PATTERN, CHARACTERIZATION AND QUANTIFICATION OF UNAUTHORIZED WASTE DUMP SITES: A CASE STUDY OF BANGALORE

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ABSTRACT

Developing country municipal solid waste management is complex, managed by multiple institutions, prone to socio-political disruptions and often requires frequent and rapid estimates of good functioning. Estimating the quantity, composition and status of municipal solid waste found at unauthorized dump sites helps in diagnosis and in improving solid waste management system. The objective of this study was to find occurrences of unauthorized dump sites and to determine quantity, area, height of dumps, waste density and waste composition at these sites. A total of 452 locations were identified and quantification of solid wastes was carried out at 268 locations by determining waste spread area, measuring dump height and density by multiple techniques. Mixed dumped wastes at site was physically segregated into twelve waste categories (organic fraction, plastic, construction debris, paper, cloth, glass, leather, metal, rubber, biomedical waste, burnt waste and industrial wastes). It was estimated about 213310 Mg of wastes were dumped in 452 unauthorized dump sites. The composition of waste dumped in unauthorized sites have 41.3% of construction debris followed by 28.9% of organic waste and other fractions constituted the remaining. The waste composition at dump site suggests less efficient recycling systems and the possible direction for the system improvements.

Keywords: Unauthorized dump site, Illegal dumping, Dump site pattern, Waste quantity, Dump site composition

INTRODUCTION

Municipal solid waste management systems of developing countries are gradually being formulated and attempt a high degree of systematization while simultaneously being faced with multitudinous set of socio-technical challenges. There are several agencies and systems to collect, manage, process, recycle, regulate, monitor and to dispose various components of municipal solid waste (MSW) and all these co-exist in every city (Chanakya and Swamy, 2011; Rana et al., 2015; Rana et al., 2017; Sharma et al., 2018; Rana et al., 2018). In this traverse towards finding workable solutions lie various imperfections. Unauthorized dumping in developing countries accounts for about 60-90% of the total solid waste disposal and it is required to understand causes, origins and solutions for disposal practices (Rajabapaiah, 1988; UNEP,

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2000; Chanakya et al., 2015).

Cities in India face moderate to severe problem of unauthorized dumping of MSW components. It is estimated that more than 60% of MSW is often disposed off in open dump sites and subject to natural degradation on vacant lands (Inanc et al., 2004; Chanakya et al., 2015). These disposal sites lack efficient waste processing systems and the natural degradation of dumped MSW along with formation of methane and leachates pose serious environmental and health risks. These dumps sometimes catch fire and continue to burn for more than a month (MPCB, 2014), even though urban local bodies (ULBs) have designated processing and disposal sites for waste treatment and disposal. Yet another issue with MSW in the developing world is inadequate capacity ranging from collection to treatment and disposal as these places are located at the edge and outskirts of the city and the current quantity of MSW received for processing generally exceeds the designed capacities. This results in unloading of unprocessed MSW nearer these sites, their pile up in specific locations and concomitant environmental issues. Frequent protests and blockades of roads by 'affected' local citizens residing nearer these sites further aggravate the waste management leading to large scale "unauthorized" dumping in and around the city (Chanakya et al., 2014). In addition, these dump sites stop operations at sunset needing loaded MSW dump-trucks to stay overnight till the facility is reopened the next day. All these are conducive to transporters to dump MSW across the city and is generally termed unauthorized dump sites.

The occurrence and number of open dump sites has been reported to be dependent on many factors such as population of the city and density at the location, distance of dump site from the road network, width of roads, per capita income of nearby residents, unemployment rate, number of waste management facilities, distance from forest edge, distance from agricultural fields and topographic features such as valleys, ravines, etc. that allow anonymity of the dumping action (Tasaki et al., 2007; Chanakya et al., 2011; Ichinose et al., 2011; Matsumoto et al., 2011). Involvement and active participation of local communities and making provisions for multiple and decentralized waste treatment facilities is expected to greatly dis-incentivize and consequently reduce the prevalence and practice of unauthorized dumping in vacant sites by increasing options and opportunities to dispose wastes, increasing access to these facilities and reducing transportation costs (Chanakya et al., 2011). Bangalore city has several topographical features such as abandoned deep quarries, unpopulated and inaccessible steep hill slopes, unclaimed land, abandoned irrigation tanks and tank beds, large unoccupied and uninhabited valleys along run-off courses, road-sides of lesser used peripheral roads are attractive locations for unauthorized dumping of wastes (Chanakya et al., 2015). The first reason can be nebulous ownership of such properties and second a persistent anonymity of these sites that allow continued use as easier to access dumping locations. Estimation of the quantity of wastes and the composition of waste accumulated on unauthorized dump sites and understanding of dump sites occurrence pattern are needed in order to strategize and activate an enforcement action plan and to propose alternative waste management options for the city. An attempt to measure the quantity and composition of waste in dumpsite were conducted in Delhi using 3D scanner (Nagpure, 2019). However, hardly any study has assessed the dump site location pattern, area, nature, quantity and composition of waste dumped in the unauthorized waste dump sites. Several control measures, legislations, incentives and penalties have been attempted and yet, such unauthorized dumps being low cash-cost option, still prevail and need to be understand better.

The objective of the study was to determine the quantity and composition of MSW found at unauthorized dump sites and attempt to understand and predict their patterns. None of the earlier studies in this region have estimated, quantified or characterized wastes disposed off or remaining in unauthorized dump sites and/or assess pattern and their causes and/or environmental liabilities. This study will help to estimate the fraction of total waste dumped in this type of dump sites, identify possible causes and enable finding solutions to overcome the environmental impacts of MSW dumps.

MATERIALS AND METHODS

The Study area

Bangalore is situated between the latitudes 12°39’00’’ to 13°13’00’’ N and longitude 77°22’00’’ to 77°52’00’’ E with an area of 741 km^2. The entire study area was divided into grids of size 2.7 km×2.7 km. The city has therefore been segmented to a) core area, b) outer area and c) peripheral areas. It has been found that the unauthorized dumping occurs both inside core area as well as outside of the core area. Core area is the old city area with high population density (>20,000/km^2). The dump sites located within the core area of the city have been reported to be small in size and often short lived (Chanakya et al., 2015). Whereas dumps outside the core area are large and persistent having a long operational life and are used as 'unauthorized' waste disposal sites. These large and long-lived dump sites cause significant environmental concerns and therefore need to be studied. Thus, the results were analyzed for two zones or areas namely, the core city area and outside the core city area (outer area and peripheral area). The ratio of core city area and outside the core city area is 1:10. Therefore, in order to estimate the quantity of wastes dumped, the composition of MSW at each site and the area over which waste is spread, a study was conducted in 452 randomly located large dump sites. These locations are spread across the city, 35 sites lying within the core city area and 417 sites lying in the region outside the core city boundary up to a distance of 10 km from city boundary in a total area of 2,274 km^2 (Figure 1). The dumpsite locations were discovered, located using pre-calibrated hand-held Global Positioning System (GPS) and photographed (Figure 2).

Occurrence of dump sites locations

The occurrence of open dumping locations in and around the city depends on population density, distance from the

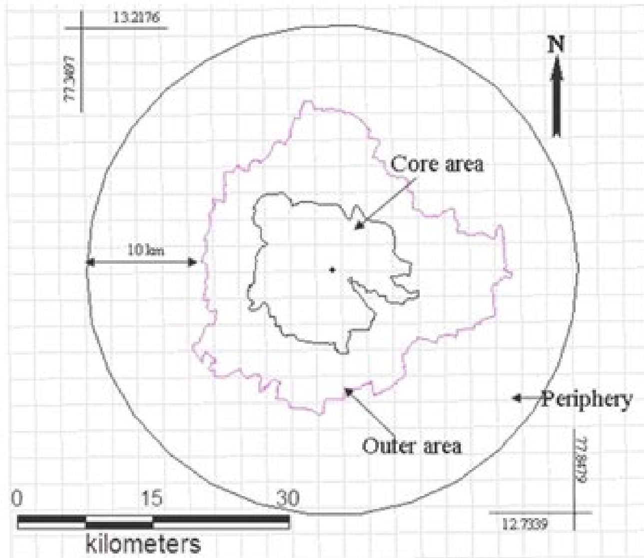

FIGURE 1
Bangalore: core area and outside core area (outer area and periphery) of the city

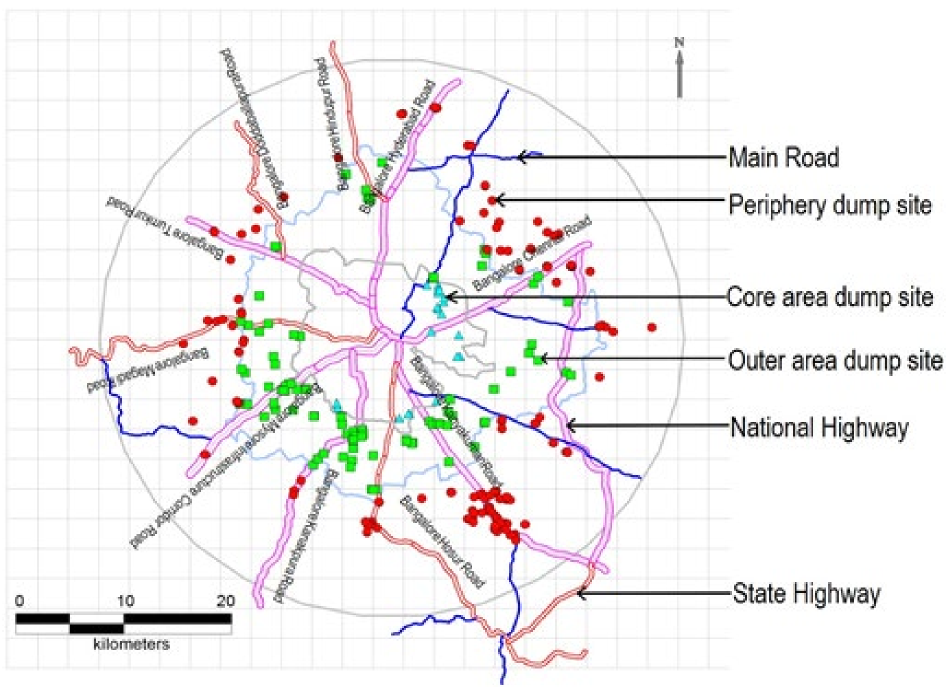

FIGURE 2
Dump sites located in core area and outside core area (outer area and periphery) of the city

centre of the city as well as approachable all-season road access emerging off these main exit roads as these are key determinant for dump sites to originate (TIDE, 2000). Buffer lines of 100 m, 100-500 m, 500-1000 m, 1000-1500 m and >1500 m were created around the major road networks of the city to determine the relation between dump site occurrence and distance from the main road network. For each of the dump sites, the distance from the Centre of the city was also determined using GIS. Ward wise population data was used to arrive at population density with frequency of dump site locations.

Physical and chemical composition of MSW at unauthorized dump sites

Waste composition was determined at 28 randomly selected dump sites. At each dump, after quartering a large quantity in a 1 m^2 area, three samples of 1 kg each from different locations of the dump were collected. The number of samples for each site was decided based on statistical analysis conducted for three sites bearing sample numbers 3, 6 and 9; all of which showed no significant differences in composition ($p>0.05$). Each MSW samples were then segregated into organic fraction, plastics, construction debris, paper, cloth, glass, leather, metal, rubber, biomedical waste, burnt waste and industrial waste. These components were physically segregated, weighed separately using digital balance (DIGI, DS-673) of 6 kg capacity and photographs were taken to record composition estimates (Chanakya and Swamy, 2011). The most probable composition was also estimated by scanning about 5-6 randomly chosen 1 m^2 surface regions of the dump site to identify the predominant waste type (Chanakya et al., 2015). It allowed three levels of validation of data: physical estimate, visual field confirmation and photograph validation. The waste samples were also collected for ultimate analysis using standard methods of APHA, 1975. The samples were weighed and dried at 105°C in an oven until samples attained constant weight to determine the moisture content and total solids (TS). Dried samples were powdered fine (<500 µm) using a laboratory grinder. The dried powder was then ignited at 550°C for 3 hours in a muffle furnace to estimate the TS and VS ratio. The dried powdered samples of 1 gram were used to analyze the carbon, hydrogen and nitrogen contents using CHN analyzer (LECO elemental analyzer). Bulk density of wastes included construction debris, organic fraction, plastic, old garbage (older dumps aged >6 months), other substances and recyclable rejects were measured. The waste was filled in a bucket of volume 0.02 m^3 and weighed in a calibrated spring /electronic balance and waste category wise density was determined. Category-wise waste density values were later used for converting waste volume into waste quantity. While it is acknowledged that wastes will compact with time and when piled to greater depths, this estimate gave the lower estimates for quantities of wastes found at each site. Previous work showed that the open dumps rarely reached depths >1 m and therefore the effect of compaction has been neglected for this study (Rajabapaiah, 1988; Chanakya et al., 2015).

Area of MSW spread at unauthorized dump sites

A total of 268 physically accessible dumps were selected to determine land area dedicated to dump sites. At these sites, the length and breadth of these dumps were measured and most often rectangular in shape as confirmed from satellite images. Spatial extent area of the dump site was visually estimated (VE), tracked with GPS and all observations were recorded on hard copies (Baars and Dyson, 1981; Waite, 1994; Mumby et al., 1997; Palmer and Hoffman, 2001; O'Donovan et al., 2002a; O'Donovan et al., 2002b; Tveit, 2009; Ode, 2010). Dump locations, spatial extent with track and waypoints were overlaid on Google Earth imagery (GE) to verify and compute spatial spread of such polygons. Spatial analysis was carried out with the help of Mapinfo Professional 7.5 SCP software. These waste dumps differed greatly in size and area. Their assessment using GPS and GIS provided area assessments of dumps with a higher accuracy.

Quantification of wastes found at unauthorized dump sites

Quantification of waste at 268 dumps has been carried out through computing the volume of the solid waste dump and later multiplying with measured waste densities of predominant wastes found in these open dumps. Volume of waste at dumps was confirmed using area and height. The height of dumps was measured using reference height measurement method (Criminisi et al., 1999). For reference height measurement, the known height of an adult volunteer observer was used as a reference to measure the height of waste dumps (Figure 3). Dumps and reference adults were positioned at the same focal plane of a camera to minimize any error in perspective.

FIGURE 3
A reference height measurement used for height of dump site (a) The known height of an adult (h_r) is used as a reference to measure the height (h) of dump site. (b) The measured height of dump site is 108 cm

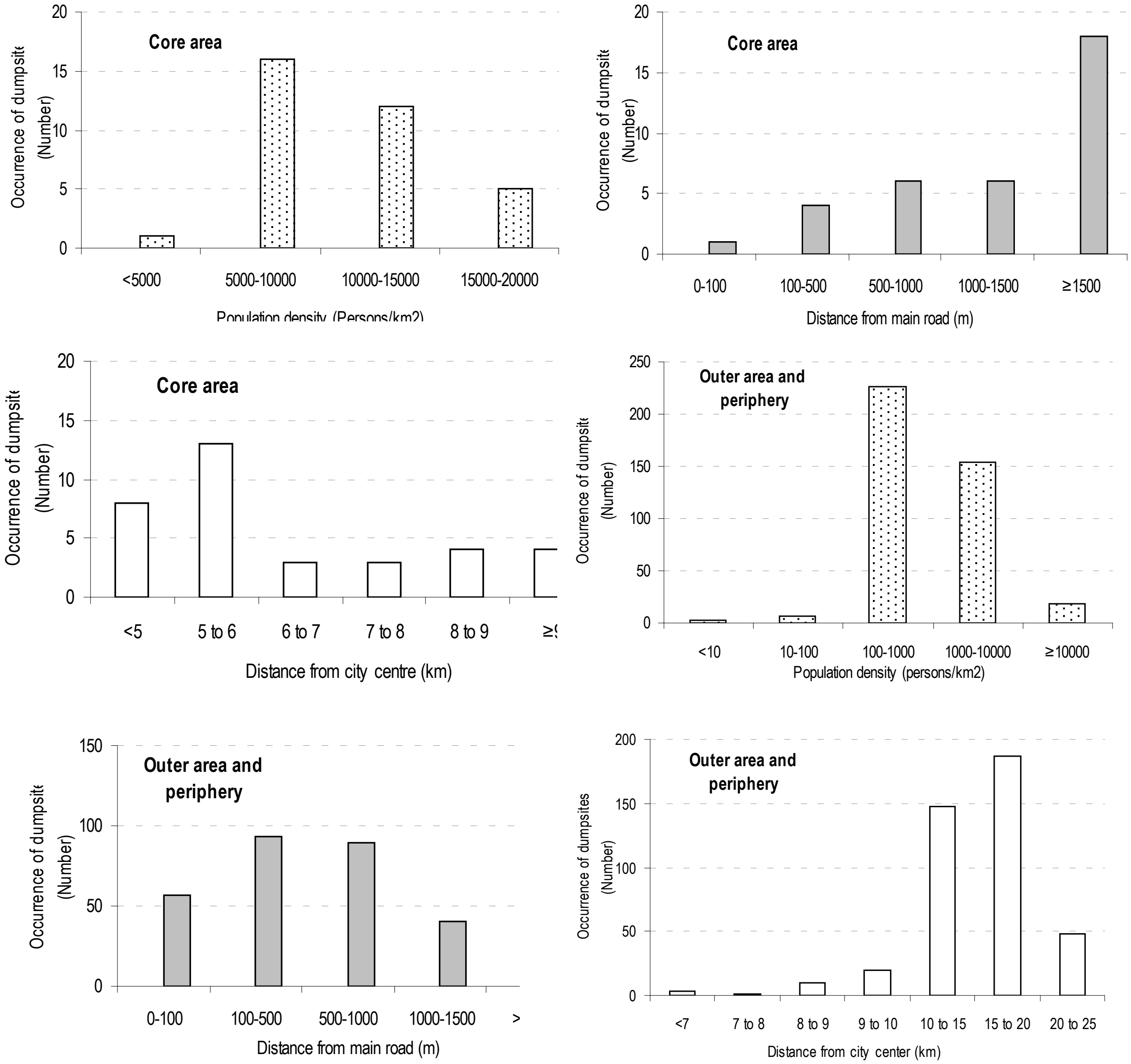

FIGURE 4

Occurrence of dump sites inside and outside (outer area and periphery) the core city area

RESULTS AND DISCUSSION

Frequency and spatial patterns of open dumps in relation to urban demography

A total of 452 unauthorized dumps spatial pattern analysis was conducted to identify regions dominated by open dumps. This effort also helped in finding undiscovered dumps while understanding the propensity for the occurrence or formation of dumps. The population density and occurrence of open unauthorized dumps were correlated. The core city area has a higher population density. Core areas with a population density of 5,000-10,000 persons/km^2 was found to have open dump sites generally smaller in size and temporary in nature (Chanakya et al., 2015). Waste composition found at these core city dump sites, it was found that the organic fraction was quite high shows very recent origin of 1-3 days mainly due to a lack of a regular waste collection and removal system. These ephemeral dump sites are cleared at this above frequency of 2-3 days but recur immediately after their being cleared. These need to be overcome by adopting a higher degree of coordination between primary collection and transportation system. A larger number of dump sites were found outside of the core area (outskirts and peripheral areas) wherein population densities ranged between 100 and 1000 persons/km^2 (Figure 4). This is comparable to the earlier study conducted in Japan (Tasaki et al., 2007). Areas with a lower population density tend to have greater number of open dump sites and is evident from the higher level of occurrences of dumps in localities more than 7 km away from the city centre (Figure 2). The area within 10 to 20 km away from the city centre had higher number (80%) of dump sites. This is attributed to availability of common lands, abandoned agricultural lands apart from sites that have lower visibility and proximity. This indicates that as the distance from the city centre increases, the number of open dumps tends to increase. Large trucks are generally responsible for the transport of MSW in quantities ranging from 5-8 t/truck load and their disposal to these specific dump sites. The specific heaps found at these locations bear out that dumper trucks or vehicles of similar capacity are predominantly responsible for these unauthorized dump sites. At these locations it is not discernible if handcarts and auto tippers carrying out primary collection at the outer area also dump at their daily collection at such dump sites. This study and related observations did not implicate them in a significant way. Unauthorized dumps by these large trucks thus require road access round the year else, it would be impossible for large garbage trucks to dump their MSW load at locations other than on the roadsides. Further, continuous visits on unprepared soil will also create difficulties for trucks to access these sites on a long-term basis. Earlier study indicated that these trucks generally prefer main arterial roads during the main part of the journey out of the city and only when they are out of the denser part of the city these trucks tend to carry out illegal dumping (Rajabapaiah, 1988). Assuming this practice still continues, an attempt is made to evolve a relationship between distance between a major road and the chosen dumps.

The main road network (National Highways, State Highways and Major District Roads; NH, SH and MDR, respectively) farther away from the city centre had more number of dumps. This is similar to earlier study findings (Rajabapaiah, 1988). However, now there is a clear region or band wherein most of the dumping occurs. Generally, areas at a distance of more than 1500 m from the main road network had higher number of dumps. This phenomenon has been observed in areas located inside the core city area, outskirts and also, along the peripheral areas (TIDE, 2000). Visual observations on the size and shape of heaps indicated that this practice of dumping was carried out predominantly by larger waste collection trucks rather than by local residents or by smaller vehicles used in the primary collection process. It is obvious that these heavy trucks require a pliable road all round the year which can bear the weight of such trucks (10-15 Mg) and hence, they can reach the dump site they usually dump wastes in. This significantly restricts the creation of a large number of open dumps at distances more than 1500 m away from the main road network of the city.

Waste composition at dumps

Out of the total number of locations covered in survey, 44% had a dominant quantity of construction and demolition wastes. The dominant component of wastes recorded in open dumps was construction debris, followed by organic wastes and plastic wastes based on the area of spread and volume of waste present. Organic and plastic wastes occur at 25% and 22% of the dumps. For dumps located in the core area, as opposed to the peripheral area discussed above, the largest number of dumps had organic wastes (48%), followed by plastic (26%) and construction debris (17%) as dominant components. The major contribution outside the core area was from construction debris as observed in earlier study (Chanakya et al., 2015). This indicated that the dumps studied were in their last phase of utilization, namely, the stage when the predominant MSW dumped was slowly being covered up by the next stage of utilization of these dumps by dumping C&D wastes (Chanakya et al., 2015).

Waste composition at 28 selected dump locations

Figure 5 depicts the segregated components at 28 chosen dumpsites. The overall waste composition was found to be predominantly 41.3% of construction debris followed by 28.9% of organic waste and other fractions constituted the remaining. The organic waste fraction was less than the generated waste in low-density, medium-density and high-density population areas (Speier et al., 2018). It shows that these sites are at the last phase of waste dumping where C&D waste provides a good cover or capping to the wastes dumped till this period and second, the presence of C&D wastes leaves the sites clear for immediate use for realty to commercialize (Chanakya et al., 2015).

Analysis of samples collected at dump site locations shows that moisture content ranges from 1 to 4%, which is extremely low compared to fresh generated waste (Sharma et al., 2019). Total volatile solids in samples were found to vary from 24 to 93%, while the total carbon content varied from 8 to 49%. The hydrogen and nitrogen content varied from 1 to 7% and 0.4 to 3%, respectively. These variations in samples indicate variability in degraded organic fraction of municipal solid waste as these sites are continuously used from 3-4 years as waste dump sites. The organic wastes constantly degrade, thereby increasing the relative percentage of inert components such as plastics and construction debris. Construction debris and demolition wastes are major components of open dump sites that remain visible for a long period as the organic and recyclable fractions are gradually lost.

Density of wastes accumulated in open dumps

Wastes accumulated in open dumps consist of construc-

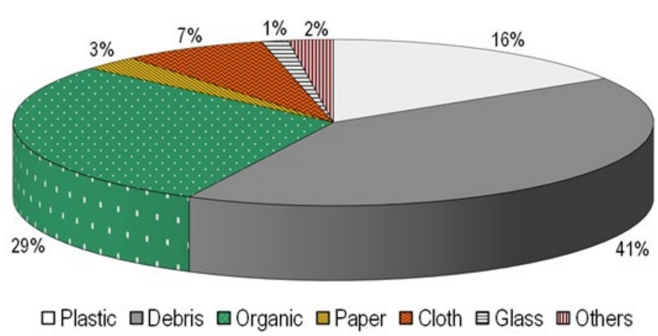

FIGURE 5
Waste composition of dump site locations

tion debris, organic wastes, plastic wastes, old wastes, other substances (viz. paper, cloth, glass, leather, burnt wastes) and rejects from recycling units. Measured densities were 1.01 Mg/m^3 (for construction debris), 0.11 (of organic wastes), 0.05 (of plastic wastes), 0.04 (of old wastes), 0.09 (of other substances) and 0.12 Mg/m^3 (of recycling rejects), respectively. Other wastes include burnt waste which are extremely fluffy and amenable to secondary dispersal by wind and rainwater. Organic wastes at this stage is partially dry and lighter than fresh organic waste when collected at the source. Most of the organic matter that has degraded or dried with time has a low density (0.04 Mg/m^3) and is categorized as "old wastes."

Waste spread area at open dump sites

Waste spread area was estimated at 268 of these locations using GPS to determine area of spread. The total area of spread was 120212 m^2. The land area of open dumps found in the core area and outside the core area were 2941.45 m^2 and 117270.5 m^2 (outer areas 48509.96 m^2 and peripheral areas 68760.58 m^2), which is equivalent to 0.02% of total area of Bangalore. The area of waste spread increased from the core to the periphery of the city as the number of dump sites also increased from inside to the outskirts of the city.

Height of open dumps

The average height of dumps was 0.69 m. The dump height varied from 0.24 to 1.09 m in the inner core areas with an average dump height of 0.56 m. The height of the dumps varied from 0.10 to 7.11 m in outside the core area depending upon surrounding area and dumpsite visibility. The average height of dump in outside the core area is 0.75 m indicating greater accumulation of waste in the peripheral regions in addition to having a longer residence time.

Quantity of wastes in open dumps

Average waste volume accumulated in 268 dump sites located inside the core area and outside the core area and peripheral area of the city are 1989 and 102660 m^3, respectively. The waste quantity measured is 63652 Mg with a share of 0.5% from core area and rest 99.5% from outside the core area (42.7% from outer areas and 56.7% from peripheral areas; Table 1). Table 1 shows that the waste quantity varied for various waste categories. The quantity of waste dumped was highest in the peripheral area of the city.

The results of this study showed that large open dumps are predominant at locations farther than 1500 m away from the main roads with low population densities (from 100 to 1000 persons/km^2) and at a distance of greater than 10 km from the City Centre. The proximate analysis of samples collected at dump site locations confirms the variability in organic components of municipal solid waste dumped in dump sites. The main component of these dumps nearer the time of its maturity is construction debris. Considering the average height of 268 estimated open dump sites, total 213310 Mg of waste is dumped in 452 locations. It is equivalent to 17% of annual MSW generated from Bangalore city and therefore is indicative of the need to find mechanisms that obviate or overcome the propensity to indiscreet dumping. This study shows a method to quantity of waste dumped in open disposal sites as well as validate this data in multiple ways to achieve a higher degree of accuracy and may be extended to other Indian /developing country situation.

CONCLUSIONS

A total of 452 dump site locations were surveyed for their spatial pattern, size, spread area, waste nature and composition. The dominant components of wastes recorded in open dumps located outside the core city area were construction

TABLE 1

Waste quantity dumped in open disposal sites across the city

Predominant waste categories	Core		Outer		Periphery	
	Location (Nos.)	Quantity (Mg)	Location (Nos.)	Quantity (Mg)	Location (Nos.)	Quantity (Mg)
Construction debris	4	170.3	58	25576.6	63	34140.4
Organic	10	147.2	23	1089.7	35	770.2
Plastic	5	14.2	15	329.2	37	693.3
Plastic+Debris					2	140.2
Plastic+Paper					1	1.9
Old	1	2.6				
Others	1	12.0	3	192.9	9	232.8
Recycling rejects					1	138.57
Total	21	346.3	99	27188.4	148	36117.3

debris, followed by plastic and organic fraction of waste. Whereas in dumps located in the core area, the largest number of dumps had organic wastes, followed by plastic and construction debris. Average height of dump site varies from 0.56 m (core city) to 0.75 m (outside of core city area). At frequent intervals, the dumps in the core area are cleared and sent to processing or dump sites in the non-core areas. Total waste quantity dumped in 452 open disposal sites is 213310 Mg, which is 17% of total annual waste generated in Bangalore city. The availability of and access to common lands, abandoned agricultural lands, lower population density, distance from city centre and from main road networks play an important role in the choice of starting an unauthorized dump site and for its continued use.

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