Journal of Applied and Natural Science
11(1): 76- 87 (2019)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Comparative study of soil properties and vegetation at various open dump and non-dumpsites in the Bengaluru city of Karnataka, India

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Article Info
DOI: 10.31018/jans.v11i1.1968
Received: December 18, 2018
Revised: January 30, 2019
Accepted: February 5, 2019

How to Cite
Joseph, J. *et al.* (2019). Comparative study of soil properties and vegetation at various open dump and non-dump sites in the Bengaluru city of Karnataka, India. *Journal of Applied and Natural Science*, 11 (1): 76- 87

Abstract
A comparative field studies on seven municipal dumpsites namely Agara 1 (12.917°N , 77.639°E), Agara 2 (12.922°N, 77.639°E), HSR depot (12.919°N, 77.644°E) , Koramangala Church (12.934°N, 77.626°E) , Koramanagla BDA (12.931°N, 77.625°E), Garvebhayipalya (12.897°N, 77.638°E) and Sanjay Gandhi hospital (12.891°N, 77.601° E), and its adjoining non-dump sites were conducted to understand their soil characteristic features and the vegetation pattern. Soil characteristics were presented in terms of the physicochemical parameters and the vegetation patterns were presented in terms of the dominance using the ecological parameter Important Value Index (IVI). Soils at the dump sites showed higher mean electrical conductivity and pH values as compared to the non-dump sites. Though the mineral content showed higher mean value in the dump sites (except chloride), there is no significant variation in the higher total soluble solutes between dump and non-dump sites($P>0.05$) As per ANNOVA there was highly significant variation in the heavy metal content between dump and non dumpsites ($P<0.01$).. With respect to vegetation analysis though 50 different species found across locations only 10 species viz *Alternatheria sessile, Amaranthus spinose***,** *Caesalpinia pulcherima, Ipomea acumilanata, Ipomea evolvulus, Parthenium hysterophorous Pisum sativum, Ricinis communis, Sida rombifolia* and *Solanum lycopersicum were found consistent across all locations* irrespective of the seasons. Among these, *A. sessile, R. communis* and *A. spinosa* were found dominant based on the IVI values across seven locations which further can be studied for their potential for phyto remediating the land pollutants such as heavy metals.

Keywords: ANOVA, dominant species, physicochemical characteristics, species diversity

INTRODUCTION

Management of urban municipal solid waste (MSW) generated from the human activity is a big challenge in most of the developing countries. Human settlements, small industries and commercial activities are the source of Urban MSW (Singh *et al.,* 2011). Dumping of Hospitals wastes poses a serious health threat (Pattnaik and Reddy 2010). These threats, with inadequate litigable and legislative measures, are even more pronounced in developing countries where large quantity of solid wastes are haphazardly dumped, without robust contingency planning, thereby infringing on the quality of certain sensitive environmental resources such as air, soil, water and vegetation (Angaye *et al.,* 2015).

In many developed countries, municipal solid wastes are dumped scientifically in designed sanitary waste disposal sites but in developing countries, they are dumped in an uncontrolled manner without any precaution to deal with gas emissions and leachate generation, which pose a threat to the environment (Sudhir *et al.,* 1996; Nagendran *et al.,* 2006). Landfilling as well as open dumping requires lot of land mass and could also result in several environmental problems. The menace of environmental pollution has been troubling the human world since early times and is still growing due to excessive growth in developing countries (Syeda *et al.,* 2014). In India, open waste dump sites are common and is a source of soil and water pollution. Waste management has become very much important with the increase in population.

Waste dumpsites with various leachates of wastes are rich in organic and inorganic pollutants which lead to the growth of different varieties of plants (Calli 2005). When compared with normal sites, not all varieties of plants grow in waste disposal sites. In some countries like Nigeria, these waste dumping sites are used for cultivation as these sites also contain decayed and composted wastes which enhance soil fertility (Opaluwa *et al.,* 2012). Plants grown on a land polluted with municipal, domestic or industrial wastes can absorb heavy metals in the form of mobile ions present in the soil through their roots These absorbed metals get bioacumulated in the roots, stems, fruits, grains and leaves of plants (Opaluwa *et al.,* 2012; Zennaro *et al.,* 2005). Such plants might be phytoremediators and are adaptive to grow in dumpsites or have other properties which are helpful in environmental studies. The growth of plants may vary with soil physicochemical properties like pH, alkalinity, electrical conductivity, mineral composition and heavy metal content.

The objective of the present study was to analyse the soil physicochemical properties as well as the vegetation in the dump and non dumpsites across various locations in the Bengaluru city of India.

MATERIALS AND METHODS

Sites of the study: Around 300 dumpsites in the city of Bengaluru were visited, and out of which, seven of them were selected on random basis for the current study. These were Agara 1 (12.917° N , 77.639°E), Agara 2 (12.922°N, 77.639°E), HSR depot (12.919°N, 77.644°E) , Koramangala Church (12.934°N, 77.626°E) , Koramanagla BDA (12.931°N, 77.625°E), Garvebhayipalya (12.897° N, 77.638°E) and Sanjay Gandhi hospital (12.891°N, 77.601°E) dumpsites. Geographical coordinates and satellite image of these dumpsites are presented in Fig. 1 and profile of the dumpsites is summarized in Table 1.

Soil sampling and analysis: Surface soil samples were collected from 15 different points randomly distributed over each sampling area. Surface litter on the soil was first removed followed by the insertion of the sampling auger to a depth of 15 cm to collect the soil samples The collected samples were brought to the laboratory in acid rinsed plastic bottles (Poly lab India).

The samples were then tested for various physicochemical characteristics such as such as pH, electrical conductivity, total soluble salts, calcium, magnesium, alkalinity, nitrates, sodium, sulphates, nitrogen, potassium and phosphorus as per the standard procedures (DAC 2011; USDA 2011). For the heavy metal analysis (Co, Cr, Cu, Fe, Mn, Ni, Zn and Pb), soil samples were first digested using hydrofluoric acid (USEPA 1983), followed by their estimation using inductively coupled plasma atomic emission spectrometry (ICP-AES; JY HROOBA 2000 France)

Vegetation sampling and analysis: The abundance of vegetation was recorded at each site using Quadrat method (Kent 2011) two times viz during summer of the year 2015 and the spring of the year 2016.Using ribbon, transects were marked at the site, in parallel manner. With the help of ribbon and 4 pointers quadrats of the definite size (1m x 1m) were laid down in each transect in the field. The different species present in each quadrat of each transect were listed down. The data was tabulated and different parameters such as density, dominance and frequency values for each species. were determined. Density refers to the number of individuals per unit area. Dominance refers to the basal area or crown coverage per unit area. Frequency refers to the fraction of sample plots containing the species. For particular species, these values may be expressed either in an absolute form or in a relative form. Relative values for density, dominance and frequency may be combined into a single factor called Importance Value Index (IVI), which reflects these three different measures of the importance of the species in the community. These various vegetation distribution measurements were determined according to the following formula.

$$Density = \frac{Number\ of\ individuals}{Area\ sampled} \quad \text{…Eq. 1}$$

$$Relative\ Density = \frac{Density\ for\ a\ species}{Total\ density\ for\ all\ species} \times 100 \quad \text{…Eq. 2}$$

$$Dominance = \frac{Total\ of\ basal\ area}{Area\ sampled} \quad \text{..Eq. 3}$$

$$Relative\ Dominance = \frac{Dominance\ for\ a\ species}{Total\ dominance\ for\ all\ species} \times 100 \quad \text{.. Eq. 4}$$

$$Frequency = \frac{Number\ of\ plots\ in\ which\ species\ occurs}{Total\ number\ of\ plots\ sampled} \quad \text{…Eq. 5}$$

$$Relative\ Frequency = \frac{Frequency\ value\ for\ a\ species}{Total\ of\ frquency\ values\ for\ all\ species} \times 100 \quad \text{…Eq. 6}$$

$$Importance\ Value\ Index = Relative\ Density + Relative\ Dominance + Relative\ Frequency \quad \text{..Eq. 7}$$

Statistical analysis: For physiochemical characteristics and the heavy metal concentration, the ANNOVA was performed on three sources of variation viz across the locations (n=7), across the sites (n=2) and across the location and the sites together. For the vegetation analysis, the ANNOVA was performed on the basis of six different sources of variations namely across (1) locations (2) sites (3) seasons (4) locations and sites together (5) sites and seasons together (6) locations and seasons together.

RESULTS AND DISCUSSION

Fig. 1. *Aerial images and geographical coordinates of dump sites (Source :Survey of India,Koramangala,Bengaluru).*

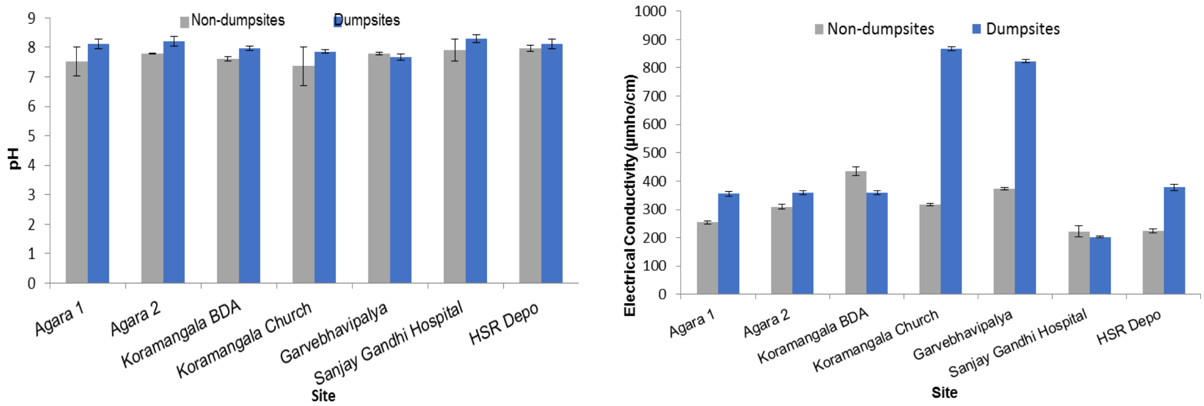

Fig. 2 (a) *pH and (b) Electrical conductivity (µmho/cm) of soils of non-dumpsites and dumpsites.*

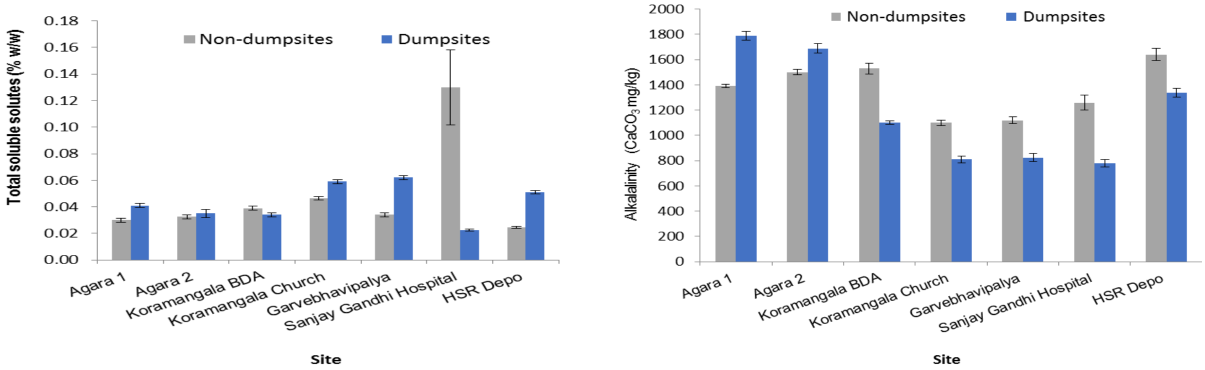

Fig. 3 (a) *Total soluble solutes and (b) alkalinity ($CaCO_3$ mg/kg) of soils of non-dump and dump sites.*

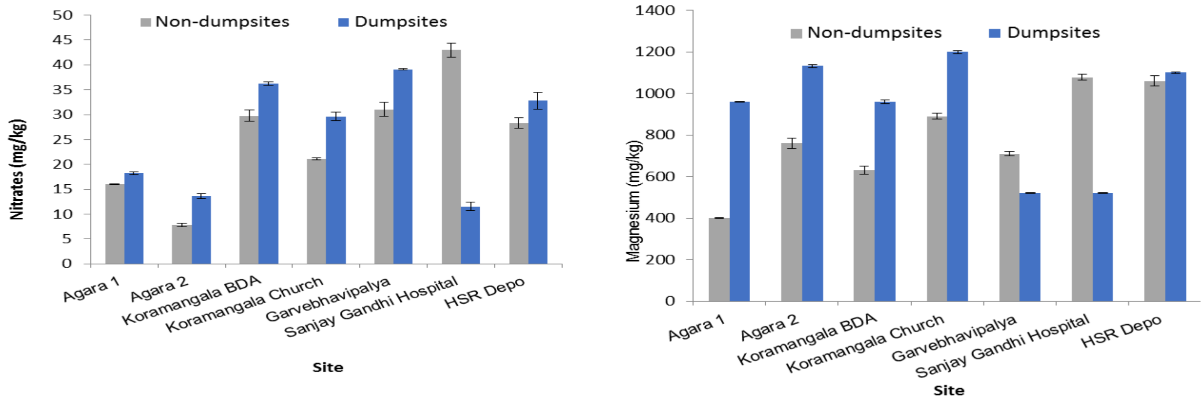

Fig. 4 (a) *Nitrates and (b) magnesium (mg/kg) of soils of non-dump and dumpsites.*

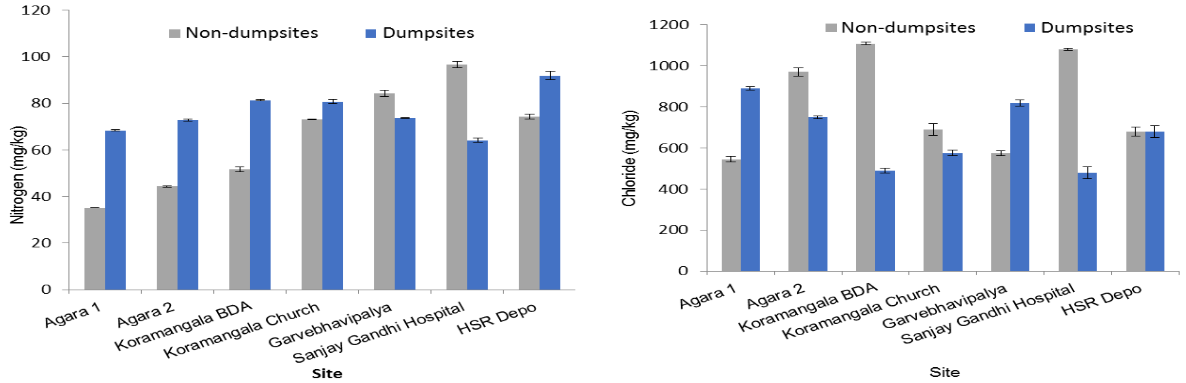

Fig. 5 (a) *Nitrogen and (b) chloride (mg/kg) of soils of non-dump and dumpsites.*

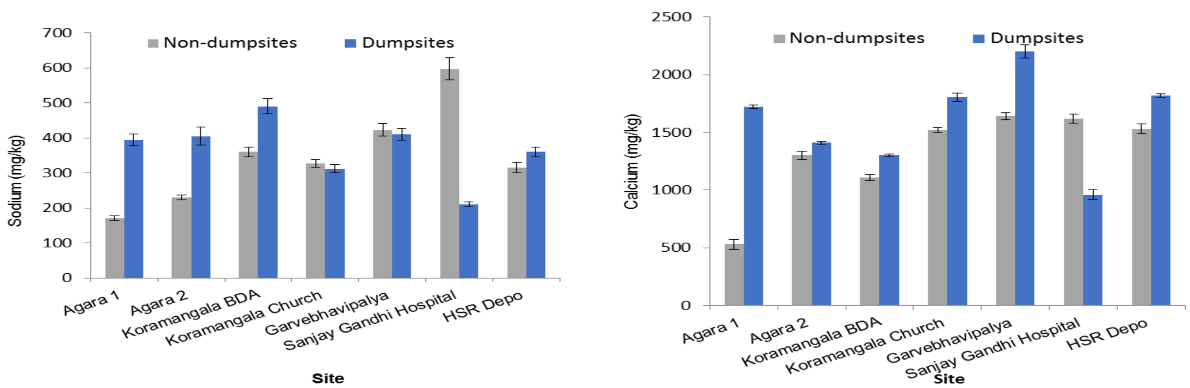

Fig. 6 (a) *Sodium and (b) calcium (mg/kg) of soils of non-dump and dumpsites.*

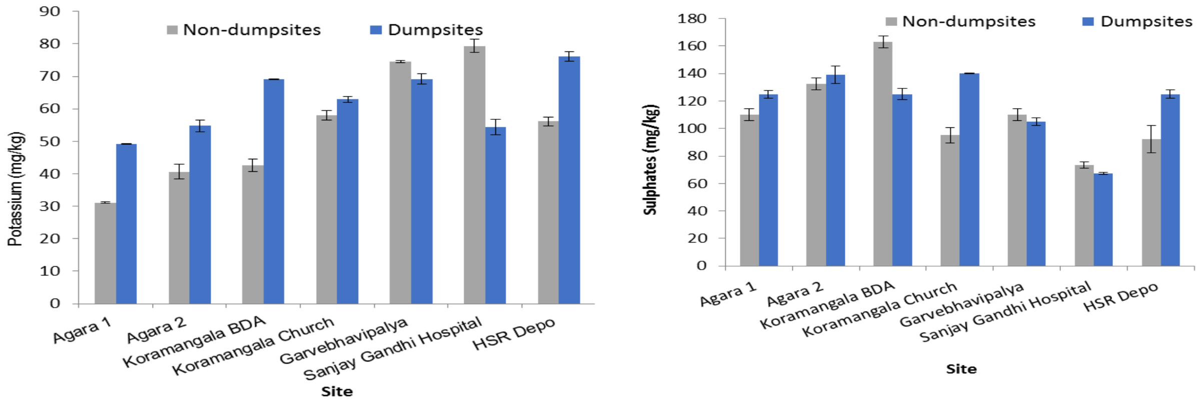

Fig. 7 (a) *Potassium and (b) sulphate (mg/kg) of soils of non-dump and dumpsites.*

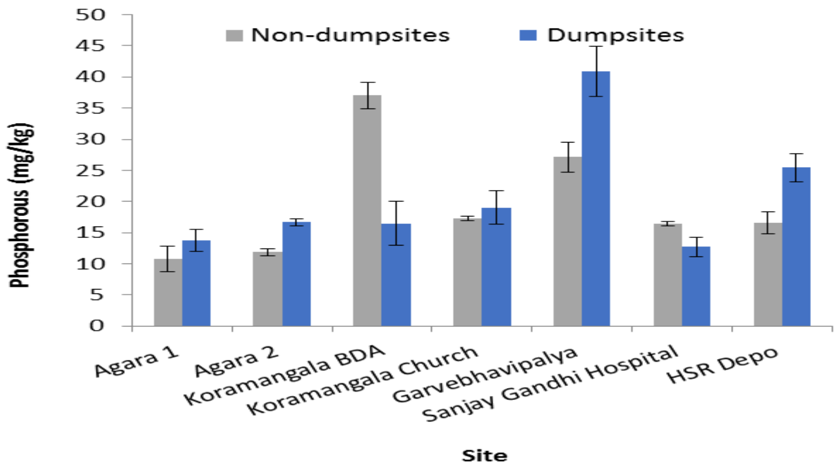

Fig. 8 *Phosphorous (mg/kg) of soils of non-dump and dumpsites.*

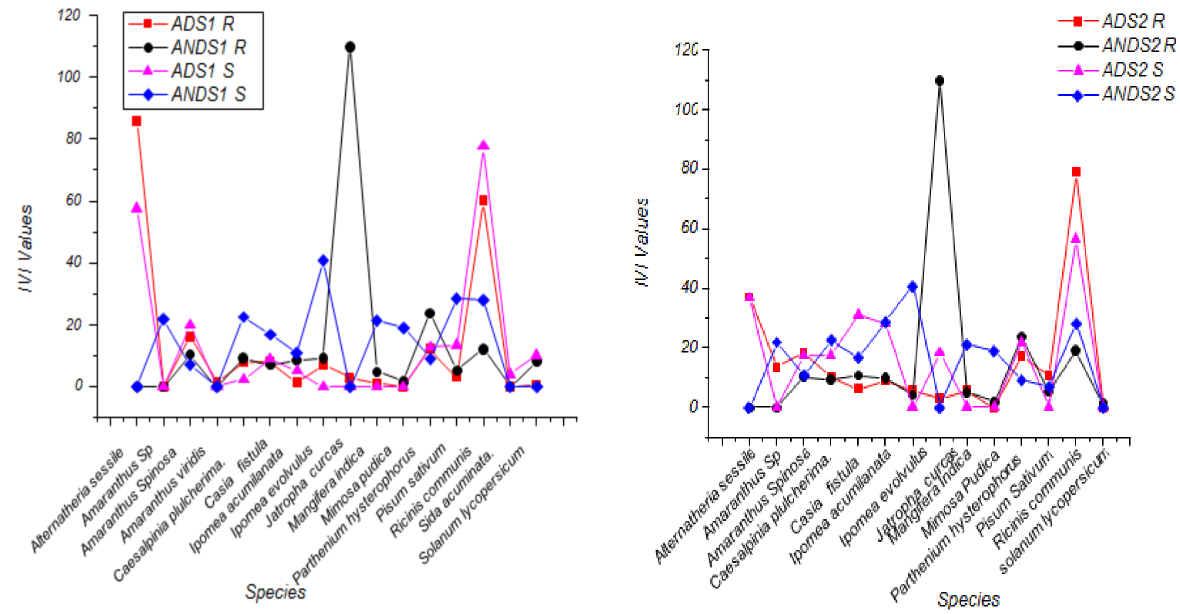

Fig. 9 *IVI values of vegetations at (a) Agara dumpsite 1 in the spring and summer seasons (ADS1R and ADS1S, respectively), and non-dumpsite 1 in the spring and summer seasons (ANDS1 R and ANDS1 S, respectively), (b) Agara dumpsite 2 in the spring and summer seasons (ADS2R and ADS2S, respectively) and non-dumpsite 2 in the spring and summer seasons (ANDS2 R and ANDS2 S, respectively)*

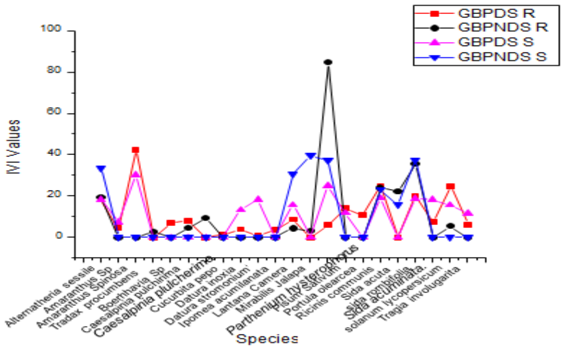

Fig. 10 *IVI values of vegetation at GB Palya dump site in the spring and summer seasons (GBPDS R and GBPDS S, respectively), and GB Palya non-dumpsites in the spring and summer seasons (GBPNDS R and GBPNDS S, respectively)*

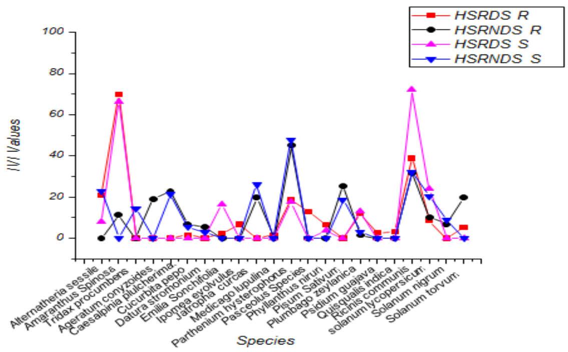

Fig. 11 *IVI values of HSR Depo dumpsite in spring and summer seasons (HSRDS R and HSRDS S, respectively), and non-dumpsite in spring and summer seasons (HSRNDS R and HSRNDS S, respectively)*

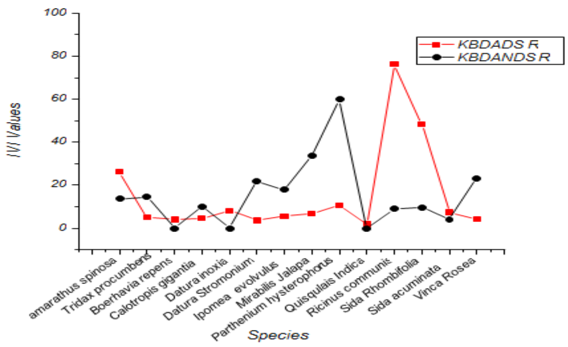

Fig. 12 *IVI values of Koramangala BDA dumpsite and non-dumpsite in spring season (KBDADS R and KBDANDS R, respectively)*

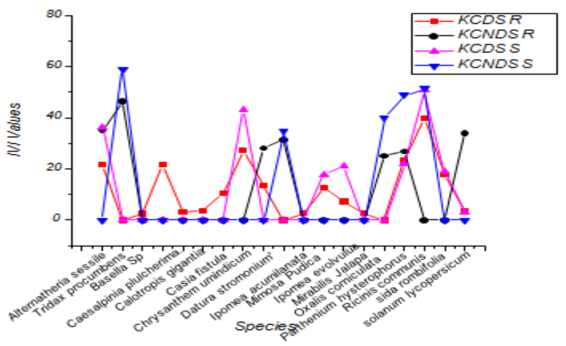

Fig. 13 *IVI values of Koramangala Church dumpsite in spring and summer seasons (KCDS R and KCDS S, respectively), and non-dumpsite in spring and summer seasons (KCNDS R and KCNDS S, respectively)*

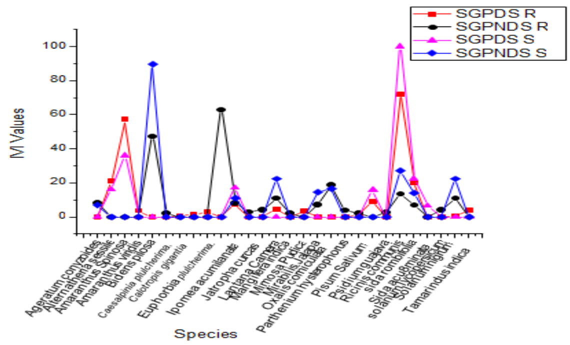

Fig. 14 *IVI values of SG Palya dumpsite spring and summer seasons (SGPDS R and SGPDS S, respectively), and non-dumpsite in spring and summer seasons (SGPNDS R and SGPNDS S, respectively)*

Soil analysis: Table 2 represents the mean values of the physicochemical characteristics of the soil of both dump and non-dumpsites across all locations while Fig 2-8 represents the same in each location.

In general, dumpsites with leachate of wastes are characterized by high concentrations of organic and inorganic pollutants (Calli 2005). The organic and inorganic pollutants alter the pH and thereby electrical conductivity of soil due to the presence of salts. In the present study, the soil pH of dump site was more alkaline(8.04±0.21) than that of non -dumpsites (7.71±0.22) The alkaline pH is very often observed at surrounding waste disposal sites aging 10 years (El-Fadel 2002). Significant amount of bicarbonate is produced during biodegradation process of organic matter which collectively results into the increase in the soil pH (Mahapatra 2011). Alteration in soil pH can affect the survival of plants and slightly acidic pH increases the nutrient uptake in plants. Alkaline pH often reduces the nutrient uptake in plants. The electrical conductivity of the soil of dump sites was found to be 1.5-fold higher than the non-dumpsites (Table 2).The high electrical conductivity in the dump sites may be attributed to the discharge of leachates loaded with the dissolved salts of sodium and magnesium (Pillai *et al.,* 2014).

Total soluble solute, alkalinity and chloride content showed a decrease of 20 %, 12.68% and 17.05 %, respectively in the dumpsites as compared to the non-dumpsites (Table 2) Minerals such as nitrogen, nitrates, potassium, phosphorous, sulphates, sodium, calcium and magnesium content

Table 1. Profile of dump sites selected for analysis of vegetations, soil and their waste profiles.

Dumping site	Organic	Plastic	Paper	Rubber	Waste Source:	Age (Average from survey):	Cleaning Frequency
Koramangala Church Dumpsite	20%-30%	30%-50%	20%-30%	Negligible < 1%	Car waste and Pedestrians	9 years	5-8 months once
Koramangala BDA Dumpsite	50%-60%	15%-25%	5%-10%	5%	Household waste from slum nearby	4.8 years	5-8 months once
Agara Dumpsite 1	70%-80%	10%-20%	5%-10%	Negligible <1%	Mostly Household waste	8 years	5-6 months once
Agara Dumpsite 2	60%-70%	10%-20%	10%-20%	Negligible < 1%	Mostly Household waste	7 years	5-6 months once
HSR DEPO Dumpsite	60%-70%	10%-30%	10%-20%	Negligible >1%	Commercial waste mainly inorganic	8 years	2 months once
Garvebhavipalya Dumpsite:	60%-70%	20%-30%	10%-20%	Negligible <1%	Household waste from apartments.	2.6 years old	1-2 months once
Sanjay Gandhi Hospital Dumpsite	70% -80%	30%-40%	5%	5%	Household waste from slums and around 3% of hospital waste.	4.6 years old	2-3 months once

were found to be in slightly higher levels (upto1.21 fold) in the dumpsite soils as compared to the non -dumpsite (Table 2) . Potassium does not have any adverse effect on soil properties, and also serves as a soil nutrient, hence there is no limiting value. Increase in the concentration of potassium is also an indicator of leachate pollution (Christensen *et al.,* 2001). Calcium, magnesium, sodium and potassium are considered to be the major cations, derived from waste materials and is related to the composition of wastes and the prevailing phase of stabilization in the landfill (Christensen *et al.,* 2001). In the present study, increase in magnesium level in the dumpsites can be attributed to the alkaline pH of soil (Schulte 2004).

Statistical analysis of physicochemical properties by one-way ANOVA is shown in Tables 3-6. All the soil characteristics such as electrical conductivity, soil pH and total soluble solutes, calcium, magnesium, nitrogen , potassium, phosphorous sodium, chloride, sulphates, nitrates and alkalinity carbonates and bicarbonates have shown significant variations ($p<0.01$) at dump site and non-dump sites across all 7 locations where as pH has not shown any significant variation.($p>0.01$).

Heavy metal analysis: Heavy metal content of dumpsites and non-dumpsites are summarized in Table 7. The overall heavy metal contamination in the dumpsite showed an increased level upto 1.74 fold as compared to non-dumpsites with the exception for Nickel which showed a marginal reduction in the content.Although overall heavy metal contamination levels were within the permissible limits stipulated by WHO (Chiroma *et al.,* 2014), there was a significant variation in heavy metal content ($p<0.01$) at different location and the sites as per one way ANNOVA(Table 8)

Rapid urbanization and limited land availability have resulted in close proximity of dumpsites to residential areas. Unprocessed indiscriminate waste dumping without proper segregation at open sites is important source of heavy metal contamination of soil and water bodies (Azeez *et al.,* 2011). Heavy metal contamination in municipal solid waste (MSW) has been attributed to unsegregated wastes such as cans, metals and sand particles (Garcia *et al.,* 2005).Similar study was done by Azeez *et al*. (2011) where they reported the presence of Cu,Pb,Fe,Cr,Ni,Mn and Zn (upto 23.77,43.38,17442,1.917,3.40,926.30 and 111.53 mg/kg respectively). Leaching of the heavy metals in to soil and further to water bodies causes the water not fit for human consumption. Impact of this heavy metal reaching the water table would be devastating to human health. Systematic sampling and distribution analysis of heavy metals in MSW is needed for assisting the waste management authorities in adopting proper segregation, treatment and disposal practices (Rajkumar and

Table 2. Physicochemical properties of soil from dump and non-dumpsites across all locations.

Parameters	Non-dump sites (Mean ± SD)		Dumpsites (Mean ± SD)	
Electrical Conductivity (μmho/cm)	305.43	±79.12	478.071	±257.64
pH	7.71	±0.22	8.04	±0.21
Total Soluble Solutes (% w/w)	0.05	±0.04	0.04	±0.01
Alkalinity Carbonates and Bicarbonates ($CaCO_3$ mg/kg)	1363.00	±209.36	1190.14	±425.40
Chloride (mg/kg)	806.79	±239.17	669.21	±160.61
Calcium (mg/kg)	1321.00	±397.15	1602.14	±409.61
Magnesium (mg/kg)	789.86	±241.55	913.29	±282.20
Nitrates (mg/kg)	25.28	±11.44	25.88	±11.24
Nitrogen (mg/kg)	65.65	±22.44	76.13	±9.29
Phosphorous (mg/kg)	19.58	±9.33	20.72	±9.82
Potassium (mg/kg)	54.63	±17.86	62.22	±9.81
Sodium (mg/kg)	346.07	±138.36	368.71	±88.37
Sulphates(mg/kg)	110.90	±29.39	118.07	±25.14

Table 3. ANOVA for soil physical properties across location over dump and non-dumpsites.

Source of variation	*df*	F Statistic		
		Electrical Conductivity	Soil pH	Total Soluble Solutes
Location	6	1270.182**	1.257	0.329
Site	1	3824.891**	3.614	5.025*
Location × Site	6	584.539**	0.838	0.329

The values are which are significant at 0.05 and 0.01 levels, have * for 0.05 and ** for 0.01 as superscripts. The values without superscripts are differently significant.

Table 4. ANOVA for calcium, magnesium, total nitrogen and phosphorus across location over dump and non-dumpsites.

Source of variation	*df*	F Statistic				
		Calcium	Magnesium	Nitrogen	Potassium	Phosphorous
Location	6	292.851**	1014.950**	1019.314**	276.196**	51.946**
Site	1	643.712**	604.354**	1136.529**	157.243**	0.663
Location × Site	6	261.809**	1176.792**	943.549**	152.414**	23.809**

The values are which are significant at 0.05 and 0.01 levels, have * for 0.05 and ** for 0.01 as superscripts. The values without superscripts are differently significant.

Table 5. ANOVA for sodium, chloride, sulphate, nitrate and alkalinity-cabrobates and bicarbonate across location over dump and non-dumpsites.

Source of variation	*df*	F Statistic				
		Sodium	Chloride	Sulphates	Nitrates	Alkalinity Carbonates and Bicarbonates
Location	6	51.037**	128.363**	100.097**	371.864**	317.732**
Site	1	12.052**	320.326**	9.204**	11.864**	153.862**
Location × Site	6	157.085**	464.653**	37.961**	295.551**	109.009**

The values are which are significant at 0.05 and 0.01 levels, have * for 0.05 and ** for 0.01 as superscripts. The values without superscripts are differently significant.

Table 6. ANOVA for soil characteristics across location at dumpsite and non-dumpsites.

Across locations Soil traits	*df*	F Statistic	
		Non-dumpsite	Dumpsite
Electrical Conductivity	6	121.551**	2557.062**
pH	6	0.809	4.867*
Total Soluble Solutes	6	20.695**	219.773**
Calcium	6	317.815**	246.672**
Magnesium	6	4254.260**	681.797**
Nitrogen	6	1170.740**	384.284**
Potassium	6	262.301**	139.095**
Phosphorous	6	25.686**	63.771**
Sodium	6	139.697**	63.655**
Chloride	6	340.412**	241.467**
Sulphates	6	144.073**	38.115**
Nitrates	6	283.385**	325.196**
Alkalinity carbonates and bicarbonates	6	65.632**	422.413**

The values are which are significant at 0.05 and 0.01 levels, have * for 0.05 and ** for 0.01 as superscripts. The values without superscripts are differently significant.

Table 7. Heavy metal content (mg/kg) of dump sites and respective non-dump sites.

Sampling site	Co (mg/kg)		Cr (mg/kg)		Cu (mg/kg)		Fe (mg/kg)		Mn (mg/kg)		Ni (mg/kg)		Zn (mg/kg)		Pb (mg/kg)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Agara Dump site 1	4.00	0.14	103.00	4.24	3.53	0.18	9845.00	219.20	61.00	2.83	19.50	0.71	17.35	0.21	13.10	0.57
Agara Non-dump site1	4.00	0.14	50.00	1.41	4.00	0.14	7700.00	141.42	145.50	4.95	13.78	0.39	11.75	0.35	5.15	0.07
Agara Dump site 2	5.15	0.07	64.50	6.36	6.65	0.21	11250.00	353.55	246.50	2.12	6.65	0.21	17.50	0.71	ND	
Agara Non-dump site2	3.75	0.07	43.50	2.12	3.80	0.28	7200.00	424.26	140.00	2.83	13.80	0.28	13.80	0.78	5.50	2.12
Koramangala BDA Dump site	5.65	0.21	63.50	2.12	16.50	0.71	17650.00	212.13	214.50	3.54	19.50	0.71	53.00	1.41	13.78	0.39
Koramangala BDA Non-dump site	2.88	0.04	53.50	6.36	3.63	0.11	8400.00	282.84	148.50	7.78	22.00	1.41	17.50	2.12	ND	
Koramangala Church Dump site	5.00	0.14	91.00	1.41	21.00	1.41	13600.00	565.69	411.50	4.95	18.50	0.71	5.15	0.07	17.60	0.85
Koramangala Church Non-dump site	ND		2.88	0.04	ND		700.00	42.43	7.95	0.21	14.00	1.41	17.35	0.21	2.88	0.04
Garvebhavipalya Dump site	4.00	0.14	41.00	4.24	19.50	0.71	11150.00	494.97	216.00	4.24	9.25	0.35	42.00	1.41	14.50	2.12
Garvebhavipalya Non-dump site	5.15	0.07	32.00	2.83	11.75	0.35	12675.00	459.62	189.50	6.36	8.88	0.18	34.00	1.41	13.10	0.57
Sanjay Gandhi Hospital Dump site	3.63	0.11	71.00	2.83	226.00	1.41	13650.00	636.40	178.50	6.36	17.50	2.12	111.00	1.41	93.00	1.41
Sanjay Gandhi Hospital Non-dump site	3.53	0.18	30.00	5.66	11.75	0.35	12350.00	494.97	174.50	6.36	16.50	0.71	48.00	1.41	23.25	1.06
HSR Depot Dump site	7.95	0.21	41.50	0.71	30.00	1.41	22250.00	1060.66	404.00	7.07	4.00	0.14	133.00	1.41	30.00	1.41
HSR Depot Non-dump site	8.00	0.01	26.00	4.24	17.50	0.71	ND		350.50	10.61	17.50	0.71	90.00	1.41	8.00	0.01
Dump sites Mean	5.05	0.14	67.93	3.13	46.17	0.86	14199.29	506.08	247.43	4.44	13.56	0.70	54.14	0.94	30.33	1.12
Non-dump site Mean	4.55	0.08	33.98	3.23	8.74	0.32	8170.83	374.76	165.21	5.58	15.21	0.72	33.20	1.10	9.65	0.64
Permissible limits (WHO)	50		100		100		50000		2000		50		300		100	

* ND- not detected

Sirajuddin 2016).

Vegetation analysis: IVI values of the plants growing in various dumpsites and non-dumpsites are shown in Figs. 9-14. The dominant species obtained from evaluation of common plant species growing in both dumpsite and non-dumpsites are shown in Tables 9 and 10, respectively. ANOVA was performed for the comparison of various consistent plants growing in both non-dumpsites and dumpsites (Table 11).

Although 50 different plant species were noticed across different locations during the study period. (Table 9 and 10) only 13 species were found in common across non-dumpsites (Table 9), while in the dumpsites the common species number was reduced to 6 (Table 10). This can be attributed to the soil contamination in the dumpsites (Syeda *et al.,* 2013). Putting together the above 19 species, ten species such as *Alternatheria sessile, Amaranthus spinose*, *Caesalpinia pulcherima, Ipomea acumilanata, Ipomea evolvulus, Parthenium hysterophorus, Pisum sativum, Ricinis communis, Sida rombifolia* and *Solanum lycopersicum* were consistent across the sites as well as the locations during the study period. Hence, only these species datasets were taken into consideration for the analysis of variance Table 11 (a and b) represents ANOVA statistics for dominance of different plant species found across various locations of dump and non-dumpsites for two seasons.

A. spinosa, C. pulcherima, I. acumilanata, P. hysterophorus, P. sativum and *S. rhombifolia* showed significant variation($0.001 \leq p \leq 0.05$) which indicates there is a difference in dominance of these species across locations. Most of the species showed no significant variation for sites (Dump and non-dumpsites) across all 7 locations except *A. spinosa, P. sativum and S. rhombifolia* which designates there was a difference in the dominance of these 3 species between dumpsite and the non-dump sites. All the species, except *I. acumilanata,* did not show any significant variation for the two seasons (i.e. spring and summer) which specifies the season doesn't have any effect on the dominance of these species. Except *S. rombifolia, A. spinosa* and *P. sativum*, rest of the species did not show any significant variation in dominance for location and sites when considered together as sources of variation whereas none of the species varied significantly in dominance across the sites as well as seasons. While considering both location and sites as sources of variation most of the species showed non-significant variation in dominance except *I. acumilanata and P. sativum.*

Altered soil composition and soil physicochemical properties between dumpsite and non-dumpsite makes the difference in botanical species diversity and growth. Changes in the physicochemical profile of the soil alter the soil fertility, providing a se-

Table 8. ANOVA of heavy metal content over dumpsite and non-dumpsites.

Source of variation	df	F Statistic							
		Cr	Co	Pb	Cu	Fe	Mn	Ni	Zn
Location	**6**	61.03**	499.96**	1578.46**	11937.56**	374.19**	839.62**	93.024**	4212.056**
Site	**1**	550.43**	197.92**	3163.13**	18058.27**	458.81**	1409.65**	23.053**	2284.500**
Location × Site	**6**	63.15**	107.16**	655.52**	10767.48**	106.19**	717.17**	55.572**	506.449**

The values are which are significant at 0.05 and 0.01 levels, have * for 0.05 and ** for 0.01 as superscripts. The values without superscripts are differently significant.

Table 9. Classification of species dominance at non-dump sites during spring and summer season.

Rainy	IVI values	Summer	IVI values
Jatropha curcus	109.77	*Bidens pilosa*	89.53
Parthenium hysterophorus	84.80	*Tridax procumbens*	59.15
Euphorbia pulcherima	63.07	*Ricinis communis*	51.52
Parthenium sp.	59.97	*Parthenium hysterophorus*	48.86
Bidens pilosa	47.45	*Ipomea evolvulus*	40.78
Tridax procumbens	46.61	*Oxalis corniculata*	40.15
Sida rombifolia	35.54	*Mirabilis jalapa*	39.60
Alternatheria sessile	35.34	*Sida rombifolia*	37.32
Solanum lycopersicum	33.96	*Datura stromonium'*	34.91
Mirabilis jalapa	33.81	*Alternatheria sessile*	33.40
Ricinis communis	31.90	*Lantana camera*	30.68
Datura stramonium	28.16	*Ipomea acumilanata*	28.75
Pisum sativum	25.37	*Pisum sativum*	28.75
Oxalis corniculata	25.21	*Jatropha curcus*	26.05
Vinca rosea	23.02	*Caesalpinia pulcherima*	22.64
Caesalpinia pulcherima	22.84	*Solanum nigrum*	22.40
Sida acuta	22.12	*Amaranthus sp*	21.88
Datura inoxia	21.89	*Mangifera indica*	21.25
Solanum nigrum	19.73	*solanum lycopersicum*	20.41
Ageratum conyzoides	19.10	*Mimosa pudica*	19.10

Table 10. Classification of species dominance at dump site during spring and summer season.

Rainy	IVI values	Summer	IVI values
Alternatheria sessile	85.84	*Ricinis communis*	99.84
Ricinis communis	79.01	*Amaranthus spinosa*	66.36
Amaranthus spinosa	69.87	*Alternatheria sessile*	57.60
Sida rhombifolia	48.38	*Chrysanthemum indicum*	43.15
Chrysanthemum indicum	27.23	*Casia fistula*	31.08
Solanum lycopersicum	24.65	*Ipomea acumilanata*	28.10
Parthenium hysterophorus	23.26	*Parthenium hysterophorus*	24.92
Caesalpinia pulcherima.	21.72	*Solanum lycopersicum*	23.94
Pisum sativum	14.11	*Sida rombifolia*	22.37
Amaranthus sps	13.65	*Mimosa pudica*	21.12
Datura stramonium	13.58	*Jatropha curcus*	18.44
Phasceolus vulgaris	12.89	*Datura stromonium'*	18.35
Ipomea evolvulus	12.74	*Sida accuminata*	18.25
Plumbago zeylanica	11.95	*Ipomea evolvulus*	17.89
Portula olearcea	10.79	*Caesalpinia pulcherima*	17.53
Casia fistula	10.51	*Eupotorium sps*	17.12
Pisum Sp.	9.23	*Emilia sonchifolia*	16.43
Ipomea acumilanata	9.22	*Pisum Sp*	15.97
Lantana camera	8.73	*Lantana camera*	15.58
Datura inoxia	8.18	*Pisum sativum*	13.45

lective environment for specific vegetation adaptive to the altered soil condition.

Diversity of plant species was recorded with seasonal variations at both dumpsite and non-dump site. Analysis of ecological indices such as IVI provides a better understanding of species dominance and community structure of vegetation at dump sites. Tripathi and Misra (2011) studied the vegetation associated with physicochemical variation at dumpsites and the corresponding non-dumpsites in Allahabad city in India. By analysis of ecological indices of species found at study sites, adaptive dominant plants were identified out of 32 species identified at dump sites. They identified that *Nepeta hindostana, R. communis*, *Lantana camara* and *Calotrophis procera* as the dominant

Table 11.(a). ANOVA of consistent species namely *Alternathera sessile, Amaranthus spinose, Caesalpinia sp., Ipomea acumilanata, Ipomea evolvulus.*

Source of variation	df	*Alternathera sessile*	*Amaranthus spinosa*	*Caesalpinia pulcherima*	*Ipomea acumilanata*	*Ipomea evolvulus*
Location	6	1.89	10.97**	6.43*	119.09**	1.41
Site	1	10.60*	53.85**	8.43*	2.41	1.92
Season	1	0.71	0.68	0.29	31.13**	1.09
Location × Site	6	2.67	8.14*	3.10	4.65	1.68
Site × Season	1	0.01	0.34	0.66	0.10	2.56
Location × Season	5	0.62	1.17	1.24	41.13**	0.52

** Significance at 1%; * Significance at 5%; df: degrees of freedom

Table 11. (b). ANOVA of consistent species namely *Parthenium hysterophorus., Pisum sativum, Ricinis communis, Sida rombifolia and Solanum lycopersicum,* over dump site and non-dump sites across locations during spring and summer season.

Source of variation	df	*Parthenium hysterophorus*	*Pisum sativum*	*Ricinis communis*	*Sida rombifolia*	*Solanum lycopersicum*
Location	6	7.17*	5.76*	2.02	246.26**	3.19
Site	1	22.28**	2.64	44.90**	91.06**	0.18
Season	1	0.05	0.01	4.96	3.72	0.76
Location × Site	6	2.97	7.90*	2.90	68.54**	1.84
Site × Season	1	0.65	2.14	0.17	0.12	3.03
Location × Season	5	0.65	5.11*	1.11	1.30	2.10

** Significance at 1%; * Significance at 5%; df: degrees of freedom

species adapted to the dumpsites analyzed. In our study, the ecological indices of vegetation across seven dumpsites and during two diverse seasonal variations (spring and summer) were analysed. In the present study based on the IVI value of vegetation across seven dumpsites, *A. sessile, R. communis* and *A. spinosa* were identified as the dominant species which have wider adaptability to thrive at dumpsites at diverse seasonal variations.

Conclusion

In consideration with all soil characteristics such as soil physical properties (electrical conductivity, soil pH and total soluble solutes), soil nutrients (calcium, magnesium, nitrogen and potassium, phosphorus, sodium, chloride, sulphates, nitrates and alkalinity carbonates and bicarbonates) as well as the heavy metals (Co, Cr, Cu, Fe, Mn, Ni, Zn and Pb), it is concluded that the dumping of unprocessed municipal wastes alters the physicochemical profile of soil significantly. Changes in the physicochemical profile of the soil further alter the soil fertility, providing a selective environment for specific vegetation adaptive to the altered soil condition. As far as vegetation analysis, 10 species viz *Alternatheria sessile, Amaranthus spinose*, *Caesalpinia pulcherima, Ipomea acumilanata, Ipomea evolvulus, Parthenium hysterophorous Pisum sativum, Ricinis communis, Sida rombifolia* and *Solanum lycopersicum* were found consistent across all locations *irrespective* of the seasons. Among these, *A. sessile, R. communis* and *A. spinosa* were found dominant across seven locations. As these plants were found thriving across locations withstanding the waste dumping flux, they can be explored further for their ability to phytoremediate the land pollutants especially the heavy metals.

ACKNOWLEDGEMENTS

Authors are thankful to Centre for Research, CHRIST (Deemed to be University), Bengaluru, India, for the financial assistance (F. No. MNG-DSC1503) towards this research. JJ and DS are also thankful to the Head of the Department of Life Sciences, CHRIST (Deemed to be University) Bengaluru, India, for supporting this research in terms of Laboratory space and equipment.

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