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Screening of Urban Plants for Monitoring Dust In Mumbai

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Abstract: Foliar dust was collected from common plants, Bougainvillea spectabilis Willd., Ficus benjamina L. var nuda, Nerium odorum Aiton. and Pedilanthus tithymaloides Poit., growing along 81 road dividers and traffic islands. Dust was collected throughout the dry season form all the four above mentioned species. Statistical analysis showed Ficus benjamina L. var nuda was the best dust capturer with $F = 56.75$, $P < 0.001$, whereas the Tukey-Kramer test showed the same species to be the best dust retainer. Eight sites in the city of Mumbai which have been established to have high suspended particulate matter were selected for this study. The sites were selected on the basis of vehicular types and count. Foliar dust on Ficus benjamina L. var nuda was estimated throughout the dry season at these selected sites. Maximum dust was found at Borivali, Western Express Highway in the month of May, 2013 with the value 29.78g/m^2. The amount of dust present on the surface of the leaves relate to vehicular count. The eight sites showed varied foliar dust values in the study. High values of foliar dust were in agreement with the existing conditions along the roadsides at different sites. Borivali site had high values of foliar dust due to construction activity along the highway, while Bandra showed high values due to it being a busy road with all types of vehicles plying. Hence Ficus benjamina L. var nuda can be used as a Phytomonitor of dust in this city.

Keywords: Mumbai, Phytomonitor, Dust, SPM

Introduction

Mumbai is one of the most densely populated and polluted cities of India. The pollutants range from NO_x, CO and SPM (Joshi and Chauhan, 2008). 40% of total air pollution problems in India is due to dust (Lone et al. 2005). The total number of vehicles in Mumbai as on January 2011 is 19,09,804 including 54.5 % two wheelers, 31.2 % cars, 3.5 % taxis, 2.8 % heavy vehicles, 7.6 % three wheeler and 0.4 % of other vehicles (MCGM, 2011) which contribute significantly to air pollution. Particulate matter concentration in Greater Mumbai is higher than the prescribed standards and WHO guidelines (Gupta et al). Researchers have shown that plants can act as biological filters, removing large quantities of particulate matter from the urban atmosphere. This is predominately due to large leaf areas. That plants can be effectively used to monitor dust in the city of Mumbai has been well documented (Joshi, 1990 and Chaphekar S. B., 1980). The major constituent of dust pollution is sticky particulate matter which is released in the exhaust of automobiles and deposited on the leaves of common roadside plants (Yunus et al., 1985). The dust interception capacity of a plant depends on its surface geometry, phyllotaxy and external characteristics of its leaf such as hairs, cuticle, length of petioles, height / canopy of trees and the prevailing weather conditions with direction and speed of the wind (Prajapati and Tripathi 2008).

Urban vegetation in Mumbai comprises of gardens, avenue trees and ornamental plants which grow along the road dividers and traffic islands at junctions of cross roads. This urban vegetation is largely maintained by Municipal Corporation or corporate sectors in their effort to keep the city green. Dust is normally measured using a high volume sampler which proves to be more or less accurate, but becomes an expensive proposition over using plants. Plants can be placed at locations where no electrical source is available and even at locations with crowded traffic conditions. The city of Mumbai with its rapid construction activities and ever increasing traffic conditions make it more vulnerable to dust pollution. Hence monitoring dust using plants even on a relative scale proves to be a good ecological indicator of dust pollution. Hence this work was carried out to indentify a commonly

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found plant species and to use it as a Phytomonitor of dust with a view to prepare a dust map of the city.

Materials and Methods

Preliminary studies

A floristic survey was conducted to identify the most commonly growing ornamental plant species growing along road dividers in the city. Most frequently found species at majority of the sites were *Bougainvillea spectabilis* Willd., *Ficus benjamina* L. var *nuda*, *Nerium odorum* Aiton. and *Pedilanthus tithymaloides* Poit. Dust from leaves of above plant spieces growing along 81 sites was collected.Leaf samples from the plants were collected in separate zipper pouches, in triplicate, every month and were then brought to the laboratory in the dry season i.e. from December 2011 to November 2012, leaves of each plant sample were washed with water using spray bottles and was carefully collected on pre-weighed Whatman's filter paper (pore size 110mm). The filter paper was then oven dried and later weighed to calculate the dust fall. Washed leaves were blotted dry and then traced on graph paper which gave the total leaf area in cm^2 and dust fall was calculated in g/m^2 (Joshi N. C., 1990, Chaphekar *et al*. 1980).

Dust monitoring methodology

Eight sites were selected on the basis of their traffic density. Leaves of *Ficus benjamina* L. var *nuda*, growing along road dividers, were washed with a brush to completely remove dust particles from the surfaces. The leaves were marked with a ribbon tied to it. On the seventh day the leaves were collected in zipper pouches. From all sites three leaves were collected. Dust was determined as mentioned above and expressed in gm/m^2. Foliar dust was determined from all eight sites in dry season from Feb-13 to Jan-14 (Table 1).

Monitoring of traffic

Traffic volume was monitored using a digital camera (Sony make, Model No. DSC – W150). Hourly traffic count was calculated by analyzing the video footage taken during field observation. Hourly traffic count has been expressed in number of vehicles per minute (Kadiyali, 1996).

Statistical analysis

Box and whisker plots were used for exploratory data analysis. The data was tested for normality using Tukey-kramer test and Analysis of Variance (Zar, 2009) was applied to determine significant differences between the plant species. Statistical analysis was carried out using SPSS software version 11.

Table 1: Description of selected sites

Site No.	Name of the Sites	Traffic Description
1	Marine Drive	Busy road facing Arabian sea, mainly with private vehicles
2	Ghatkopar, Eastern Express Highway	Broad and very busy road showingheavy traffic including all type of vehicles
3	Mulund, LBS Marg	Very busy but comparatively narrower road mainly with heavy vehicles. leaves collected away from traffic signal
4	Borivali, Western Express Highway	Very busy and broad road with heavy traffic including all types of vehicles. Construction activity going on.
5	Goregaon, SV Road	Narrow road having good frequency of slow moving traffic including all types of vehicles
6	Malad, Linking Road	Main and busy road having moderate to heavy traffic, all types of vehicles.small scale industries
7	Bandra, Linking Road	Busy road, narrow in size with all type of vehicles showing moderate to heavy traffic.traffice signal
8	Krishna Chandra Marg	Short length, narrow and busy road with all type of vehicles, traffic signal

Results and Discussions

The dust fall quantified on the leaf surfaces of *Bougainvillea spectabilis* Willd., *Ficus benjamina* L. var *nuda*, *Nerium odorum* Aiton. and *Pedilanthus tithymaloides* Poit. at eighty one sites, throughout the dry seasons of 2011-12 are represented in the Fig 1 in the form of Box plots. One way ANNOVA results show that *Ficus benjamina* L. var *nuda* had significantly best dust depositions with $F = 56.75$, $P < 0.001$. Tukey-Kramer test also showed that *Ficus benjamina* L. var *nuda* was the best dust retainer form the four plant species.

The sites were visited at peak hours to record the vehicular count. Number of 2-wheelers, 3-wheelers, 4-wheelers and heavy vehicles (Busses, Trucks, etc.) were recorded. For counting different types of vehicles three observations of one minute each were considered. The average count of various automobiles passing per minute from each site was expressed (Table 2).

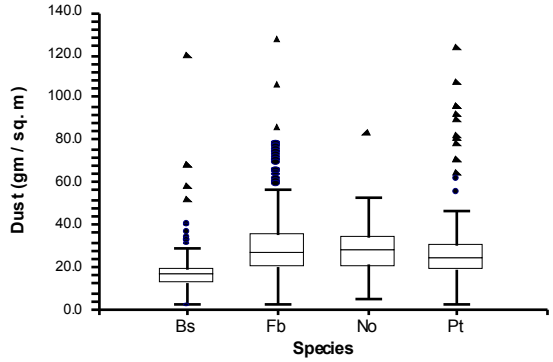

Fig. 1: Dust capturing capacities of different plant species

Dust Monitoring

Ficus benjamina L. var *nuda* was used to monitor dust at 8 critical sites in the city, in the dry months from February 2013 to January 2014 season. The intermediate period between June to September being the monsoon period, dust was not collected from the leaves of the plants species. The results are represented in Table 3.

Table 2: Average number of vehicles per minute at study sites

Site No.	2-Wheeler per min	3-Wheeler per min	4-Wheeler per min	Bus/Truck per min	Total
1	9	0	14	4	27
2	16	7	24	15	62
3	15	10	20	19	64
4	27	19	22	8	76
5	13	15	20	5	53
6	14	11	14	10	49
7	12	21	13	5	51
8	10	16	15	3	44

Table 3: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* in gm/m^2 at different sites

Site No.	Fb-13	Mr-13	Ap-13	My-13	Oc-13	Nv-13	Dc-13	Jn-14
1	4.29	5.71	10.12	8.22	6.93	5.38	4.66	5.32
2	8.82	4.29	15.13	20	11.46	10.12	8.93	10.43
3	5.07	6.67	11.84	14.03	12.94	12.53	10.69	13.77
4	5.5	28.75	23.19	29.78	15.86	11.56	10.35	12.65
5	12.02	5.71	14.67	17.9	7.94	9.21	8.07	9.33
6	10.95	8.33	13.65	15.5	13.81	10.42	12.97	11.15
7	18.18	22.5	14.32	16.41	10.35	8.24	9.15	7.79
8	22.67	10.5	13.77	18.91	13.27	10.18	11.51	8.68

Site 1: Marine Drive:

This site was found to be with the least dust in the study period. The highest amount of dust was recorded in the month of Apr-13, followed by May-13, whereas in Feb-13 it was the least for this site. Being located opposite the sea front, this site is influenced by sea blowing the dust away from the leaves. Moreover a traffic restriction in this area prevents entry of heavy vehicular and three wheeler traffic. Dust values were low for this site in comparison to other sites.

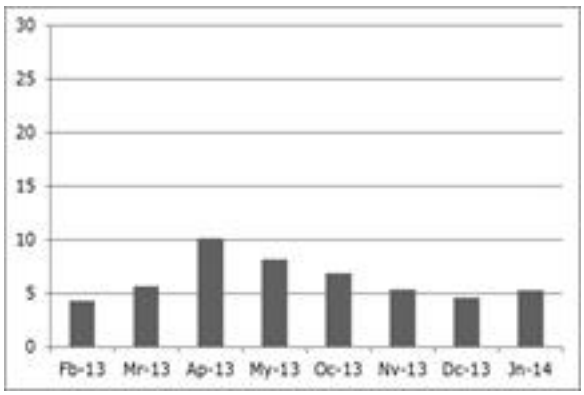

Fig. 2: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 1 in gm/m^2

Site 2: Ghatkopar, Eastern Express highway:

At Ghatkopar, maximum amount of dust on the leaves was observed in the month of May-13 and in Apr-13, with dust values 20 gm/m^2 and 15.13 gm/m^2 respectively. In Mar-13, dust deposition was least for the site.

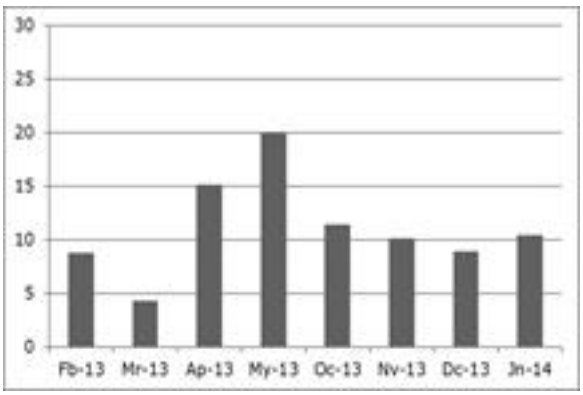

Fig. 3: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 2 in gm/m^2

Site 3: Mulund, Lal Bahadur Shastri Marg:

The dust values recorded at Mulund were high from Apr-13 to Jan-14 with values greater than 10 gm/m^2 whereas in Feb-13 and Mar-13 it was less than 10 gm/m^2. May-13 showed the highest dust deposition for the site, 14.03 gm/m^2 and Jan-14 showed second highest value, 13.77 gm/m^2.

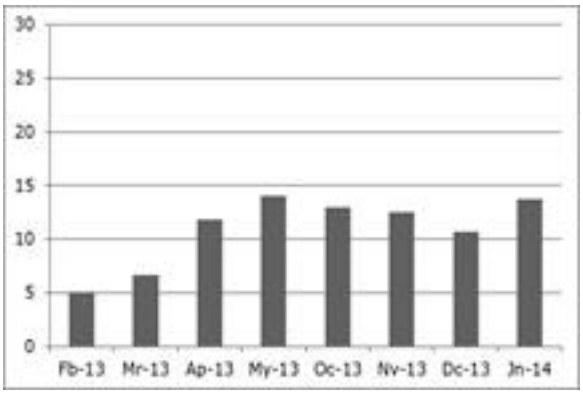

Fig. 4: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 3 in gm/m^2

Site 4: Borivali, Western Express highway:

At Borivali all the months except Feb-13 had foliar dust greater than 10 gm/m^2. Maximum foliar dust was recorded in May-13, with 29.78 gm/m^2 and Mar-13, with 28.75 gm/m^2. Least dust was noted in the month of Feb-13, with value of 5.5 gm/m^2. This site had construction activity going on in the vicinity resulting in consistently high dust values. Moreover, this site was located at National highway with high density of vehicles, resulting into high dust values.

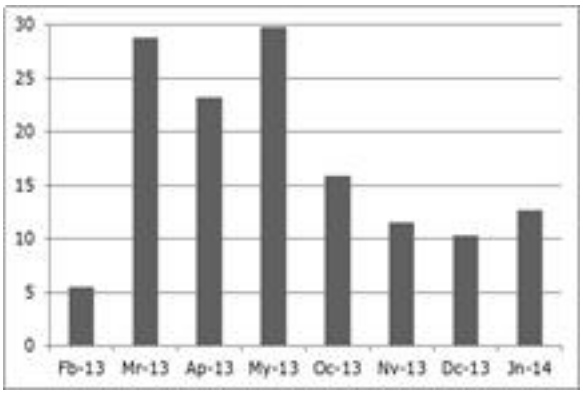

Fig. 5: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 4 in gm/m^2

Site 5: Goregaon, Swami Vivekanand Road:

Foliar dust at this site was higher in Feb-13, Apr-13 and May-13 than the remaining five months. May-13 was dustiest of all months, with a value of 17.9 gm/m^2 and Apr-13 also showed higher dust value of 14.67 gm/m^2. Mar-13 was the month showing least amount of dust.

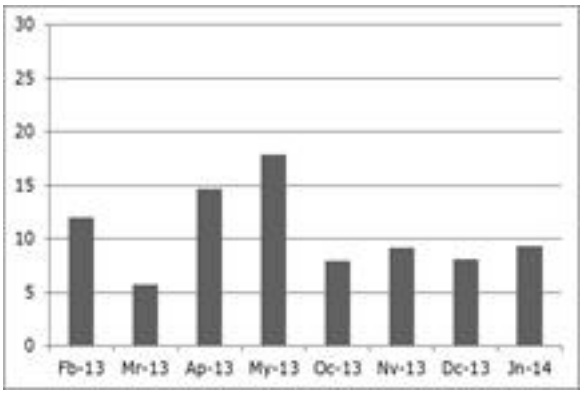

Fig. 6: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 5 in gm/m^2

Site 6: Malad, Linking Road:

At Malad, foliar dust was found to be less in the month of Mar-13 while rest of all months showed dust content on the leaf surfaces more than 10 gm/m^2. Highest dust deposition was recorded in the month of May -13. The dust values of Feb-13, Nov-13 and Jan-14 were between 10-12 gm/m^2, whereas, the dust values of Apr-13, Oct-13 and Dec-13 were very high, with values between 12-14 gm/m^2.

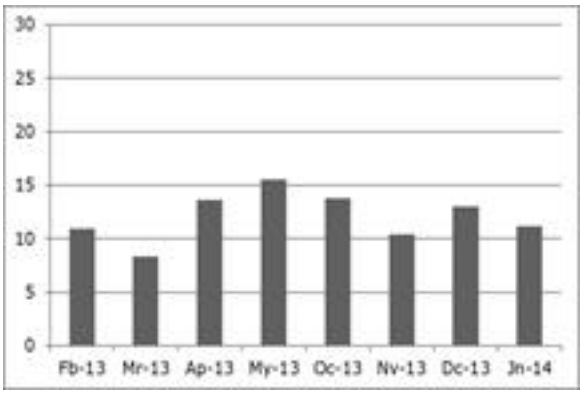

Fig. 7: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 6 in gm/m^2

Site 7: Bandra, Linking Road:

This site was located near a traffic signal and showed high dust values. The highest dust value was recorded in Mar-13, 22.5 gm/m^2. The second and third highest values were observed in Feb-13, 18.18 gm/m^2 and May-13, 16.41 gm/m^2 respectively. In Jan-14 the least dust value was recorded, 7.79 gm/m^2. This road is one of the arterial roads connecting the north of the city to south with all types of vehicles, including 3 wheelers like auto-rickshaws.

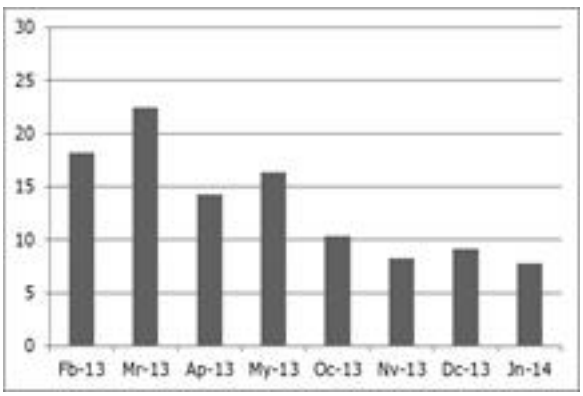

Fig. 8: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 7 in gm/m^2

Site 8: Krishna Chandra Marg:

This site too recorded very high values of foliar dust. Feb-13, with 22.67 gm/m^2 was the dustiest month at this site followed by May-13, being 18.91 gm/m^2. Except Jan-14, all the months showed foliar dust greater than 10 gm/m^2. The site was located at intersection of main roads, with all types of vehicles, showed high foliar dust values throughout the study period.

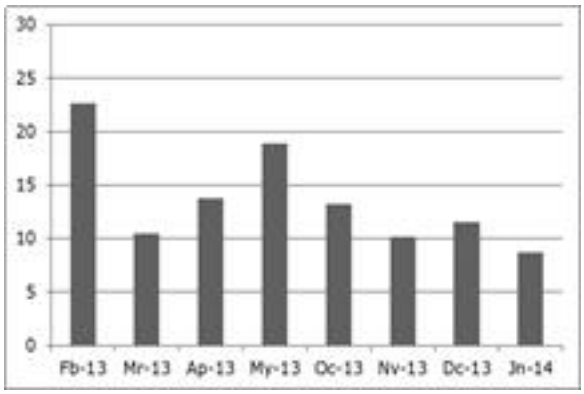

Fig. 9: Dust fall on the leaves of *Ficus benjamina* L. var *nuda* at Site 8 in gm/m

Conclusion

Statistical analysis suggested Ficus *benjamina* L. var *nuda* to be the better dust capturer than *Bougainvillea spectabilis* Willd., *Nerium odorum* Aiton. and *Pedilanthus tithymaloides* Poit. (Fig. 1). *Ficus benjamina* L. var *nuda*, was used to monitor dust throughout the dry period at eight sites. Dust retention capacities vary from species to species and depends on several morphological characters of the plant species is a well known fact.

The dustiest site showing maximum foliar dust in the entire study was seen at Borivali, Site 4. The number of vehicles too was highest at this site, being 76 vehicles / minute. Similarly Marine Drive, which is least dusty, showed only 27 vehicles / minute. At Bandra linking road, vehicle count per minute was lesser 51 vehicles / minute and 44 vehicles / minute at Krishna Chandra Marg, but the dust values were higher at these sites because of more frequent signals and also predominance of three wheelers, buses and trucks (Table 3 and Fig. 10)

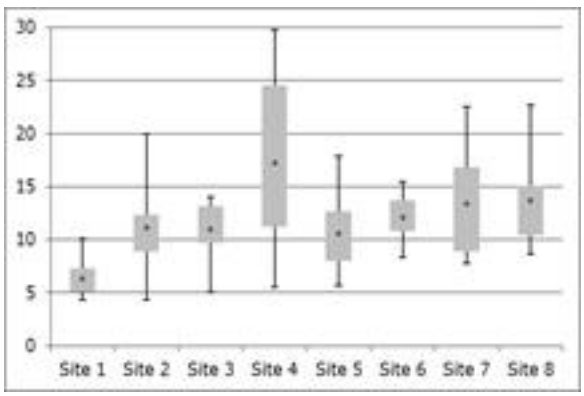

Fig. 10: Box-Whisker Plot for Foliar Dust deposition (gm/m^2) of *Ficus benjamina* L. var *nuda* in study area

During the span of eight months study, May 2013 was found to be the dustiest month. There is a gradual increase in foliar dust values from December to the month of May. Similar trend was also observed by Shetye et al 1980 on dust deposition on road side tree in the city (Fig 11). Based on the studies carried out in the current work, a foliar dust map of city of Mumbai is prepared (Fig 12). Usually, air quality is measured by specific monitoring stations for different gases and suspended particles, especially PM_{10}. The limited number of these stations in the city does not allow monitoring of dust in large number of areas, particularly in a big city like Mumbai. Therefore the use of *Ficus benjamina* L. var *nuda* as a Phytomonitor of dust has an advantage over advanced and more sophisticated methods. The plant is relatively easy to handle with simple methodology. The main advantage is that plant is commonly available in the city. The drawbacks are mainly related to the measurement quality, in terms of reproducibility and sensitivity, because of the high heterogeneity of the living conditions. Apart from monitoring dust *Ficus benjamina* L. var *nuda* can serve as an important plant species in an urban environment for green belt development and air quality management.

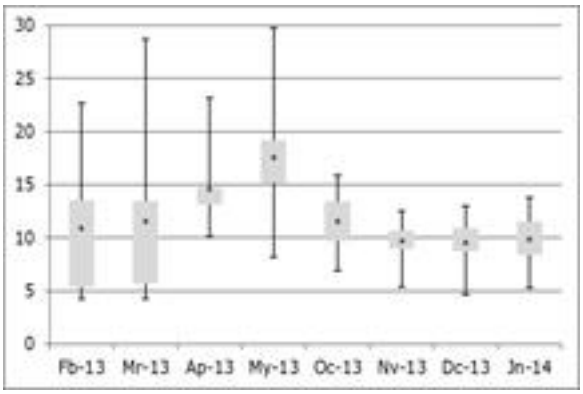

Fig. 11: Box-Whisker Plot for Foliar Dust deposition (g/m^2) of *Ficus benjamina* L. var *nuda* in Study period

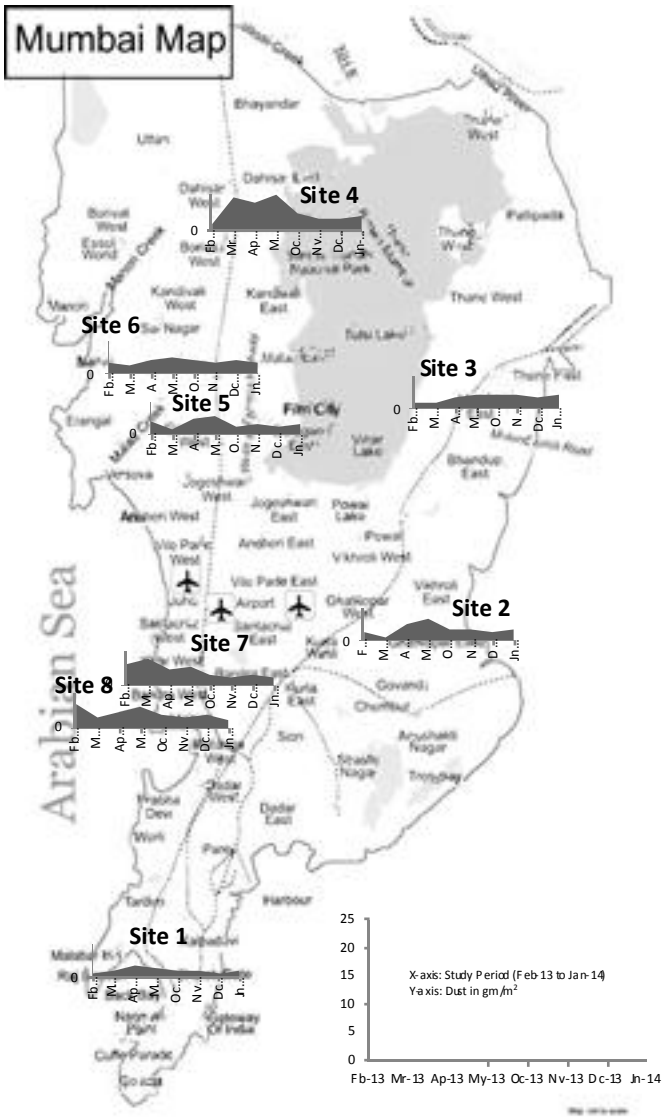

Fig. 12: Foliar Dust Map of Study Area

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Conflict of interest: None Declared