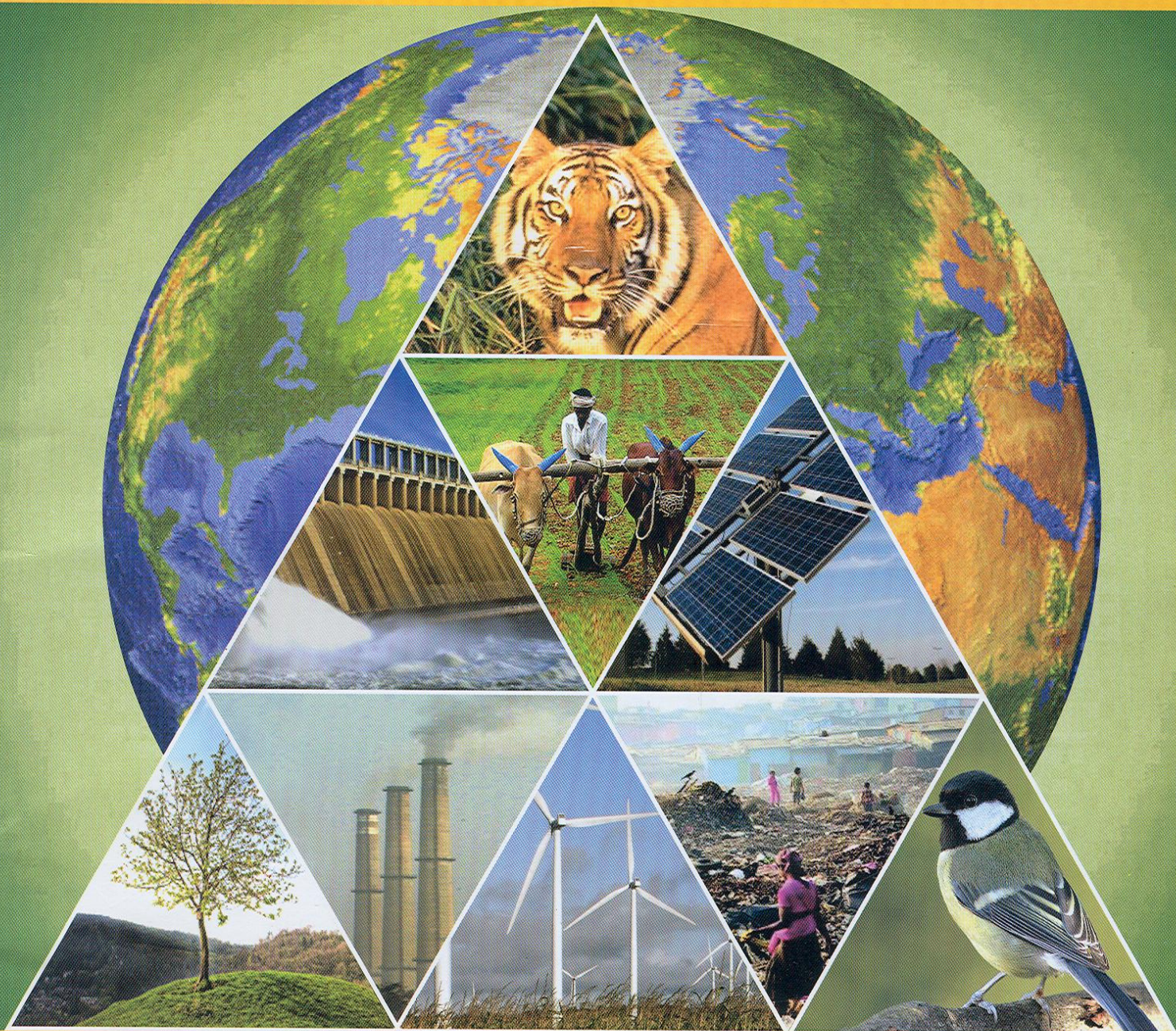


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INTERVENTIONS IN THE MANAGEMENT OF URBAN SOLID WASTE

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ABSTRACT

Major functional elements of urban solid waste management (USWM) are collection, segregation, storage, transportation, treatment and disposal. Waste collection constitutes a vital component in the management of urban solid waste. Solid waste collection in India is undergoing a change from community bins to Door-to-Door (DtD) collections. Community's encouraging response to this transition has motivated the city municipality to deal with the waste handling and management through the local residential associations. This paper provides an overview of existing current practices of all functional elements of urban/municipal solid waste management as well as a comparative analysis of DtD collection versus the community bins in the Indian Institute of Science campus, Bangalore. The campus waste management has evolved from the community bins to DtD collection with segregation of garbage at source level. Detailed field investigations were carried out to assess relative merits of interventions in the waste management system with the conventional system through characterization and quantification of waste. It reveals an improvement in waste collection evident from higher quantum of waste collection (three to four times) in DtD collection apart from significant improvements in the local environment evident from reductions in littering on road, disease vectors apart from the reductions in street dogs in the campus.

Key words: Urban solid waste (USW); Functional elements; Door-to-Door collection; Waste management

INTRODUCTION

Solid waste is heterogeneous mixture of solid materials which does not have any further use to the society. Municipal solid waste refers to wastes generated from commercial and residential places situated in a municipal or notified area (MSW rule, 2000) in an urban locality. Rapid urbanization coupled with the burgeoning population has enhanced the quantity of waste, resulting in serious environmental problems due to lack of appropriate planning and management. This necessitates suitable management strategies in an environmentally compatible manner while adopting principles of economy, aesthetics, energy and conservation (Tchobanoglous et al., 1997). This will reduce the risk

to the environment and human health at all levels starting from generation to disposal of waste. (Kassim and Ali, 2006). Nevertheless, successful implementation of the environmentally sound management of solid waste requires active participation of all stakeholders and sectors like administrative, financial, legal, planning and engineering (Joseph, 2002; Ramachandra and Varghese, 2003; Ramachandra, 2009).

Selection of appropriate collection system in a locality is one of the key steps in management and planning of municipal solid waste (MSW). Community bin and DtD collection are two frequently used collection systems in India. In community bin collection, all wastes will be collected in bins located at each lane of the respec-

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tive locality. It provides a good chance for rag pickers to recover many of the recyclables (Chanakya and Sharatchandra, 2005) and sometimes leads to the creation of unauthorized open collection points (Sharholy et al., 2008). Compared to this, DtD waste collection mechanism involves the collection of residential wastes at each doorstep by the municipal authorities. In DtD collection, waste collectors, collect waste from each household at fixed time and transfer to the transfer station or designated location. Different colour containers are used to collect segregated waste – organic, recyclables and hazardous. In DtD collection, the quality of service is much better than community bin collection (Obirih-Opareh and Post, 2002). Littering on roads and overflow of community bins have declined with the introduction of DtD collection.

Educational (colleges, universities, research) institutions have ethical and legal obligations (MSW rule, 2000) to manage and treat wastes locally apart from maintaining the cleanliness and hygiene of the environment (Mbuligwe, 2002; Singh et al., 2007; De Vega et al., 2008). In this paper, a comprehensive investigation of MSW and DtD collection are carried out, at Indian Institute of Science campus, followed by a comparative analysis to evaluate the effects of waste collection system in Urban/Municipal Solid Waste Management (MSWM).

CURRENT MSWM PRACTICES IN INDIA

The functional elements of waste management are: storage, segregation, collection, transportation, treatment and disposal. Presently, most of the metropolitan cities MSWM system includes all the elements of waste management where as majority of small cities and towns MSWM system comprises only four activities collection, storage, transportation and disposal (Sharholy et al., 2008, Ramachandra, 2009; 2011).

- **Waste storage:** Storage of waste means the temporary containment of waste, at house level or at community levels. At household level, old plastic buckets, plastic bins and metal bins are used for storing waste and at community level, wastes are stored in masonry bins, cylindrical concrete bins, metallic and plastic containers (Joseph, 2002; Kumar et al., 2009). Stored wastes are collected and transported

to the transfer station or processing site at regular intervals.

- **Waste segregation:** Waste segregation is to segregate the waste into different categories like; wet or organic waste and dry or inorganic waste. In the conventional method, partial segregation of news paper, milk pouches, etc are happening at house level, but rest get mixed up during waste storage. In few places with the active participation of NGO and community, segregation at source/ at house level is in place (Patnaik and Reddy, 2009; Ramachandra, 2009). However, it is still at very preliminary stage. Informal recycling sector play an important role in waste segregation and waste management (Sudhir et al., 1996).
- **Waste collection:** Waste collection is the removal of waste from houses and all commercial places to collection site from where it will go for further treatment or disposal. Its efficiency is a function of two major factors; manpower and transport capacity (Gupta et al., 1998). Community bin and DtD collection are the collection systems which are prevalent in India (Kumar et al., 2009; Kumar and Goel, 2009; Patnaik and Reddy, 2009; Ramachandra, 2009). Indian cities are shifting from community bin collection to DtD collection to improvise the existing waste management system. Most of the cities are either fully or partially covered with DtD collection (Kumar et al., 2009). In Kolkata DtD collection facility is only limited to 60 - 61% in present collection system (Chattopadhyay et al., 2009; Hazra and Goel, 2009), where as in Bangalore it has reached up to 94 - 100% of total waste collected from residential area (Ramachandra and Bachamanda, 2007; Kumar et al., 2009).
- **Waste transportation:** Waste transportation of the stored waste to final processing sites or disposal sites at regular intervals is essential to avoid bin overflow and littering on road. Usually light and covered vehicles with carry capacity of around 5 tons per trip are used for transportation of wastes (Rajabapaiah, 1988, Ramachandra, 2009). In small towns bullock carts, tractor-trailers, tricycles etc. are mainly used for transportation (Sharholy et al., 2008).

- Waste treatment and recovery:** The method adopted for treatment of organic waste is either composting or biomethanation. Composting through aerobic treatment produces stable product-compost which is used as manure or as soil conditioner. In metropolitan cities, compost plants are underutilized due to various reasons, most important reasons are unsegregated waste and production of poor quality of compost resulting in reduced demand from end users (Kumar et al., 2009, Chattopadhyay et al., 2009, Ramachandra, 2011). Vermi-composting is also practiced at few places. Biomethanation through microbial action under anaerobic conditions produces methane rich biogas. It is feasible when waste contains high moisture and high organic content (Chanakya et al., 2007; Kumar and Goel, 2009). Recyclable waste which can be transformed into new product like plastic, rubber, glass, metal and others are collected separately and auctioned by recycling industries (Agarwal et al., 2005).
- Waste disposal:** Waste disposal is the final stage of waste management. As in urban area, uncontrolled

and unscientific disposal of all the categories of waste including organic waste has led to the environmental problems such as contamination of land, water and air. In larger towns or cities the availability of land for waste disposal is very limited (Gupta et al., 1998; Mor et al., 2006; Ramachandra, 2009). In many places, a major fraction of urban wastes are directly disposed in low lying area or in hilly area at city outskirts (Lakshmikantha, 2006; Talyan et al., 2008; Chattopadhyay, 2009). In this backdrop, MSW rule 2000, GOI (Government of India) was introduced to regulate all components of waste management. Landfilling or disposal is restricted to non-biodegradable, inert waste and other wastes that are not suitable either for recycling or for biological processing as per MSW rule, 2000.

METHOD

Study area: The study has been carried out in the IISc (Indian Institute of Science) campus located at northern part of Bangalore City (Fig 1). Campus boundary

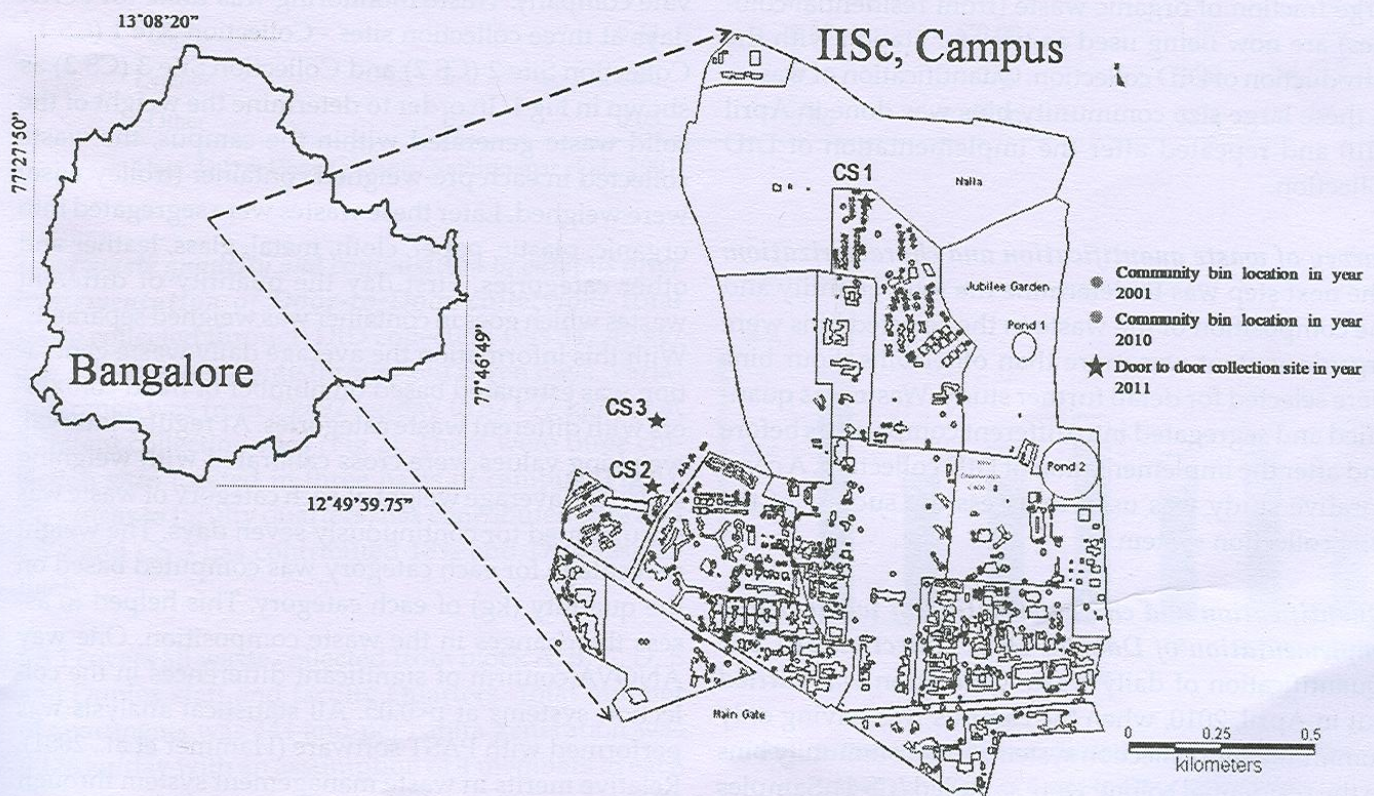


Fig. 1: Spatial distribution of bins

limits are enclosed within 13.01 to 13.02° latitude and 77.55 to 77.57° longitude. It covers an area of 180 hectares. The campus waste management has evolved from the community bin collection to DtD collection (implemented in 2011) with segregation of garbage at source level. It was possible to analyze the composition of the waste in different bins before and after the implementation of collection system. It was also advantageous to evaluate impacts associated with collection practices to analyze the merits of DtD collection compared to the earlier community bin collection.

Selection of bins: Visual surveys of bins were undertaken for one week covering all bins in the campus and compared with the earlier study (Sathiskumar et al., 2001) to understand the changes, if any. The purpose was to determine the area where bins receive more quantity of organic fermentable waste. Bins situated near departments, hostel, cafeteria/mess and residential area was selected and 142 bins were surveyed to see their waste composition as well as to find bins which are frequently used for organic waste. Among these 142 bins, about 12 large size hut bins are present. Among these large size hut bins, 4 bins which used to receive large fraction of organic waste (from residential colonies) are now being used as transfer station with the introduction of DtD collection. Quantification of wastes in these large size community bins was done in April 2010 and repeated after the implementation of DtD collection.

Survey of waste quantification and characterization: The next step was to determine the total quantity and the composition of the waste in the selected bins were organic content was more than other bins. Four bins were selected for detail further study. Waste was quantified and segregated into different components before and after the implementation of DtD collection. A comparative study was used to assess the success of the DtD collection system.

Quantification and characterization of waste before implementation of Door-to-Door collection at CS 1: Quantification of daily waste generation was carried out in April, 2010, when the campus was having only community bin collection system. Four community bins in the residential colony were sampled (CS 1). Samples

were selected based on one week visual monitoring of that area. These four sampling points were representative because large number of residents throws their waste in these community bins. These four bins were continuously monitored for three days. In order to determine the weight of the solid waste generated daily within the campus, all four community bins were completely emptied. Plastic sheets of size 1.1 m×1.1 m were spread in the bins, to enable easy collection of daily wastes. Wastes were collected twice daily (morning and evening) and segregated manually into different categories- organic, plastic, paper, cloth, metal, glass, leather and other and each component were weighted separately (Kumar and Goel, 2009). Weighing scales were re-calibrated and cross calibrated regularly. These bins were thus monitored for three days and category wise average weight of waste is computed.

Quantification and characterization of household wastes after implementation of Door-to-Door collection: Quantification of daily waste generation was also carried out during March-April, 2011, after the implementation of DtD collection. DtD collection and waste management in the campus was outsourced to a private company. Waste monitoring was done for seven days at three collection sites - Collection Site 1 (CS 1), Collection Site 2 (CS 2) and Collection Site 3 (CS 3) as shown in Fig 1. In order to determine the weight of the solid waste generated within the campus, the waste collected in each pre-weighed container (trolley wise) were weighed. Later these wastes were segregated into organic, plastic, paper, cloth, metal, glass, leather and other categories. First day the quantity of different wastes which goes in container was weighed separately. With this information the average daily waste generation was estimated based on number of filled containers with different waste categories. At regular interval, weighing values were cross calibrated with weighing scale. The average weight of each category of waste was documented for continuously seven days. The weight percentage for each category was computed based on the quantity (kg) of each category. This helped to assess the changes in the waste composition. One way ANOVA confirm of significant differences in the collection systems at $p < 0.05$. All statistical analysis was performed with PAST software (Hammer et al., 2001). Relative merits in waste management system through

DtD collection and community bin (at site 1) were analyzed to understand the benefits of interventions in waste collections.

RESULTS

Waste quantity and composition with change in collection: The quantity of waste reaching to collection site has been significantly increased. Before DtD the total waste collected at CS 1 was 58.34 kg/day – an average of 0.033 kg/capita/day. Whereas after DtD collection

226.84 kg/day was collected at the same collection site, corresponding to 0.128 kg/capita/day – a increase of 0.095 kg/capita/day. This highlights the improvements in waste collection through DtD collection mechanism due to minimized littering on roadsides and drains. Before DtD collection (community bins) waste was having 75.51% organic, 7.48% plastic, 5.78% paper, 3.40% cloth, 1.36% metal, 4.76% glass and 1.70% other. Compared to this, waste composition after DtD collection was 81.64% organic, 11.58% plastic, 4.96% paper, 0.83% cloth, 0.23% metal, 0.36% glass, 0.16% leather and 0.25% other (Table 1).

Table 1: Waste characterization at collection sites

Type of waste	Average (%)		Average (kg)			
	IISc campus*	IISc campus after DtD	CS 1 (Residential area)		CS 2	CS 3
			Before DtD	After DtD		
Organic	73.0	79.59	2.22	185.57	43.77	46.84
Plastic	9.5	12.7	0.22	26.32	11.25	6.43
Paper	18.0	6.2	0.17	11.28	7.07	3.00
Cloth		2.6	0.10	1.88	2.05	5.10
Metal		0.2	0.04	0.53	0.24	0.00
Glass		0.5	0.14	0.82	0.00	1.00
Leather		0.1	0.00	0.35	0.00	0.00
Other		0.2	0.05	0.56	0.00	0.04

Note: DtD = Door-to-Door; *Sathiskumar et al., 2001

Total waste quantity and composition of campus after implementation of Door-to-Door collection: Total waste collected through DtD collection was 347.46 kg/day, which was varying throughout seven days. Variation range was from 239.92 kg/day to 523.72 kg/day at different collection sites (Fig 2). There were three collection sites located in three parts of campus (Fig 1). CS 1 (near to faculty quarters) has contributed 65% and CS 2 and CS 3 has contributed 18% and 17%, respectively.

CS 1 covers all waste collected from block A, B, C, D, E and Duplex staff and faculty Quarters. Total number of apartments was 444 and per capita generation was 0.128 kg/day with an assumption of 4 members in each

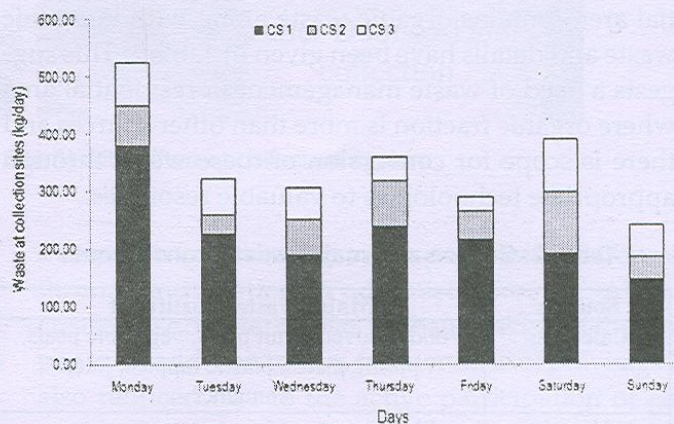


Fig. 2: Day wise waste collected in the campus after implementation of Door-to-Door collection

family. CS 2 covers all waste collected from 195 apartments located in block Thunga, Cauvery, Kapila and Ramanujan and new staff quarters and staff quarters. It has per capita generation of 0.08 kg/day. CS 3 covers SSQ (B block), SSQ (C block), HMT road (A and B block), YPR (A and B block) and Aryabhata block and their per capita generation is 0.106 kg/day. Per capita generation was high at CS 1, which leads to high percentage contribution of total waste collected at collection sites. Statistical analysis reveal of significant variation in compositions at CS 1 compared to other two collection sites. Organic, plastic and paper are three large contributing waste components in all three sites. The statistical analyses indicate of significant difference between three collection sites for organic (F:30.02, p<0.005), plastic (F:19, p<0.005) and paper (26.23, p<0.005) wastes.

DISCUSSION

Current solid waste management practices

Solid waste sources in campus: Major sources of organic wastes in the campus are residential area, cafeterias, mess, and hostels. Hostels and departments generate inorganic waste dominated by paper and plastic. This goes directly to the collection site apart from collection by an informal sector. The inorganic segregated wastes are given to an agency (ITC-BBMP). Cafeterias and mess has high percentage of food and vegetable waste (organic waste) which is given to piggeries through common collection bins. Waste from residential area contains organic waste along with inorganic waste and details have been given in Table 2. This suggests a need of waste management in residential area where organic fraction is more than other sources and there is scope for conversion of these waste through appropriate technologies to valuable resources.

Table 2: Source and major waste constituents

Sources	Major waste constituent
Cafeterias	Food leftovers, fruit peels, vegetable peels, plastic plates, plastic rappers, juice container
Hostel	Plastic rappers, juice container, paper, plastic bags, metals, leather
Departments	Plastic rappers, paper, glass bottles, plastic
Residential area	Food leftovers, fruit peels, vegetable peels, plastic, cloth, glass, metals, leather

Solid waste generation rates and characteristics: MSW generally consist of organic waste and inorganic/ dry waste which mainly consist of paper, plastic, cloth, glass, metal and leather. The respective composition of campus MSW after implementation of DtD collection is shown in Table 1. The proportion of organic waste is much higher (82%) than other constituents of waste. Therefore, there is great potential of organic waste recovery from residential area of campus. The waste is suitable for feeding animals or it can also be used as feed materials in composting and biogas production. The quantity of paper, plastic, glass and metal is relatively small because most of these recyclable materials are collected before entering the MSWM system (Tai et al., 2011).

The total waste generated in the campus is 347.46 kg/day after implementation of DtD collection (in 2011). Table 1 infers that the generation rate is varying in all three collection sites of campus. The quantity of waste collected at site CS 1, CS 2 and CS 3 were 226.84 kg/day, 62.74 kg/day and 57.87 kg/day, respectively. It indicates that in residential area the largest generator of waste was near CS 1 followed by CS 2 and CS 3. This implies that the number of apartments near to CS 1 is higher than other two collection sites as well as residents near CS 1 produce more waste. Resources consumption and consequently waste generation at CS 1 are higher than both CS 2 and CS 3. Day wise results for CS 1, CS 2 and CS 3 collection sites are given in Fig 2. Total waste generation is high on Monday and Saturday which reflect higher consumption during week-ends.

The comparable generation rates of waste for CS 1 and CS 3 at 0.128 kg/c/day and 0.106 kg/c/day, respectively, as opposed to 0.08 kg/c/day for CS 2 can be attributed to their standards of living as well as to daily food habit. The average per capita waste generation for Bangalore city was 0.35 kg/c/day at household level (Chanakya et al., 2009), which is higher than the present estimation, which is attributable to the current sampling location's social and economic aspects.

Solid waste management with collection system: The results suggest that significant progress has been made towards the key objective – increasing the efficiency of waste collection system. Changes in the collection prac-

tice, has seen the improvements in waste collections by three to fourfold as in CS 1. This large difference in total waste quantity collected shows the efficiency of DtD collection. Important features of both the collection system; DtD and community bin collection are discussed in Table 3.

Table 3: Comparative analysis of collection systems

Variables	Door-to-Door collection	Community bin collection
Waste storage	Plastic container	Cement container
Waste segregation	Source segregation is possible to implement	Source segregation is not possible to implement
Waste collection efficiency	More	Less
Waste transportation	Regular	Irregular
Waste quantity collected	More	Less
Surrounding environment	Clean	Less clean

In community bin collection system, wastes generated in all residences were not reaching to the collection site. Community bins are located at the centre of locality which leads to waste littering in different unauthorized locations of campus. Change in collection process has also stopped littering of waste on road side, drainages and also around community bins (Fig 3). This has significantly reduced dog and monkey menace in the residential colony of the campus. Community bin collection system also requires maintenance of bins at regular intervals as broken bins leads to other complications. Source segregation helps to separate collection of recyclables, which fetches additional revenue. Also, daily disposal of waste has minimized odour problem in the locality.

Waste composition has not changed much with the changes in the collection process as well as with time (Table 1). The largest quantity came from organic waste generated from leftovers of prepared food or from the waste generated during food preparation (Fig 2). This waste was generated throughout the day (breakfast, lunch, dinner) and is deposited mixed with all differ-

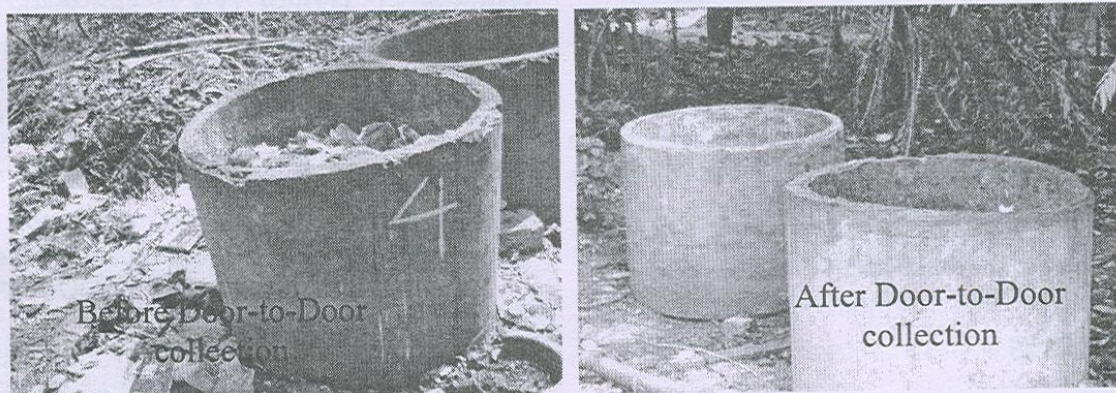


Fig. 3: Bins near CS 1 (Collection Site 1) with different collection system

ent type of waste in dustbins. After DtD collection, percentage of plastic has increased almost one and half time more than 2010. Reason could be that with this collection practice, usually waste is handed over by each residence in plastic pouches. Waste composition has also changed with time. Earlier studies (2000) shows that waste compositions - paper was 18% of total waste generated at that time (Sathiskumar et al., 2001) which has reduced to 5.7% and 4.9% in 2010 and 2011 respec-

tively. This could be due to the paperless environment through automation in administration, etc. Also, increased use of internet has probably reduced the use of paper. In addition to this, frequent use of polybags has also reduced due to the active participation of environment conscious groups (mainly consisted of housewives) has motivated many to switch over paper as packaging materials in including grocery and vegetable vendors on the campus.



CONCLUSIONS

The study provides insight into the improvements in the locality through the introduction and sustenance of an effective waste collection system through DtD collections. Analysis of the data before and after DtD collection suggests that the collection system has a significant effect on the quantity of waste collected in the area through improvements in the waste collection. The total waste collected through DtD collection in the campus was 347.46 kg/day. Out of total waste 65% was contributed from collection site 1 (CS 1), where collected waste has increased three to four times more than before implementation of DtD collection system. Per capita waste which reaches to collection site has increased one and half times (0.033 kg/day to 0.128 kg/day) more with the change in the collection practice. This equates to a reduction in littering and unauthorized dumping of waste. It has also maintained a clean environment in the campus. There is still scope for further improving existing solid waste management practices in the campus through the treatment of organic fractions locally and enforcing the efficient waste management practices.

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