chlorophyll fluorescence of *Ilex* *rotunda* and *Ficus microcarpa* has grown close by a ceramic plant are less affected than for *Machilus chinensis*. Least changes of the photosystems II have been observed with *Ilex rotunda* [96]. The chlorophyll fluorescence data of the mangrove, *Avicennia marina*, indicated that leaves coated with dust exhibited significantly lower photosystem II (PS II) quantum yield, lower electron transport rate through PSII, and reduced quantum efficiency of PSII (F-v/F-m) [91]. Nanos and Ilias [97] are reporting similar results for olive trees exposed to cement dust. In their study, cement dust decreased leaf total chlorophyll content and chlorophyll *a*/chlorophyll *b* ratio. As a result, photosynthetic rate and quantum yield decreased. Long-term effects include a change in the leaf biochemistry and a possible increase in plant pathogen and *Phytophagous arthropods* incidence [98]. Taylor *et al.*, [98] reported leaf rolling and interveinal necrosis in *Phaseolus vulgaris* after deposition of cement. Sperber [99] already assumed that plants adapted to low light conditions are less affected by dust depositions than plants adapted to grow directly in the sun.

Dust may Effect on the Pigments Content

Air pollution stress leads to stomatal closure, which reduces CO_2 availability in leaves and inhibits carbon fixation. The net photosynthetic rate is a commonly used indicator of the impact of increased air pollutants on tree growth [100]. Plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. It has reported that depending on their sensitivity level, plants show visible changes which would include alteration in the biochemical processes or accumulation of certain metabolites [101]. Sulphur dioxide (SO_2^{-}), nitrogen oxides (NO_x) and CO_2 as well as suspended particulate matter. These pollutants, when absorbed by the leaves, may cause a reduction in the concentration of photosynthetic pigments viz., chlorophyll and carotenoids, which directly affected to the plant productivity [102]. A relationship between traffic density and photosynthetic activity, stomatal conductance, total chlorophyll content, and leaf senescence has been reported [103]. One of the most common impacts of air pollution is the gradual disappearance of chlorophyll and concomitant yellowing of leaves, which may be associated with a consequent decrease in the capacity for photosynthesis [104]. Chlorophyll is found in the chloroplasts of green plants and is called a photoreceptor. Chlorophyll itself is actually not a single molecule but a family of related molecules, designated as chlorophyll "*a*", "*b*", "*c*" and "*d*". Chlorophyll "*a*" is the molecule found in all plant cells and therefore its concentration is what is reported during chlorophyll analysis [105]. Chlorophyll is the principal photoreceptor in photosynthesis, the light-driven process in which carbon dioxide is "fixed" to yield carbohydrates and oxygen. When plants are exposed to the environmental pollution above the normal physiologically acceptable range, photosynthesis gets inactivated. The distribution of plant diversity is highly dependent on the presence of air pollutants in the ambient air and sensitivity of the plants. Chlorophyll measurement is an important tool to evaluate the effects of air pollutants on plants as it plays an important role in plant metabolism and any reduction in chlorophyll content corresponds directly to plant growth [102]. Chlorophyll is an index of productivity of the plant. Whereas certain pollutants increase the total chlorophyll content, others decrease it [101]. Changes in concentration of pigments were also determined in leaves of six tree species exposed to air pollution due to vehicle emissions [102]. The shading effects due to deposition of suspended particulate matter on the leaf surface might be responsible for this decrease in the concentration of chlorophyll in a polluted area. It might clog the stomata thus interfering with the gaseous exchange, which leads to an increase in leaf temperature which may consequently retard chlorophyll synthesis. Dusted or encrusted leaf surface is responsible for reduced photosynthesis and thereby causing a reduction in chlorophyll content [102]. A considerable loss in total chlorophyll, in the leaves of plants exposed to pollution supports the argument that the chloroplast is the primary site of an attack by air pollutants such as SO_2 and NO_x. Air pollutants make their entrance into the tissues through the stomata and cause partial denaturation of the chloroplast and decrease pigment contents in the cells of polluted leaves. A high amount of gaseous SO_2 causes destruction of chlorophyll [106]. Several pieces of research have recorded reduction in chlorophyll content under air pollution [75], [102], [104], [105], [106]. On the contrary, several pieces of research have exhibited an increase in chlorophyll content under air pollution, such as Tripathi and Gautam [106] reported that *Mangifera indica* leaves subjected to air pollution showed an increase (12.8%) in chlorophyll content [106]. Agbaire and Esiefarienrhe [101] in a study have demonstrated that plants from experimental site contain more chlorophyll compared with those from the control. Increase in the content of chlorophyll a, chlorophyll b, total chlorophyll, and carotenoid in *Albizia lebbeck* and *Callistemon citrinus*, has been reported by Seyyednejad *et al.,* [87]. Investigation proved that chlorosis, is the first indicator of Flour effect on the plant [107]. Yun [108] showed the reduction in photosynthesis because of the PSII function damage, in sensitive species of tobacco. Carotenoids exist in plasma of plant tissues, photosynthetic or non-photosynthetic; the function of carotenoids in chloroplasts is as pigments to capture the light. But probably, the more important role is in protecting the cells and live organisms encounter with damage of free radical oxidative [109]. Plants fumigated with 40, 80 and 120 ppbv concentrations of O_3 exhibited a significant reduction in total chlorophyll content, RuBP carboxylase activity and net photosynthesis [110]. Carotenoids protect photosynthetic organisms against potentially harmful photoxidative processes and are essential structural components of the photosynthetic antenna and reaction center [102]. Carotenoids are a class of natural fat-soluble pigments found principally in plants, algae, and photosynthetic bacteria, where play a critical role in the photosynthetic process. They act as accessory pigments in higher plants. They are tougher than chlorophyll but much less efficient in light gathering, help the valuable but much fragile chlorophyll and protect chlorophyll from photoxidative destruction [105]. In a study conducted by Joshi and Swami [104] on *Eucalyptus cirtiodora* subjected to air pollution, highly reduced carotenoid contents were observed and in another study by the same group reported that the carotenoids concentration was reduced due to vehicular emission [102]. Several researchers have reported reduced carotenoid content under air pollution [75], [105], [106].

Dust Interference with Stomata functions

The effects are devastating in an arid environment, because even drought-tolerant crops, if wind stressed, show an increased rate of water loss due to increased stomatal conductance, abrasion of the vapor barrier and an increase of transpiration [110], [111]. A positive effect of the vegetation to the environment is its air filtering ability: dust particles in the atmosphere get deposited on the leaves, which improves the air quality. The leaves' ability to act as dust receptors depends upon their surface geometry, orientation, epidermal and cuticle features, leaf pubescence and plant height [112]. However, at the same time, dust on the leaf surface affects plant growth and development. For example, dust deposits on the leaves can alter their optical properties, especially the surface reflectance in the visible and near-infrared range of the wavelength [113]. Dust particulate matters deposition can cause blockage of the stomata on the upper surfaces of the vegetation under natural condition and to a smaller extent at the lower surfaces. According to Krajickova and Mejstrik [93], the stomatal diameters of most plants usually range from 8-12 µm. Therefore, dust particle size is an important criterion for a possible leave penetration. Particles with PM_{10} and smaller sizes can theoretically interfere with stomatal functions. Clogging the leaf stomata lowers the rate of transpiration and carbon assimilation, which finally causes a significant reduction in the photosynthesis rate. Dust affect less plant, which exhibits physical protection structures such as trichomes compared to plants without such physical barriers. Cornisch *et al.,* [114] concluded that an increase in yield is associated with the stomatal conductance in Pima cotton (*Gossypium barbadense* L.). Stomatal conductance depends on environmental factors, the position at the canopy and age of the leaves [115]. Coal dust significantly reduced carbon dioxide exchange of upper and lower leaf surfaces of the mangrove, *Avicennia marina* by 17-39%, whereby the reduction was generally greater on the lower leaf surface, which has the dense mat of trichomes and salt glands [91]. Nano and Ilias [97] describe a decrease of the stomatal conductance to H_2O and CO_2 in *Olea europaea* exposed to cement dust, resulting in a reduced productivity of olive trees. Hirano *et al.,* [64] found that dust decreased stomatal conductance of cucumber and kidney beans in the light, but increased it in the dark by plugging the stomata, when the stomata were open during dusting. When the dust of smaller size particles was applied to the plants, the effect was greater. However, the effect was negligible by closed stomata during dusting. Fluckiger *et al.,* [116] found, that 1 mg cm^{-1} of silica dust was necessary to cause a decrease in stomatal diffusive resistance in *Populus tremula,* but only 0.5 mg cm^{-2} was necessary to cause an increase in leaf temperature. Metabolic functions in plants operate only in a certain optimal temperature range. If a leaf heats up above 34°C, photosynthetic enzymes begin to denature and the leaf cannot perform its normal function. For example, Jiao and Grodzinski [117] describe an inhibition of photosynthetic export in *Salvia splendens* above 35°C in both photorespiratory conditions, whereby photosynthesis only under photorespiratory conditions was inhibited. Sucrose and raffinose but not stachyose accumulated in the leaf at 40°C. Plants react in this situation with an increase in transpiration to lower leaf temperatures.

Dust interaction with the Cuticle

Ulrichs *et al.,* [38] and Majumder *et al.,* [118] used silica dust applied to *Brassica* leaf surfaces as insecticides. The dust had strong lipophilicity and weak hydrophobic characteristics. Thereby, the dust got physically absorbed on the surface waxes of the leaves causing an irreversible damage resulting in a reduced photosynthetic rate. Bacic *et al.,* [119] made comparisons between the surfaces of *Pinus halepensis* needles from a site with relatively clean air and one near to a cement factory in Croatia. Induced changes in the appearance and quantity of surface wax were recorded only for the samples collected near to the cement factory. In particular, crystalline wax in supra-stomatal cavities appeared to coalesce and subsequently additional amorphous wax formed around the rim of the stoma. However, this effect depends on physico-chemical properties of the dust particulates and environmental conditions. Ulrichs *et al.,* [120] showed that application of fly ash on leaves did not interact with the leaves in open fields. In open field conditions, small size particles drift easily from the leaf surface via air movement and precipitation. Therefore, dusts impair directly neither leaf surfaces nor photosynthesis significantly.

Dust effect on Sugar

Soluble sugar is an important constituent and source of energy for all living organisms. Plants manufacture this organic substance during photosynthesis and breakdown during respiration [106]. Tripathi and Gautam [106], in their study, revealed a significant loss of soluble sugar in all tested species at all polluted sites. The concentration of soluble sugars is indicative of the physiological activity of a plant and it determines the sensitivity of plants to air pollution. Reduction in soluble sugar content in polluted stations can be attributed to increased respiration and decreased CO_2 fixation because of chlorophyll deterioration. It has been mentioned that pollutants like SO_2, NO_2, and H_2S under hardening conditions can cause more depletion of soluble sugars in the leaves of plants grown in the polluted area. The reaction of sulfite with aldehydes and ketones of carbohydrates can also cause a reduction in carbohydrate content [106]. Some researchers showed that Concentrations of total and soluble sugars decreased significantly in the sensitive trees to the air pollution. In damaged *Quercus cerris* leaves the decrease in concentrations of sugars was higher in September. The decrease in total sugar content of damaged leaves probably corresponded with the photosynthetic inhibition or stimulation of respiration rate [121]. Furthermore, an increase in the amount of soluble sugar is a protection mechanism of leaves it has been shown in Pinto bean in exposure with different concentration of ozone [122]. Following ozone exposure, soluble sugars in pine needle decreased [123]. Subsequently, they increased, frequently in association with foliar injury [122], [124]. The increase of soluble sugars was also observed following chronic exposure [124]. The increase in soluble sugar was reported in *Albizia lebbeck* and *Callistemon citrinus* grown in the industrial land [88]. Investigations revealed that the more resistant species plants to the air pollution as compared to sensitive species showed more concentration of soluble sugar [125], [126].

Dust effect on Proline

Some workers have been published the increase in free proline content in response to various environmental stresses in plants [127]. Typical environmental stress (high and low temperature, drought, air, and soil pollution) can cause excess Reactive Oxygen Species (ROS) in plant cells, which are extremely reactive and cytotoxic to all organisms [127]. High exposure to air pollutants forces chloroplasts into an excessive excitation energy level, which in turn increases the generation of ROS and induces oxidative stress [100]. The deleterious effects of the pollutants are caused by the production of Reactive Oxygen Species (ROS) in plants, which cause the peroxidative destruction of cellular constituents [75]. It has been reported that proline act as a free radical scavenger to protect plants away from damage by oxidative stress. Although the scavenging reaction of ROS with other amino acids, such as tryptophan, tyrosine, histidine, etc. are more effective compared with proline, proline is of special interest because of its extensive accumulation in plants during environmental stress [128]. Tankha and Gupta [129] showed the increase in the content of proline with increasing SO_2 concentration. According to existence of SO_2 and CO in the industrial area as the result of chemical activities, these results probably indicate that it has been clearly inconceivable to designate a harmless threshold toxic SO_2 concentration for level of particular species since other environmental factors during pollution profoundly affect the degree of damage [87]. A significant increase in the content of proline in *Albizia lebbeck* grown in the polluted area has been reported the concentration of proline increased in leaves of *Callistemon citrinus* planted round petrochemical site in comparison with control site [88]. Proline is a universal osmolyte accumulated in response to stress and may have a role in plant defense reactions [130]. Obviously proline has main role in protection in different kinds of stress. Accumulation of proline in plants is a physiological response to osmotic stress [131]. The effects of pollutants on plants include pigment destruction, depletion of cellular lipids and peroxidation of polyunsaturated fatty acid [75]. There appears to be a relationship between lipid peroxidation and proline accumulation in plants subjected to diverse kinds of stress, for example, proline accumulation in leaves of plants exposed to SO_2 fumigation [129], heavy metals [128] and salt [132] stress has been reported [128], [129], [132].

Dust effect over the soil

Dust particulates drift resulting from agricultural liming and fertilization can have an eutrophication effect on nearby soils. The best-studied dust particulates depositions are for coal fly ash from power plants. For decades, numerous researchers have looked into the possible use of coal fly ash in agriculture [133], [134], [135]. Hard coal fly ash is a small less, grey, fine-grained and powdery substance, which consists mainly of spherical, glassy particles. Main components of coal fly ash are SiO_2, Al_2O_3, and Fe_2O_3. Both Logan and Harrison [136] and Wong [137] described coal fly ash as rich in calcium and magnesium oxide and thus explaining the high pH value observed by others. Coal fly ash contains polychlorinate biphenyls, polycyclic aromatic hydrocarbons, and various metals in the mg per kg range. In various investigations, fly ash as substrate was used and data were interpreted from the viewpoint of plant nutrition [138], [139], [140]. Generally, changes in soil chemistry after dust particulates depositions may be most important for long-term effects on plants [141].

Soil nutritional value

Plants use inorganic minerals for nutrition. Many factors influence nutrient uptake for plants. Ions can be readily available to roots or could be “tied up” by other elements or the soil itself. Soil alkaline or acidic in pH makes minerals unavailable to plants. The optimal soil pH ranges for most crop plants between 5.5 to 6.2 or slightly acidic. This creates the greatest average level for availability for all essential plant nutrients. Therefore, extreme fluctuations in pH can cause deficiency or toxicity of nutrients. Cawse *et al.*, [142] found that rainfall around a cement plant in South Wales was high in phosphorus and vanadium and had a pH in the alkaline range. Garden cress was relatively insensitive to pH changes [143], [120]. Theis and Wirth [144] found that major components of coal fly ash particulates were Al. Fe and Si with smaller concentrations of Ca, K, Na, Ti, S and numerous trace elements. Some of those elements like Ca, Fe, Mg and K are required for plant growth [145], [146]. Some others like Be, Se and Mo can be toxic. Generally, coal fly ash is not an optimal source of phosphorus since it was found to be inferior to monocalcium phosphate [147]. However, Ca^{2+} and Mg^{2+} can increase plant growth, as shown for legumes [133], [134]. Next, to the nutritional value, dust particulates can have negative effects on the soil nutritional value. As for example, alarming concentrations of lead were found in the dust of densely populated urban areas and in water and land of various areas near the industrial waste disposals [148]. Plants absorb lead and accumulation of this metal is reported for roots, stems, leaves, root nodules, seeds etc. [149]. Furthermore, the lead content of plant tissues increases with the increase of exogenous lead level. Lead affects plant growth and productivity, whereby the magnitude of the effect depends on the plant species. Photosynthesis has been found to be one of the most sensitive plant processes and the effect of the metal is multifacial. Lead also inhibits Nitrogen fixation and NH_4 assimilation in the root nodules. It appears that toxic effect of this metal is primarily at the physiological level [148]. Warambhe et al., [150], had evidence that high coal fly ash depositions result in high soil pH values and phytotoxic boron contents in these areas that disturb plant growth. Only after sufficient precipitation, the phytotoxic characteristics of the substrates with very high coal fly ash content decrease. Other researchers claimed that higher boron contents in coal fly ash have soil-ameliorating characteristics [137]. Cline *et al.*, [151] showed that yields of soybeans increased up to 35% by coal fly ash applications on sandy and clay soils in the south of Ontario. On the yield of corn, coal fly ash had, however, no effects.

Soil texture and density

Normally, dust particulates deposition makes only a fraction of the topsoil volume. Therefore, a change of the physical structure of the soil is very unlikely. This is, of course, different dust particulates are collected and artificially deposited or mixed in the soil. For example, soil properties are influenced by coal fly ash application [152]. Here the physical and chemical properties of soil vary according to the original properties. Several researchers described the role of increasing coal fly ash contents in the soil with positive effects on the water holding capacity in sandy [153], [154], and coarse-grained [155] soils.

Impact of Dust on Plant Communities

Some of the earliest references regarding to dust influences on plant community structures date back to 1910. Parish [156] was interested in the shrub and grassland vegetation in California near cement factories. He found a shift in the vegetation community close to some cement factories [157]. Lotschert and Kohm [158] reported bark pH and Ca^2 content changes in the bark of trees after long-term dust exposure. Since water stress is one of the major urban stressors for trees such findings can help to select plant species and varieties in anthropogenically determined systems.

2. CONCLUSION

Present work provides basic information about the variation in dust particles accumulation of plant species. Variation of dust pollutions positively shows the impacts on plants species with the alteration of morphological, biochemical, epidermal, stomata functions, soil conditions, and soil nutritions and also species communities etc. Deposition of quarry dust has resulted in the reduction in the leaf area and chlorophyll content and also in the stunted growth. In this article, we summarized the influences of dust pollution on various parameters of vegetation.

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CONFLICT OF INTEREST

The authors have no conflict of interest.

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