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Dust Removal Capacity of Some Tree Species from Ambient Air in an Indian Metropolitan City

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Abstract

In the present day highly populated, urbanized, industry-based world, dust in the form of suspended particulate matter (size <10 μm) is one of the major key sources of air pollution that severely affect the human health. Plants with various canopy cover, pattern of phyllotaxy and leaf texture have the ability of retention of that dust particles from the ambient air. In the present study, four tree species *Alstonia scholaris*, *Neolamarckia cadamba*, *Ficus religiosa* and *Ficus benghalensis* were selected to understand the variation of dust deposition capacity in a metropolitan city, Kolkata, through a time scale of day length. Result reveals that *Alstonia scholaris* has the maximum retention capacity of dust particles followed by the *Neolamarckia cadamba*, *Ficus religiosa* and *Ficus benghalensis*. And the pattern is same in different time interval of the day, even during heavy traffic. The study would be helpful in urban development planning for selection of tree species towards mitigation of dust pollution.

Keywords: Air pollution; Dust amelioration; SPM; Canopy; Phylotaxy; Metropolitan city

1. Introduction

Suspended particulate matter (SPM) in the atmosphere in the form of dust is one of the major pollutants of urban air. Automobile exhaust, emissions from power plants and other industries, constructions of buildings and roads and even pollens and spores are the sources of SPM. Depending on its source, these SPM differs in composition, sizes and phases. Particles less than 10 μm (PM10) in diameter can easily enter the airways and upper lung area of humans whereas particles having less than 2.5 μm diameter can reach alveolar region (Pickrell *et al.*, 2009). Exposure to these suspended fine particulate matters are linked to several health hazards, starting from modest changes in respiratory tract and impaired pulmonary function to more severe cases like increased risk of death from respiratory and cardiovascular diseases, even lung cancer (WHO, 2002). Short exposure of less than 1 hour to SPM has been linked to cardiovascular and respiratory diseases (Curtis *et al*, 2006; Schwarze *et al*, 2006). Temporary exposure of few hours to high concentration of PM 2.5 increases the risk of myocardial infection. WHO in 2002 estimated 80,000 deaths annually caused by particulate matter.

Plants have the ability to filter particles

from air and return those on its leaves (Beckett *et al*, 1998). Some particles are absorbed into trees and most particles are retained on plant surface (Nowak, 2006). Trichomes or leaf hair may increase the dust capturing capabilities (Bakker, 1999). Epicuticular waxy layer plays an important role in accumulation of SPM as the waxy layer gets penetrated by particles and deposited inside the layer (Kaupp *et al.*, 2000; Jouraeva *et al.*, 2002). Trees with greater leaf area are able to capture more SPM as compared to the same ground area (Fowler *et al.*, 1989).

The transfer rate of dust particles from air to vegetation surfaces mostly depends on dust properties and the nature of receiving environment (Grantz *et al.*, 2003). Dust particles less than 10 μm can be transported by wind from source to several thousand kilometres (WHO, 2006) but Vehicular emissions and agriculture related activities generate local dust close to the source (Leys *et al.*, 1998). Dust particles get deposited on vegetation surfaces mostly in three ways viz. Wet deposition, dry deposition and occult deposition (Prajapati, 2012). Among these, wet deposition is the most efficient for fine particles of atmospheric origin e.g. cadmium, chromium, lead etc. (Smith, 1990). Whereas, rate of dry depositions is much slower compared to the wet or occult depositions - a continuous process affecting all exposed surface of plant body (Hicks, 1986). The particles with diameter of more than 1 μm, gravitational sedimentation is main depositional process (Chamberlain, 1986). The phylotaxy, roughness, wettability and age of the leaf determine dust retention capability (Neinhuis and Barthlott, 1998).

Kolkata, one of the age-old significant metropolitan cities of the World, lies in the eastern part of India with an area of 185 km^2 harbouring the habitation of 4.5 million people (2011 census, Government of India). Due to this large population, SPM in ambient air of Kolkata mostly sourced from vehicular emission standing at 312 tons daily (CPCB, 2012) and other fine particles. The canopy of the trees of such metropolitan plays a pivotal role in reducing SPM in the air. But due to variation of the morphological nature in leaf architecture, the deposition of dust particles on the leaves may vary from species to species. Thus, the present research was pursued to identify some trees with their capacity of accumulation in the abatement of particulate pollution which would help in future plantation program and green belt development in urban landscape.

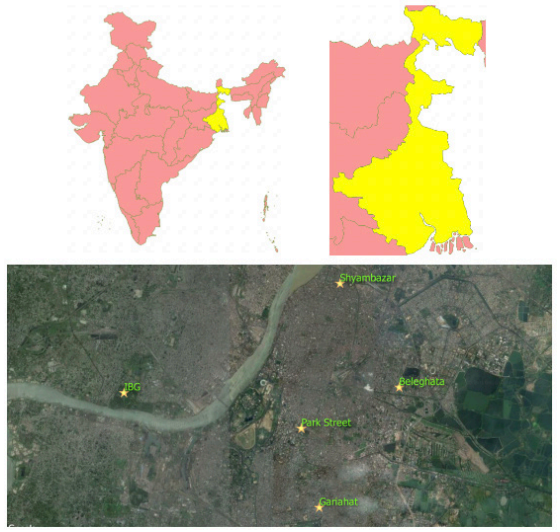

Figure 1. Map of 5 sampling sites in Kolkata (Map source: QGIS & Google Map)

2. Materials and Methods

Study site

The work was done in Kolkata metropolitan area (22.5726° N, 88.3639° E) having mean annual temperature from 22.3°C to 31.6°C and mean annual rainfall of 1821.8 mm with altitude between 6 to 9 m above mean sea level and falls in tropical climate with seasonal variations. In the present study, five sampling sites were selected out of which four (Gariahat, Beleghata, Park Street and Shyambazar) are at important road junctions of the city with high exposure of exhaust and other anthropogenic activities. Another sampling site was set at Acharya Jagadish Chandra Bose Indian Botanic Garden (AJCBIBG), Shibpur, as control site, 11 Km away from the city.

Four tree species were selected which were available in each of the sampling site. The species were: i) *Alstonia scholaris* R.Br, ii) *Neolamarckia cadamba* (Roxb.) Bosser iii) *Ficus religiosa* Forssk. iv) *Ficus benghalensis* L. From each of the five sampling sites three mature healthy leaves from the outer periferry of the branches were chosen at a height of 6 feet from the base of each selected tree to study the dust deposition at an interval of 3-hours and 24-hours. Each selected leaf was washed through distilled water, demoistened, exposed for scheduled time (3hrs or 24 hrs) and then collected in pre-weighed polythene air tight zipper pack (W1). The collected leaves in pre-weighted polythene bags were brought to the laboratory and weighed (W2) using a Remi weighing balance. The leaves were then washed with distilled water and wiped with tissue paper to get rid of excess water on leaf surface. The washed and demoistened leaves were then weighed again (W3) and the results noted down to get the amount of dust deposited on leaves (W4) through the equation W4 = W2- (W1+W3). This surface area of each leaf was measured by using millimeter graph paper. The rate of dust deposition per unit area was calculated by dividing weight of dust by leaf area.

3. Results and Discusssions

Dust deposition at 24-hour interval

Suspended particulate matter or dusts in the ambient air deposited mainly on adaxial surface of the leaves. The deposition is dependent not only on the source of SPM but on the morpho-anatomical structure of the leaves like texture, shape, size etc. The average of the dust deposition on the leaves at 24-hour interval from all the sites except IBG revealed that *Alstonia scholaris* had the maximum dust deposition (0.5650 mg/cm^2 ± 0.1299) following *Neolamarckia cadamba* (0.4738 mg/cm^2 ± 0.1270), *Ficus benghalensis* (0.3791 mg/cm^2 ± 0.09004) and *Ficus religiosa* (0.3685 mg/cm^2 ± 0.1018).

In case of IBG, dust deposition was very less having maximum in *Ficus benghalensis* (0.1957 mg/cm^2), followed by *Ficus religiosa* (0.1845 mg/cm^2), *Alstonia scholaris* (0.1793 mg/cm^2) and *Neolamarckia cadamba* (0.1172 mg/cm^2).

The maximum depositions of dusts on the leaves of *Alstonia scholaris* may be due to thick sticky leaf surface and whorled phyllotaxy. The large canopy covers and long internodal length which promotes maximum exposure for the ambient air in case of *Alstonia scholaris*. The leaves of *Neolamarckia cadamba* are less thick and not in whorled phyllotaxy that may have caused lesser amount of dust deposition. *Ficus benghalensis* and *Ficus religiosa* had more or less nearly same amount of dust deposition in a particular site may be due to their close taxonomic resemblance and textural pattern. The dust deposition on the same species in the Indian Botanic Garden (IBG) was in the following order: *Ficus benghalensis* > *Ficus religiosa*> *Alstonia scholaris*> *Neolamarckia cadamba*. As the amount of dust in the AJC Bose Indian Botanic Garden was very less in the air, the pattern of deposition in the metropolis area was not applicable

Dust deposition at a three-hour interval

During the study, the dust deposition at three-hour interval on the selected trees showed that, in all sampling sites of metropolitan city,

Alstonia scholaris had a maximum deposition and *Ficus benghalensis* had the minimum. *A. chinensis* & *F. religiosa* were both in intermediate position. The data revealed that, *A. scholaris* was with highest deposition during 2 PM to 5 PM and *F. benghalensis* had the lowest value of deposition during 11 AM to 2 PM at Gariahat. In all four sampling stations there was a pattern of deposition in all of the four species in order of 2 PM to 5 PM>8 AM to 11 AM>11 AM to 2 PM except at Gariahat. The maximum deposition during late afternoon was probably due to maximum traffic activity. During the 11 AM to 2 PM due to minimum traffic activity, the dust deposition was probably minimized. But at 8 AM to 11 AM, the office hours start with increased vehicular run that causes higher amount of dust deposition. Therefore, traffic activities regulate the rate of particular deposition on the leaf surface. AJC Bose Indian Botanic

Table 1. Dust deposition rate on four tree species in four different places in Kolkata and in Indian Botanic Garden in 24 hours interval

	Gariahat (mg/cm^2)	Beliaghata (mg/cm^2)	Park Street (mg/cm^2)	Shyambazar (mg/cm^2)	Average (mg/cm^2)	IBG (mg/cm^2)
Aistonia scholaris	0.584 ± 0.1407	0.648 ± 0.1522	0.376 ± 0.1496	0.652 ± 0.0453	0.565 ± 0.1299	0.179 ± 0.1301
Neolamarckia cadamba	0.408 ± 0.0544	0.600 ± 0.0620	0.329 ± 0.0020	0.558 ± 0.1432	0.474 ± 0.1270	0.117 ± 0.0901
Ficus benghalensis	0.334 ± 0.0740	0.394 ± 0.1535	0.290 ± 0.2398	0.498 ± 0.0524	0.379 ± 0.0900	0.196 ± 0.1014
Ficus religiosa	0.346 ± 0.0408	0.445 ± 0.1890	0.234 ± 0.1077	0.450 ± 0.1207	0.369 ± 0.1018	0.185 ± 0.0252

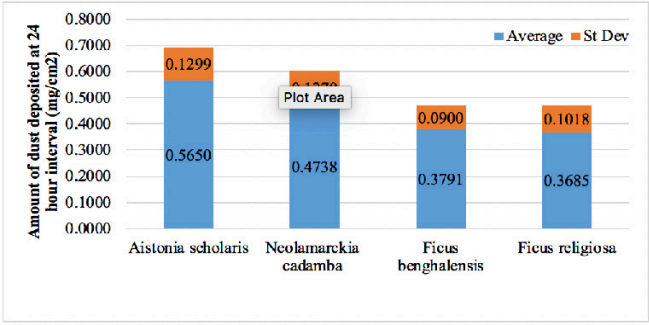

Figure 2. Average of dust deposited on four tree species in four places except IBG at 24 hours interval.

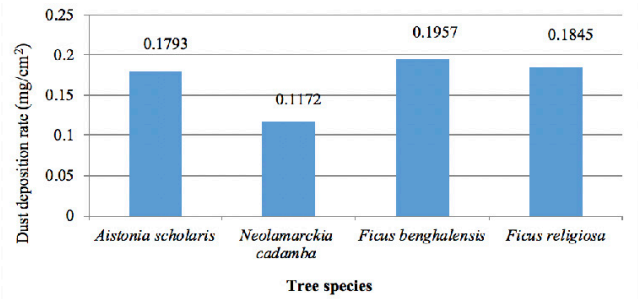

Figure 3. Dust deposition rate on four tree species in Indian Botanic Garden at 24 hours interval.

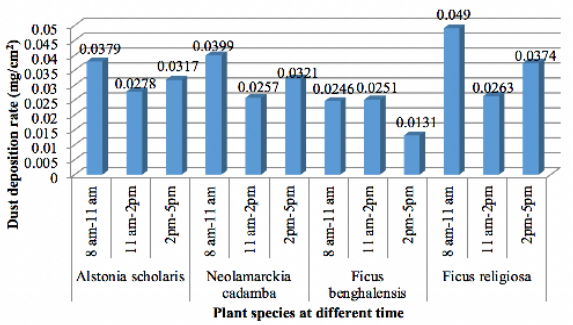

Figure 4. Dust deposition rate (mg/cm^2) on four tree species in four different places in Kolkata in 3 hours interval

Table 2. Dust deposition rate (mg/cm^2) on four tree species in 4 sampling sites at 3 hours interval

Tree species	Interval time of the day	Beleghata (mg)	Park Street (mg)	Gariahat (mg)	Shyam Bazar (mg)	Avg (mg)	Sd (mg)	IBG (mg)
Alstonia scholaris	8 am-11 am	0.252	0.26	0.236	0.223	0.243	0.017	0.038
	11 am-2pm	0.233	0.214	0.199	0.15	0.199	0.035	0.028
	2pm-5pm	0.318	0.262	0.25	0.255	0.271	0.032	0.032
Neolamarckia cadamba	8 am-11 am	0.201	0.19	0.127	0.199	0.179	0.035	0.04
	11 am-2pm	0.19	0.18	0.086	0.164	0.155	0.047	0.026
	2pm-5pm	0.217	0.225	0.153	0.229	0.206	0.036	0.032
Ficus benghalensis	8 am-11 am	0.073	0	0.054	0.096	0.056	0.041	0.025
	11 am-2pm	0.056	0	0.026	0.032	0.028	0.023	0.025
	2pm-5pm	0.091	0	0.043	0.099	0.058	0.046	0.013
Ficus religiosa	8 am-11 am	0.166	0.127	0.237	0.19	0.18	0.046	0.049
	11 am-2pm	0.135	0.086	0.213	0.123	0.139	0.053	0.026
	2pm-5pm	0.198	0.153	0.231	0.202	0.196	0.032	0.037

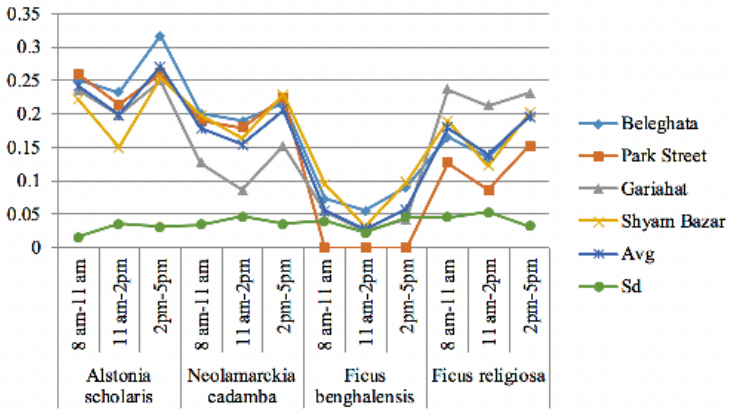

Figure 5. Average dust deposition rate (mg/cm^2) on four tree species in four different places in Kolkata at 3 hours interval

4. Conclusion

In the crowded city like Kolkata having dust pollution, several roadside/ avenue trees have the capacity to accumulate dusts from the ambient air. The study reveals that the leaves of *Alstonia scholaris* have the maximum capacity to accumulate the dusts. This medium high tree has less requirement of space for spreading its canopy spreading, thus worthy to plant to along the road side.

Ficus benghalensis and *Ficus religiosa* require much space for spreading its canopy and prop-roots and thus may be planted in parks and gardens for reducing dust pollution. As *Neolamarckia cadamba* is very tall in nature, it is better to be planted in parks instead of road side.

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