Spatial analysis of ambient heavy metal pollutants in the tree leaves in Kanchipuram town, Tamil Nadu, India

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Abstract. Spatial distribution and accumulation of nine harmful heavy metals (Pb, Zn, Mn, Fe, Cr, Cu, Cd, As and Al) on the leaf surfaces of five tree species namely *Saraca asoca, Ficus religiosa, Syzygium cumini, Pongamia glabra and Terminalia catappa* were analysed to identify the level of contamination of ambient air in Kanchipuram town, TamilNadu. The leaf samples were collected during February-March 2018 from six sites located within the town in the distributed manner and analysed by using inductively coupled plasma mass spectrometry. The results revealed that the concentration of As, Cd, Cr and Pb were invariably found lesser than their detectable limit, Fe (289mg/kg), Al (162mg/kg) was identified to be maximized, Cu, Mn and Zn lower levels. The absorption capacity of *Ficus religiosa* was poor and other species were shown good responses. The concentrations of Al, Cu, Fe, Mn and Zn were very low in sites 1, 2, 3, 6 where the trees were numerous and found high at sites 4 and 5 may be due to anthropogenic activities and vehicular emission. According to the analysis, the selected species performed as bio indicators and were developed around the industries to maintain greenbelts and enhance air quality.

Keywords: Accumulation, Ambient, Species, Bio monitoring, Bio indicators

1 Introduction

Air pollution is one among the critical environmental issues in many parts of the globe out of which heavy metals pose a greater threat to the surrounding environment and endangers the health of human beings. These metals originated from various sources such as combustion of any fossil fuels, vehicular emissions and automobile exhausts, wear and tear of tires, agriculture, household activities, metallic corrosion and re-entry of particles from the road surface [1, 2]. Heavy metals emitted into the atmosphere will continue for a longer period with scattered levels and interact with other natural elements in the atmosphere [3]. Metals can be found on the plant's surfaces, soil and dust on the road either by the process of absorption or adsorption [4, 5]. The accumulation of trace metals by plant is much higher than the levels found in soil which proves that the trace elements are taken up from the atmosphere [6]. Urbanized areas are most prone to these effects, since numerous mobile and stationary sources, including energy production, waste treatment, industrial activities, construction, and vehicle exhausts, emit huge amounts of toxic metals into the soil and atmosphere [7]. Monitoring by equipment is costly and suitable only in limited areas. Green plant species acted as a filter for refining the air by absorbing and accumulating the pollutants from the ambient air [8, 9, 10]. Hence different plant species were used as bio monitors to know the details about the quality of the environment [11, 12]. Monitoring by plant species is the cheapest method and to assess the various sampling sites at the same time [13, 14, 15, 16]. Plants located closer to the roads exhibited higher concentrations than those in other locations [17]. Plant species which accumulate more amounts of heavy metals in various parts cannot provide the sufficient details about the environmental conditions [18, 19, 20]. The plants which show more tolerance to air pollutants are generally preferred in industrial and urban areas to maintain the green belt environment [21]. The passive (natural) and active (transplant) monitoring methods have been practiced to monitor air pollution in urbanized areas most frequented by various workers, both in other parts of the world as well as in India [22]. Passive biomonitoring by lichens and mosses are the effective method of studying the spatial distribution of heavy metals in the larger areas [23, 24, 25, 26]. Even though lower plants were the ideal bio monitors due to its lesser availability in the urban and industrialized areas higher plants are widely used [27, 28, 29, 30]. Deciduous or evergreen trees can absorb and adsorb the atmospheric pollutants very well, especially their green leaves compared with any other part of the tree [31, 32, 33, 34]. Heavy metals accumulate in leaves in large quantities [35].

The object of this study was to examine the spatial distribution of nine heavy metals, including iron (Fe), Aluminium (Al), Zinc (Zn), Copper (Cu), Manganese (Mn), Arsenic (As), Cadmium (Cd), Chromium (Cr) and Copper (Cu) absorbed on leaf surface of trees such as *Ficus religiosa* (Peepal), *Pongamia glabra* (Pongam), *Saraca asoca* (Asokha), *Syzygium cumini* (Jamun) and *Terminalia catappa* (Almond). Species were chosen based on their availability and proximity to or facing the roadsides from various sites across a wide area. Additionally, the research identified the species with the highest absorption capability of selected metal pollutants on their surfaces.

2. Materials and methods

2.1. Selected Tree Species

Plant species selected for the present work include *Saraca asoca*, *Terminalia catappa*, *Pongamia glabra, Ficus religiosa and Syzygium cumini*, which are all naturally occurring and available on all chosen sites.

Saraca asoca- It comes under the family of Caesalpiniaceae. It is an evergreen tree growing 7 to 10m high and the leaves are 15 to 20cm long with 6-12 leaflets and in oblong shape [36].

Terminalia catappa- It is associated with the family of Combretaceae. It is a tall, clear, semi-evergreen fast-growing tree. It is an erect tree coming to 15-25 m tall, with the greatest distance across of 1-1.5 m and strengthened base [37].

Ficus religiosa- As a semi evergreen tree, its height ranges from 10 to 30 meters, and its trunk measures 3 meters in diameter. Its leaves are dark green, and it grows 10-17m long [38].

Pongamia glabra- It is a tree which is losing its leaf annually and grown to a height of 15-25m and 0.5-0.8m diameter of trunk. Its leaves are 4-7.5 cm length and 1.7-3.2cm in width [39].

Syzygium cumini- It belongs to the family of Myrtaceae. It has grown up to 30m height and diameter at the crown is 11m and 0.6 to 0.9m at its base. The leaves are 2.5–10 cm in width and 5 to 25 cm long and elliptical or oblong in shape [40].

2.2 Study Area

The town of Kanchipuram covers a total area of 11.605 sq.km and its population density as of 2011 was 1, 64,265 per square kilometre. It is around 72 km from Chennai, Tamil Nadu's capital. Kanchipuram town is placed at 12.8387°N and 79.7016°E along the bank of Vegavathi river, a tributary of the Palar River, and is 83.2m above the mean sea level [41]. Kanchipuram is popular for its silk weaving and different types and designs of silk sarees can be found there, thereby earning it the title "Silk City". Nowadays, the town's population is extensively grown in city regions because of numerous motives like its distance closer to Chennai, cost of living is cheap, and plenty of industries. Fig. 1.

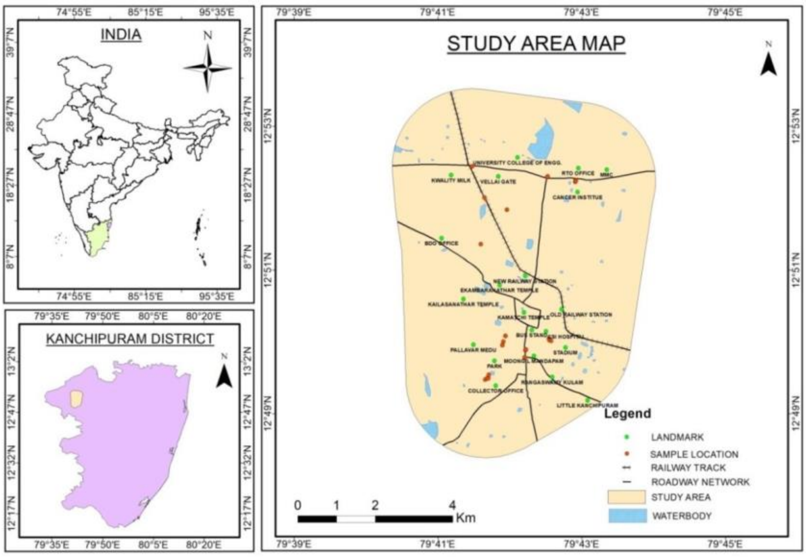

Figure 1. Map shows the study area

2.3 Sampling Sites

Research was conducted at six sites within Kanchipuram, with sites chosen from across the different zones:

Site 1, called Vellagate, is on the Kanchipuram-Tirupati state highway, as well as with many rice mills within the vicinity. Site 2, called CSI Hospital, is located with government hospitals, although the vehicular movement is heavy due to the traffic regulations. Among the sites chosen for testing, Site 3 is within the confines of the Cancer research institute and Bakthavatchalam polytechnic college, located off the Chennai-Bangalore highway and 4 km from Kanchipuram bus station. Site 4, Moongil Mandapam, is considered a high traffic area since it is the entrance point through which all the vehicles enter the town from various directions. Site 5 includes a collector's office, police training center, and department of archaeological survey and 2 km distance from the bus stand. In Site 6, which is an inhabited area with many houses and large parks, there is less movement of four wheelers, however, during the Varadharajar temple festival, the traffic is diverted to this side. As a result, it was chosen as a control site.

2.4 Sampling

Samples were collected in February-March 2018 between 6 a.m. and 8 a.m. to ensure that there had been no rain for over thirty days prior to sampling and that the majority of dirt had been absorbed by the leaves through their surface. Leaf samples were picked up randomly at a height of 1.8 meter to 2.4meter near the roadside and carefully stored in zip lock bags for heavy metal analysis. The leaves were then taken to a laboratory for analysis (Liu et al., 2017; Tak et al., 2019). The collected samples were digested with the help of closed loop microwave digester, and analyzed by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) [42, 43].

2.5 Statistical Analysis

With the experimental data obtained, the mean, median, and standard deviation of each variable was calculated with the help of Microsoft Excel. Pearson correlation coefficient between both independent and dependent variables was computed by using a software known as statistical package for social sciences (SPSS) version 18.0.

2.6 Spatial Distribution of the Pollutant by GIS

Based on the sampling sites the base map was prepared by using Arc map in Geographic Information System and added the experimental results in the concerned sites. Thematic map was prepared for all the tested parameters and classified by using interpolation technique. The map represents the spatial difference between each metal with proper scales and color selected that distinctly shows the variations in their concentration throughout the sampling period.

3. Results and discussion

Based on the selected locations and specific tree species, this study examined and illustrated changes in heavy metals accumulated on the leaf surfaces of selected five tree species, likely Iron, Aluminium, Zinc, Copper, Manganese, Arsenic, Cadmium, Chromium and Lead. Maximum, minimum, mean, median, and standard deviation of the heavy metals viz., Fe, Cu, Zn, Al and Mn were specified in Table 1 and the concentration of other heavy metals As, Cr, Cd and Pb were noted at below detectable limits.

Most of the heavy metal pollutants are released into the atmospheric air from the sources namely rubbing tires and brake pads (Cu, Zn, and Cd), abrasion of metals from roads due to corrosion (Fe, Ni, Cu, Zn, Cd) and combustion of fuel with additives (Zn, Cd, Pb) [44, 45, 46]. Metals like Pb and Zn emitted due to the high density of traffic, disused automobile parts and elation of vehicle tires [1, 2]. Fe let out into the air from both man-made and natural sources [47, 7, 29].

The level of heavy metals varied with locations and selected species. The amount of Fe ranged between 4.1 to 213 mg/kg in *S.asoca*, and the other metals such as Cu, Zn, Al and Mn were identified as 0-3.4, 0-10.4, 2.5-94.3 and 0-17mg/kg respectively. In *T.catappa*, the heavy metal concentration range was observed as 3.6-116, 0-5.1, 0-7.7, 0-63.4 and 0-10.5 mg/kg for Fe, Cu, Zn, Al and Mn respectively. Metals Fe, Zn varied as 0-2.2 and 0-2.08 mg/kg and other metals like Cu, Al and Mn were found as zero in *F. religiosa*. The observed values of Fe, Cu, Zn, Al, and Mn in P. glabra were 0-289, 0-5, 0-18.3, 0-162 and 0-23.3 mg/kg, respectively. In *S.Cumini* maximum and minimum range of concentration of Fe, Cu, Zn, Al and Mn was found as 0-119, 0-42.1, 0-9, 0-26.5 and 0-26.3 respectively.

Table 1. Statistical Approach of Heavy Metals Accumulated on the Leaf Surface of Five Species from the Sampling Areas.

Species	Parameters	Mean	Median	SD	Max	Min
S. asoca	Fe	98.57	79	90.77	213	4.1
	Cu	1.60	1.45	1.76	3.4	0
	Zn	5.98	7.15	3.79	10.4	0
	Al	33.77	21.6	36.75	94.3	2.5
	Mn	5.42	3.15	6.89	17	0
T.catappa	Fe	46.95	30.95	49.58	116	3.6
	Cu	2.32	1.95	2.57	5.1	0
	Zn	3.65	3.8	3.34	7.7	0
	Al	27.30	18.6	28.63	63.4	0
	Mn	4.08	1.85	5.10	10.5	0
F. religiosa	Fe	0.37	0	0.90	2.2	0
	Cu	0	0	0.00	0	0
	Zn	0.35	0	0.85	2.08	0
	Al	0	0	0.00	0	0
	Mn	0	0	0.00	0	0
P.glabra	Fe	79.23	21.7	115.74	289	0
	Cu	2.45	2.15	2.72	5.7	0
	Zn	7.40	6.55	7.26	18.3	0
	Al	49.02	33.55	62.95	162	0
	Mn	8.83	3.6	11.25	23.3	0
S.cumini	Fe	39.50	30.90	47.20	119	0
	Cu	7.83	0.00	16.90	42.1	0
	Zn	3.18	1.90	3.86	9	0
	Al	10.03	7.35	11.62	26.5	0
	Mn	8.92	2.85	11.91	26.3	0

The average concentrations of all the five metals were in the descending order of Fe > Al > Zn >Mn> Cu (98.57 > 33.77 > 5.98> 5.42 > 1.60) in *S.asoca*, Fe > Al >Mn> Zn > Cu in *T.catappa* (46.95 > 27.30 > 4.08 > 3.65 > 2.32) and in *P. glabra* (79.23 > 49.02 > 8.83 > 7.40 > 2.45), Fe > Zn >Al, Mn and Cu (0.37 > 0.35 > 0) in *F. religiosa* and Fe > Al >Mn> Cu > Zn (39.50> 10.03 > 8.92 > 7.83 > 3.18) in *S. cumini*. [29] assessed the level of heavy metals such as Ag, As, Cd, Co, Cu, Cr, Hg, Mo, Ni, Pb and Zn absorbed on seven tree species in Yerevan city and concluded that the higher levels of metals emitted from man-made sources. [9] tested the leaves of thirty-two plants sampled from road sides of Beijing city in China and resulted that the removal efficiency of heavy metals by some species was good and used for the planning of greenbelt in the future [48]. The research on the deposition of lead on three plant species Prosopisjuliflora L, Eucalyptus spp. and Dalbergia sissoo Roxb located along the roadsides in different sites in Sargodha city, Pakistan and justified that all the tree species were acceptable bio indicators for lead metal. [12] carried his work about the response of three tree species such as *Tectonagrandis*, *Mangifera indica* and *Ficus religiosa*, *Eucalyptus*, *Butea mono sperma* and *Azadirachta indica* for heavy metal contamination such as Zn, Mn, Pb, Hg, Fe, Cu, Cr, Cd and As in the highly polluted city Korba, India and found that *Azadirachta indica* was a good bio indicator.

The present study showed that most of the heavy metals, like Cd, Cr, As and Pb were below their detection levels in the leaves of all selected five tree species at all six selected sites, while the metal concentrations varied widely with the sites and species. Concentration of Fe was greatly varied in the selected six sites. The highest amount of Fe absorbed was found at site 2, 4 and 5 by *S.asoca,* site 5 by T.catappa, site 4 by *S.cumini* and *P.glabra*. The response shown by *F. religiosa* was very poor. Out of all five species *S.asoca* acted as an effective indicator for Fe. Higher amounts of Fe may be emitted into the atmosphere from the source such as abrasion of vehicles and due to corrosion of metals on roads. Though site 2 is coming under a sensitive area, movement of vehicles is more due to one way traffic rules and regulation, hence it is shown more amounts of Fe only on *the S.asoca*. Fig. 2 Cu concentration was not found at sites 1, 2 and 3 on all selected five species and its value was higher at site 4, heavy traffic area by *S.cumini* and at the remaining sites the value was on the lower side. Cu was not found on *F. religiosa* in any sites. Higher values may be wear and tear of tires and metal corrosion on roads. Fig. 3.

Zn was found with higher amounts only at site 4 and site 5 on *P. glabra* due to the movement of higher numbers of vehicles and deterioration of tires. It was observed that lower values were found in all species and in most of the places it was below their detectable limit. Fig. 4 *P.glabra* was the best indicator for Zn compared to other species. Al concentration was higher at site 4 on *P.glabra*, at site 5 and 6 with above average values and found almost on all species except *F.religiosa*. Al was not found at all five sites on *F.religiosa*. The source for the emission of Al into the atmosphere may be from combustion of fuel, disposal of municipal solid waste from its production point and usage of Al on the higher side. Fig. 5 Mn was found below their detectable limit at sites 1, 2 and 3 on all the selected five tree species. The sites 4, 5 and 6 were polluted with lower values of Mn with the maximum of 26.3 mg/kg in site 4 by *S.cumini*. *F. religiosa* showed zero value of Mn. Fig. 6. Out of all five species selected *P.glabra* and *S.asoca* showed good responses to the absorption of five metals almost in all selected five species and the *F. religiosa* was shown very poor responses towards all pollutants in all sites. Site 4 was observed as a polluted site due to heavy vehicular traffic.

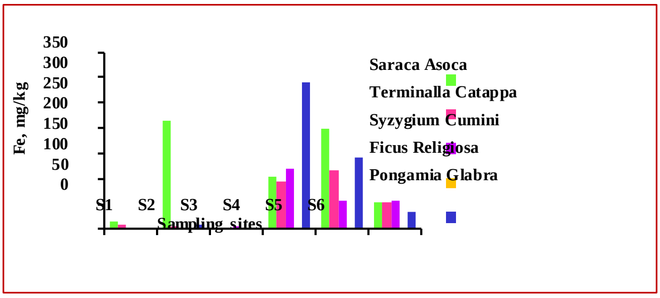

Figure 2. Fe Concentration

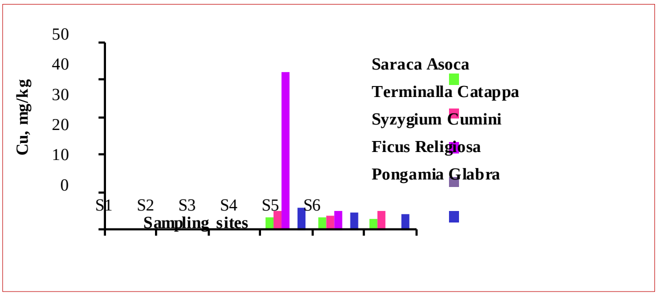

Figure 3. Cu Concentration

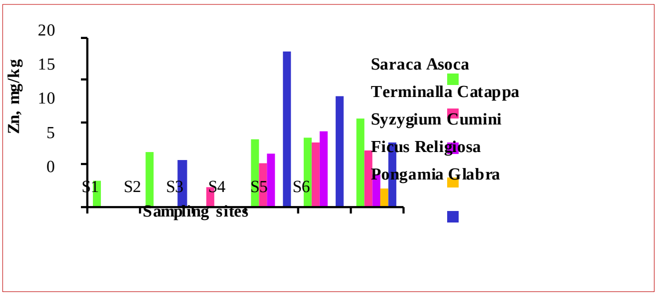

Figure 4. Zn Concentration

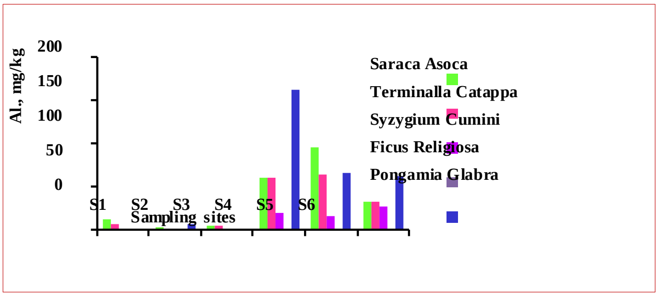

Figure 5. Al Concentration

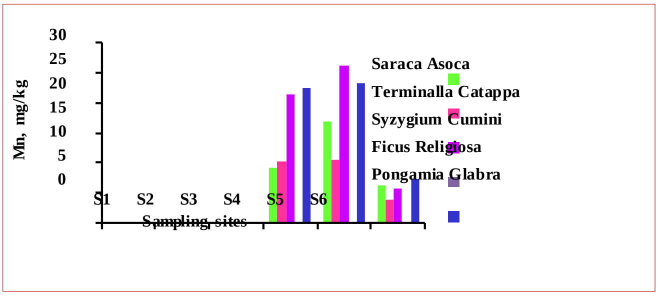

Figure 6. Mn Concentration

Spatial distribution of the selected heavy metals concentration was plotted in all the chosen sampling sites by using Arc map in GIS with interpolation method. Concentration of metal distributed in the selected sites was observed as alike. Based on the intensity of absorption the sites were categorized in Table 2.

Table 2. Classification of Sites

Categories	Range
Low deposited site	0 to 0.25
Medium deposited site	0.26 to 0.50
High deposited site	0.51 to 0.75
Strong deposited site	0.76 to 1.0

Metals such as As, Cr, Cd, Pb was not found on all five species in the selected sites. Site 1, site 2 and site 3 categorized as low deposited sites since the intensity of metals viz, Al, Cu and Mn were within the range of 0-0.25. The metals like Fe and Zn lying within the range of 0.26-0.50 on site 2, are falling under medium deposited sites. Site 4 and site 5 were highly polluted in general with all metals and classified as strong deposited sites. The reason might be due to more vehicular movement and other man-made activities such as open burning. Site 5 is highly polluted with Al and Zn and other metals with lower values. It clearly indicated that the dumping of Al related waste and their usage will be more in that area. Intensity of Heavy Metal Absorption at High Point in the Selected Sites was shown in fig. from 7a-7e.

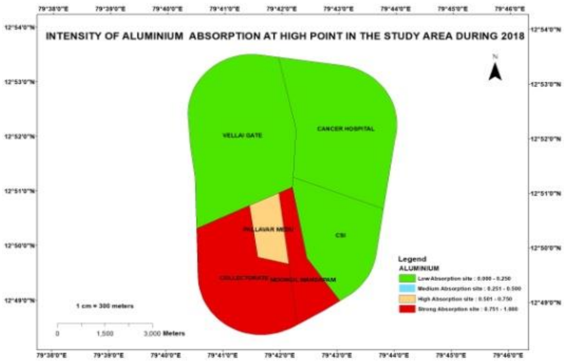

Figure. 7 (a)

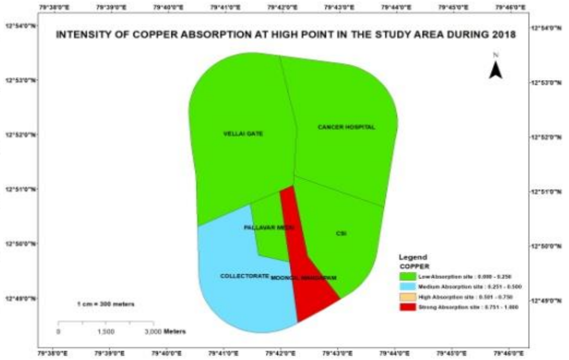

Figure 7 (b)

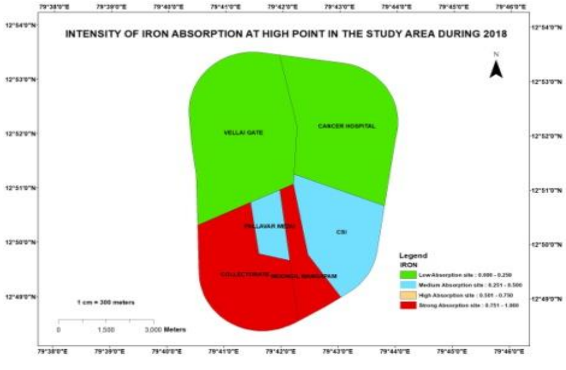

Figure 7 (c)

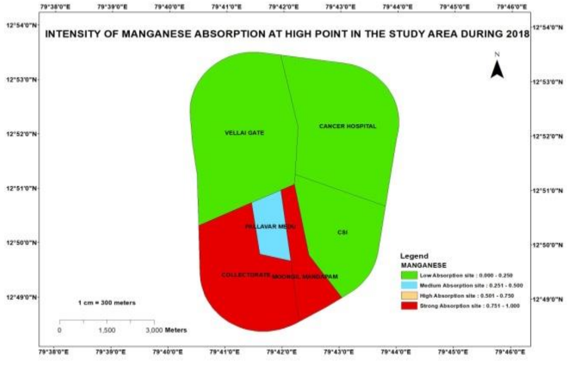

Figure 7 (d)

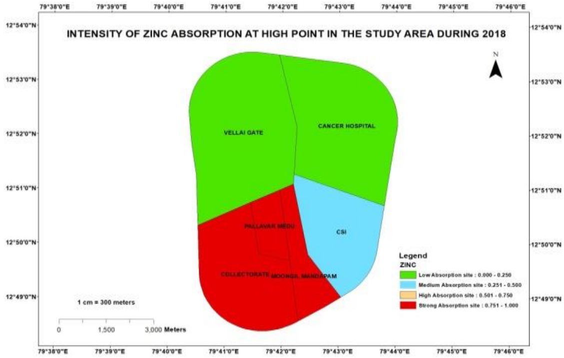

Figure 7 (e)

Figure 7 (a) to Figure7 (e) Intensity of Heavy Metal Absorption at High Point in the Selected Sites

4 Conclusions

The five selected tree species such as *F.religiosa*, *P. glabra*, *S.asoca*, *S. cumini*, and *T.catappa* for the absorption of heavy metals namely Fe, Al, Zn, Mn, Cu, As, Cr, Cd and Pb in the air were preferable for all selected sites and distinctly specified the variations in the concentration of heavy metals pollutants. The metals like As, Cd, Cr and Pb were found at lower than their detectable amounts. The concentration of Fe (213-4.1 mg/kg) and Al (94.3-2.5 mg/kg) were identified on the leaf surface of all five species in six selected sites compared with other metals in difference. In all selected five species the efficiency towards the capacity of absorption was found more in *P.glabra and S.asoca* and considered as the best biomonitors and the *F. religiosa* is very poor and *T.catappa* and *S.cumini* showed good responses. From the spatial analysis, site 4 and site 5 were found with high intensity of pollutants and categorized as strong deposited sites due to heavy traffic and many anthropogenic activities. Hence, all the five selected trees were acting as bio monitors and suggested to be grown in and around the industries and in urban areas to maintain the green, sustainable environment thereby reducing the pollution and improving the nature of air.

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