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# The role of non-governmental organizations in residential solid waste management: A case study of Puducherry, a coastal city of India

**Ramamoorthy Rajamanikam[1], Gopalsamy Poyyamoli[1], Sunil Kumar[2] and Lekshmi R[1]**

**Abstract**

Poorly planned and uncontrolled urbanization in India has caused a variety of negative, often irreversible, environmental impacts. The impacts appear to be unavoidable and not easily mitigable due to the mounting public health problems caused by non-segregation of solid wastes at source and their subsequent improper management. Recently in India, non-governmental organizations (NGOs) and other civil society organizations have increasingly started to get involved in improving waste management services. Municipal solid waste management being a governmental function, the contribution of NGOs in this field has not been well documented. This study highlights the activities and services of Shuddham, an NGO functioning in the town of Puducherry within the Union Territory of Puducherry in South India. The NGO program promoted much needed awareness and education, encouraged source separation, enhanced door-to-door collection, utilized wastes as raw materials and generated more job opportunities. Even though source separation prior to door-to-door collection is a relatively new concept, a significant percentage of residents (39%) in the study area participated fully, while a further 48% participated in the collection service. The average amount of municipal solid waste generated by residential units in the Raj Bhavan ward was 8582 kg/month of which 47% was recovered through active recycling and composting practices. The study describes the features and performance of NGO-mediated solid waste management, and evaluates the strengths and weaknesses as well as the opportunities and threats of this system to see whether this model can sustainably replace the low-performance conventional solid waste management in practice in the town of Puducherry. The experiences from this case study are expected to provide broad guidelines to better understand the role of NGOs and their contributions towards sustainable waste management practices in urban areas.

**Keywords**

Non-governmental organization, residential solid waste management, source separation, participation rate, resource recovery, SWOT

## Introduction

A high population growth rate, the decline of opportunities in rural areas and a change from a stagnant low-paying agricultural sector to better-paying urban occupations have frequently contributed to urbanization in the third world (Jain, 2007; Vij, 2012). However, unplanned and rapid urbanization in India has triggered rapid environmental degradation that has led to several problems, such as land insecurity, degraded water quality, excessive air and noise pollution, and hygiene and sanitation related issues (Gupta et al., 2012; Maiti and Agrawal, 2005; Uttara et al., 2012). In parallel to these problems, solid waste management (SWM) is emerging as a major public health and environmental concern in the urban areas of many developing regions. A rapid rise in production and consumption patterns has resulted in additional solid waste generation by different sectors such as the agricultural, industrial, commercial, residential and institutional sectors. Improper SWM is reported to cause substantial negative environmental impacts (for example, pollution and greenhouse gas emissions from landfills), as well as health and safety problems in the surrounding communities (Abul, 2010; Bandara and Hettiarachchi, 2010; Ramachandra and Bachamanda, 2007).

Municipal solid waste (MSW) management encompasses planning, engineering, organization, administration, and the financial and legal aspects of activities associated with generation, growth, storage, collection, transport, processing and disposal of solid

[1]Department of Ecology & Environmental Sciences, Pondicherry University, Puducherry, India
[2]Solid and Hazardous Waste Management Division, CSIR-National Environmental Engineering Research Institute, Nagpur, India

**Corresponding author:**
Sunil Kumar, Solid and Hazardous Waste Management Division, CSIR-National Environmental Engineering Research Institute (CSIR-NEERI), Nehru Marg, Nagpur, India.
Email: s_kumar@neeri.res.in

wastes in an environmentally compatible approach by adopting the principles of economy, aesthetics, energy and conservation (Tchobanoglous et al., 1993). The urban local bodies (ULBs) consisting of municipal corporations and municipalities charged with the responsibility of providing MSW services (together with other municipal services) are finding it increasingly difficult to perform their function (Nema, 2009; Patel et al., 2011). The public sectors in many countries are unable to deliver waste management services effectively, resulting in uncollected waste on roadsides and in other public places. Hence, there is an urgent need and opportunity to involve the private sector, civil society organizations and communities in waste management. There is increasing evidence of successful participation of community and civil society organizations in MSW management (Dorval, 2007; Rathi, 2007; Tukahirwa et al., 2011).

Non-governmental organizations (NGOs) and other civil societies in India have recently started to get involved in improving waste management services. NGOs may help in the building up of capacity of people or community groups to help them play an active role in local SWM by contributing to their awareness of waste management problems (Joseph, 2006; Velis et al., 2012). Case studies show that motivated individuals, NGOs and community-based organizations (CBOs) can successfully setup and manage waste-collection systems that facilitate improvement of overall environmental concerns (Ahsan et al., 2012; Colon and Fawcett, 2006). The tried and tested sophisticated methods for MSW management used by government agencies, as adopted in developed countries, cannot be blindly implemented in the third world (Wilson et al., 2012, 2013). Since the role of NGOs in MSW management has not been well documented, there is an urgent need to document the implemented work comprehensively in an urban setting in a developing country such as India.

This study highlights the activities and services of Shuddham, an NGO functioning in the town of Puducherry within the Union Territory (UT) of Puducherry in South India. Shuddham was formed by a group of local residents to improve waste management services by initiating source segregation and adaptation of sustainable recycling and composting practices. To accomplish this, they had to gain the confidence of the municipal body and work closely with the local community to change patterns of waste disposal. The study describes the features and performance of NGO-mediated SWM and evaluates the strengths, weaknesses as well as opportunities and threats of this system to see whether this model can sustainably replace low-performance conventional SWM in practice in the town of Puducherry. Waste stream analysis and resource recovery rate provide a better understanding on the underlying trend or dynamics of residential waste generation which is important to frame policies/programmes that can aid waste reduction practices. The experiences from this case study are expected to provide broad guidelines to better understand the role of NGOs and their contributions towards sustainable waste management practices in urban areas.

## Methods

### Documentation of existing practices

The waste management system and operational efficiency of the NGO 'Shuddham' (in the local language, *shuddham* means cleanliness) was documented and evaluated for a six-month period between December 2009 and May 2010 in the Raj Bhavan ward of the town of Puducherry. The study methods involved primary data collection by direct field visits, informal interviews and group discussions and secondary data collection from the official records of concerned authorities. Direct field observations were conducted to study the structure and functioning of Shuddham in residential SWM. Structure refers to the existing principles and policies, organizational framework and roles and responsibilities. Function refers to service delivery consisting of detailed information about sources, quantity generated, collection, transfer, transportation, secondary segregation, resource recovery practices and final disposal of MSW. Analysis of strengths, weaknesses, opportunities and threats (SWOT) is a valuable tool for determining the extent of success of any program, so that the strengths and opportunities of the current system can be reinforced and weaknesses and threats can be eliminated or avoided during planning and decision-making to further improve the system (Saxena et al., 2010). SWOT analysis was performed to determine whether this NGO-mediated waste management (Shuddham model) is sustainable in the long term and superior to the conventional method followed in Puducherry.

*Waste stream analysis and resource recovery rate.* For assessing the residential waste generation rate and its resource recovery potential, the overall waste stream from the daily door-to-door collection was sorted and weighed by category using manual weighing machines, both small-scale (postal weighing scale with a capacity of 1 kg and accuracy of 5 g) and medium-scale (hanging scale with an accuracy of 50 g and rated load 100 kg) during the study period. The researcher followed the tricycle (collection vehicle) and recorded the number of residents utilizing the tricycle collection facility, waste category, level of waste segregation, number of trips made by the particular tricycle and number of bags collected per trip. For each tricycle the assorted wastes were allocated to one of five categories. Kitchen waste, recyclables, garden waste, sanitary and hazardous wastes were weighed, recorded at the primary storage centre and transported to the Shuddham Resource Centre where secondary sorting into recoverable subcategories was being undertaken by trained female workers. Data regarding resource recovery and recycling activities were directly collected from the records maintained at Shuddham Resource Centre. The unsorted mixed waste portion in the tricycles was also weighed at the primary storage site but not sorted into categories. The quantity of recovered materials was compared with the total collected waste to calculate the resource recovery rate for residential solid waste in the Raj Bhavan ward. A two-way ANOVA test was applied to determine the statistically significant difference for waste generated over time (months) and the difference in each category of generated waste using the data analysis tool in Microsoft Excel 2003–2007.

### Description of study site

*Profile of Puducherry UT and Raj Bhavan.* Puducherry is one of the four enclaves of the UT of Puducherry and is situated on the Coromandel Coast (east coast) of India, 150 km south of Chennai city. With a rich historical connection to the French and being endowed with a unique cultural, spiritual and architectural heritage, it has become a destination for national as well as internationals tourists who come to experience its special ambiance. It continues to maintain a strong tie with France through its institutions and by attracting investment from abroad. Originally designed for a population of 50,000 it remains unprepared for the strains of population growth and an expanding tourism industry. As of 2011, Puducherry UT had a population of 1.24 million with a decadal growth rate of 27.72% (Census of India, 2011). Due to unplanned growth and development, there has been an enormous strain on the infrastructure and environment of the city and, in particular, on the treatment and disposal of domestic wastewater and MSW, affecting the quality of the living environs.

The study area is located in the northern part of the French town of Puducherry, formally known as the Raj Bhavan ward. A major tourist attraction, it is geographically divided from the rest by Bharathi Park in the centre of the town. The study area encompasses 17 streets with 301 residential buildings, three hospitals, four government institutions, two private institutions, three schools, two temples, eight hotels and 17 shops, including the famous Aurobindo Ashram, Manakula Vinayagar Temple, Bharathi Park, heritage buildings, monuments, etc. The Raj Bhavan ward covers an area of 34 ha and supports a population of around 1700 residents.

A map of the study area is shown in Figure 1.

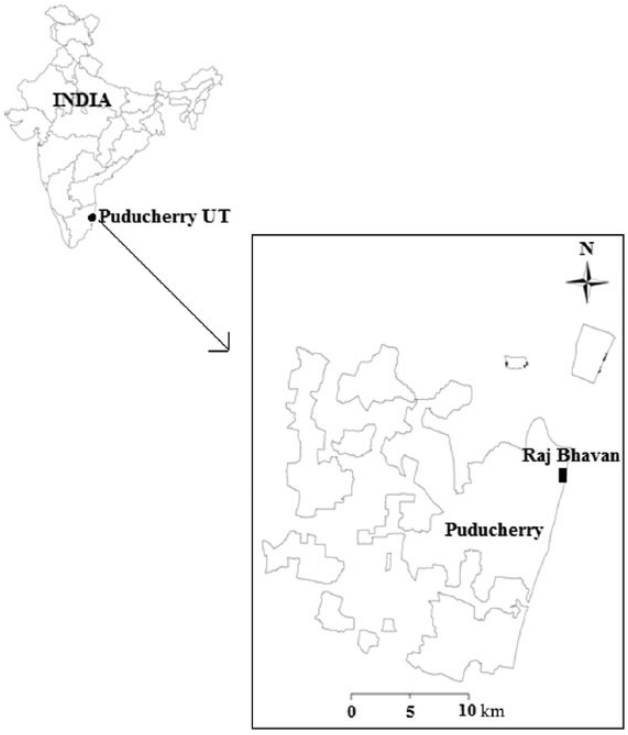


**Figure 1.** Map of the study area.

## Results and discussion

### Overview of existing SWM in Puducherry municipality

Puducherry municipality was constituted as a civic body in 1880 by a French metropolitan decree and attained its present form in 1973. It has a total area of 19.46 km$^2$ and is divided into 42 wards with a population of 220,865. The municipality government is responsible for the collection and disposal of garbage in all 42 wards. During the study period, INR 25 lakhs (US$ 40,000) per month was being allocated from the city's budget for management of MSW in Puducherry municipality. In addition, INR 17 lakhs (US$ 27,000) per month was spent on private contractors, NGOs and self-help groups for collection and disposal of MSW.

Throughout the municipality, the common practice was to dump the mixed residential, commercial and biomedical solid waste into concrete waste bins provided for the purpose, or openly dumped on the nearest street corner to be picked up by the municipality workers or by hired private contractors. The municipality has not been periodically updating or increasing the community bins in proportion to the growing population and development in Puducherry. The private contractors work for profit rather than on the principle of keeping the city clean. Many of them cut down the frequency of collection trips to once or twice per week in order to save on transportation costs, and also employ fewer labourers than as proposed in the official estimate to cut down on salary expenses. Better services are offered to high-income groups, who do not mind paying the private contractors unofficially in order to keep their streets clean. An insufficient number of bins has led to people having to walk a greater distance to dispose of their waste; and low collection frequency has kept the bins in an overflowing state. These factors prompted people to resort to roadside littering, illegal dumping and indiscriminate burning of MSW. Wastes from the overflowing bins and street corners attracted cattle, dogs, cats and vermin. Municipal or private contract labourers picked up the waste with bare hands and deposited it into trailers moved by tractors. The waste was then transported to the open dump at Karuvadikuppam (an area of 15 ha with a population of 6866 in and around the dump) or illegally dumped on the outskirts of town and in nearby ecologically sensitive water bodies, such as Ousteri Lake and Thengaithittu Lagoon. In many localities, garbage remained on the streets for days due to insufficient collection services. The collected garbage was disposed of in the open dump, without any treatment or secondary resource recovery, where waste was burnt from time to time to make room for additional solid waste. Such improper handling of solid waste may pose health hazards to the workers and the residents around the dumps (Pattnaik and Reddy, 2010). Furthermore, the environment and natural resources could be degraded through foul air, toxic leachate into the soil and groundwater and the spread of vector-borne diseases. Factors challenging efficient waste management were identified by the researchers as lack of segregation at source, poor infrastructure,


**Figure 2.** An Overview of Solid Waste Management by the Municipality in Puducherry region.

operational inefficiency, a shortage of educated and skilled personnel, inadequate monitoring and a lack of political concern. An overview of SWM practices by the Puducherry municipality is illustrated in Figure 2.

## *An overview of Shuddham NGO waste management practices*

*Organizational framework*. Shuddham was the only NGO engaged for solid waste collection and disposal services in

Puducherry during the study period, dealing with the Heritage Town section formally known as Raj Bhavan ward. Unlike private individual contractors engaged for the same services, waste management undertaken by Shuddham followed a set of well-defined policies under an organizational set-up with the objective of achieving a 'clean and green environment'.

The organization was formed in 2002 by a few local residents, who mobilized the rest of the community and took up the responsibility of managing the waste generated in the ward. The project was implemented with funding from Puducherry municipality. A team of 30 members – a manager, a supervisor, 24 female sanitation workers known as 'beautifiers' and four residents – formed the core of the project. Capacity-building workshops among the staff and sanitation workers were organized to create awareness about principles of alternative SWM and to improve their perception and solid-waste handling skills. Follow-up outreach programs were organized from time to time to keep them committed to their respective roles and responsibilities. The roles and responsibilities of each staff member were well-defined and distributed. The core team had the overall responsibility of evolving strategies and operational plans, of building collaboration with the government and other service providers, conducting monthly reviews and analysis of existing standards, formulating and controlling the budget, participating in professional group meetings, emergency planning, inspection, and developing research work. The core team collectively delegated responsibilities to execute the policy and plan, co-ordination and maintenance for ensuring the community's involvement, staff management (recruitment and training), identification of current issues and deficiencies, payment procedures, complaints reports, purchasing and replacing equipment, and documentation through a dedicated manager. The supervisor was responsible for ensuring day-to-day staff support, safety standards, public relationships, inspection of the area, maintenance of the equipment and the waste logbook. Sanitation workers executed tasks outlined by the supervisor, gave feedback on the state of the roads, segregation by residents and equipment failure, and maintained good relationships with community members.

*Shuddham working principle.* The priority for sanitation workers was to collect segregated waste at the source, at the household level, and to minimize the waste sent to the dump yard. A key focus was education; they carried out regular waste management awareness campaigns for the residents, including education individually imparted at their doorsteps. Such regular meetings with residents helped to improve the service and on the other hand enlightened people about proper use of the system as applied in their locality. The NGO created visual materials such as posters, pamphlets and documentary videos, for a better understanding of the importance of the issues. While being educated about the adverse environmental impacts associated with inappropriate solid waste management, residents were also sensitized to other environmental and health issues, such as vector-borne diseases, pollution, sustainable development, etc. The conventional practice of SWM under contractors is twice-in-a-week collection from bins (usually when community bins overflow) and streets followed by transportation to the dump yard. The services delivered by other private contractors were observed to be complaint-driven and differential to income groups whilst the sanitation activities of Shuddham were mainly commitment-driven. Core activities undertaken by Shuddham were sweeping, door-to-door collection and transportation, resource recovery (secondary segregation, composting, recycling) and final disposal of MSW.

One of the first initiatives of the implemented programme was to remove the outdated concrete rings (bins) in the streets where residents had previously thrown their garbage (zero-bin approach). Because household waste was being picked up door-to-door, there was no need for these community bins. Removing the rings was done to prevent the residents from continuing to throw their mixed garbage into the rings, thereby bypassing the segregated collection. Removal of the rings had multiple benefits: it created healthier living conditions for people by removing the cattle menace on the street as well as disease-bearing pests, such as rats and mosquitoes. It contributed to the development of tourism activities by providing clean, litter-free streets.

*Encouraging source-level segregation.* Systematic source separation is a crucial component of any successful waste management system that facilitates efficient financial management through minimum energy and labour inputs in the downstream process (Fujii, 2008; Matter et al., 2013; Tai et al., 2011). Shuddham recognized the importance of sustainable source-level segregation through community sensitization in order to achieve efficient resource recovery. To achieve this, it undertook a series of continuous community outreach and training programs in order to motivate and sustain the interest of the residents for segregating waste into different primary categories. The residents were encouraged to sort their household waste into the following five categories: (a) kitchen waste; (b) recyclables; (c) garden waste; (d) sanitary waste; and (e) hazardous wastes. Pamphlets were handed out to the residents on how to handle and sort waste. To motivate the habit of keeping recyclable waste materials separate from food waste and other hazardous waste streams, Shuddam provided residents with a bag free of charge on which was printed a list of recyclables to be collected and sorted. The categories of MSW encountered were classified as given in Table 1. Waste management practices adopted by Shuddham are illustrated in Figure 3.

*Beautifiers.* The sanitation workers (ladies) employed in the study site under the NGO were known as beautifiers. Of a total 24 beautifiers employed in the Raj Bhavan ward, 19 were engaged in routine cleaning activities such as door-to-door waste collection, road sweeping, side drain cleaning, etc., while the remaining five were deputed for secondary waste segregation at the sorting station (Resource Centre). It is now widely accepted that, throughout the world, the workers and waste pickers handling solid waste without protective clothing are exposed to occupational health and accident risks related to the content of the materials they are handling, and emissions from those materials and the equipment being used (Bunn et al., 2011; Cointreau and Mundial, 2006; Ross and Pons, 2013). Hence, Shuddham implemented a monitoring program to ensure the occupational health and safety of its beautifiers, who were provided with basic protective workwear (gloves, mask, soap


**Figure 3.** Role of NGO in MSW Management, Rajbhavan Ward.

and a pair of uniforms) and instruction on avoiding occupational health risks. Once a month, the NGO provided safety and hygiene education, awareness of occupational health hazards and training in handling the equipment to improve the workers' understanding of health issues. But even after such efforts, these workers were found to be less concerned about potential occupational injuries

**Table 1.** A classification framework for residential solid waste.

| Categories of wastes | Material composition |
|---|---|
| Kitchen waste | Food waste, egg, prawn and crab shells, flowers and leaves, vegetable peelings, tea and coffee powder, coconut shell and husk, hair, etc. |
| Recyclables (non-biodegradable) | Plastics, paper, cardboard, cloth pieces, unbroken glass bottles, leather items, metal, tyres and tubes, ropes and string, wood, sponge, Styrofoam, etc. |
| Garden waste | Leaves, twigs, grass cuttings and hedge trimmings. |
| Sanitary waste | Sanitary napkins, diapers, bandages, tissue paper, other medical waste (needles and syringes). |
| Household hazardous waste | Household cleaning solutions, automobile waste, chemicals, paints, solvents, shoe polish, pharmaceuticals, batteries, light bulbs, electronics items such as TV, computers, circuit boards, etc. |

**Table 2.** Collection methods for different waste generators.

| Sl. No | Solid-waste source | Collection method |
|---|---|---|
| 1 | Residents | (a) Ground floor – daily door-to-door collection by tricycle<br>(b) Second floor and above – daily tricycle collection using pulley system for waste transfer |
| 2 | Small shops | Daily door-to-door collection by tricycle |
| 3 | Apartments | Blocks of many flats – a TATA Ace van collected the segregated waste kept at a communal place on the ground floor in a red jumbo bag for dry wastes and a large green bucket for organic wastes |
| 4 | Institutions | Same method as described above, but twice per week |
| 5 | Hotels | Daily collection of segregated waste using a TATA Ace van and mixed waste collected by tractor with trailer |

Sl. No: Serial Number.

and personal hygiene due to poor living conditions and illiteracy. The awareness program can be considered less effective since the workers remained reluctant to use the protective clothing due to the hot tropical climate and during the period continued to use soiled equipment without washing.

*MSW collection and transportation.* Shuddham identified the key areas that needed attention in order to achieve maximum solid waste removal. A zero community bin strategy was implemented, coupled with a direct door-to-door waste collection service in order to deter people from littering on the streets. The study area was divided into three zones for efficient management purpose. One tricycle of 250–300 kg carrying capacity was allotted per zone of 90–105 households for door-to-door collection of MSW. Each household was instructed to keep their wastes sorted into the different categories, which were recovery-friendly. Shuddham experimented to minimize the disadvantages of conventional open waste transport using tractors with trailers, replacing them with the alternative of a TATA Ace van (mini load carrier), with a closed chamber for waste storage that would not be as aesthetically displeasing or emit foul odour as would the former. Altogether in the study area, three tricycles, one TATA Ace and two tractors with trailers were employed on contract to collect and transport the waste from 301 residents and 22 commercial units. Daily waste collection services were provided for residential and commercial units in order to manage food waste, which decomposes quickly, emits odours and potentially attracts vermin. A weekly waste collection service was provided for institutions, which generate more non-biodegradable wastes. Source-separated collection enabled community participation, efficient resource utilization and hazardous waste disposal. The modes of collection and transport for MSW from different sources are given in Table 2. Collection efficiency was found to be 87% (Table 3).

The segregated waste collected by tricycle was temporarily stored in closed containers and kept at the nearest street corner with least habitation before being transported for secondary segregation. The waste was stored in closed containers in an odour-controlled and secure manner to caused less environmental and aesthetic concerns for residents. When mixed waste was received, some separable items (metal, glass and high-density plastics) would be recovered on the site. The different categories of waste would later be transferred manually into the TATA Ace van and transported to the respective sorting sheds of the Resource Centre on the same day. Leak-proof containers were used for food-waste storage to avoid leakage of leachate during transportation. The mixed wastes from the community beyond recovery and rejected materials from the sorting shed were directly carried out into the dumping yard by the tractor with trailers for final disposal.

*Community response and participation.* The successful recycling and recovery effort is directly related to community participation in source-level segregation. In the study area, a total of 39% of households from the 17 streets provided their waste in a segregated manner (Table 3) while 48% of households gave mixed wastes. Some of the reasons expressed by the people who sent mixed wastes were: not having enough space to keep too many dustbins in their house; not interested in investing in dustbins, either due to cost or durability; senior citizens relying on their servants for waste disposal found it difficult to insist on segregation. Of the 17 streets in the studied site, Compagine street

**Table 3.** Levels of residents' participation in segregation, mixing and dumping of MSW in Raj Bhavan ward.

| Sl. No | Street name | Source-separated waste | | Mixed waste | | Non-participants (dumping on the streets) | | Total number of residents |
|---|---|---|---|---|---|---|---|---|
| | | Number of residents | Percentage (%) | Number of residents | Percentage (%) | Number of residents | Percentage (%) | |
| 1 | SV Patel | 10 | 30 | 20 | 61 | 3 | 9 | 33 |
| 2 | Lolitholandal | 16 | 47 | 18 | 53 | 0 | 0 | 34 |
| 3 | Bellcomb | 4 | 36 | 7 | 64 | 0 | 0 | 11 |
| 4 | Debassyn | 14 | 36 | 15 | 39 | 9 | 24 | 38 |
| 5 | Dupuy street | 8 | 42 | 10 | 53 | 1 | 5 | 19 |
| 6 | Saint gilles | 8 | 47 | 5 | 29 | 4 | 24 | 17 |
| 7 | Marine street | 5 | 35 | 7 | 50 | 2 | 14 | 14 |
| 8 | Lauriston | 6 | 31 | 11 | 58 | 2 | 11 | 19 |
| 9 | Nehru street | 2 | 50 | 2 | 50 | 0 | 0 | 4 |
| 10 | Rangapillai | 0 | 0 | 2 | 100 | 0 | 0 | 2 |
| 11 | Saint Martin | 4 | 57 | 2 | 29 | 1 | 14 | 7 |
| 12 | Francois Martin | 13 | 57 | 10 | 43 | 0 | 0 | 23 |
| 13 | Manakula Street | 8 | 22 | 18 | 50 | 10 | 28 | 36 |
| 14 | Perumalkoil | 1 | 11 | 3 | 33 | 5 | 56 | 9 |
| 15 | Cors de garde | 2 | 40 | 2 | 40 | 1 | 20 | 5 |
| 16 | Compagnie | 11 | 73 | 4 | 27 | 0 | 0 | 15 |
| 17 | Saint Louis | 6 | 40 | 7 | 47 | 2 | 13 | 15 |
| Total | | 118 | 39 | 143 | 48 | 40 | 13 | 301 |

Sl. No: Serial Number.

had the maximum participation in the programme with 73% of households providing segregated solid waste(Table 3). It was observed that the residences of this street are comparatively highly educated and well aware of garbage-related issues. The lowest segregation of MSW observed was for Rangapillai street, Perumalkovil st. and Manakula Vinayaygar Koil st., due to either a low level of awareness or the ignorance/apathy of the residents and commercial establishments. Regarding waste management behaviour, altogether 87% of residents participated with the Shuddham initiative, in which 39% segregated their waste at source level, 48% sent mixed wastes and 13% of people chose not to use the door-to-door collection systems. On enquiry, it was found that the major fraction of non-participants expressed their opinion that the timing of door-to-door collection of MSW between 6 am and 9 am was not appropriate since it was office, school or breakfast time, to which housewives devoted their major attention. Hence, they felt that it was an additional burden on their daily schedule.

*Residential solid waste generation.* In the study area, a total of 619 individuals were present in 301 households. The average solid waste generated by residential unit per day was 286 kg (0.460 kg/person/day) (Table 4). The per capita generation rate observed in the study area was consistent with the average per capita solid waste generation rate of many Indian cities (Asnani, 2006; Chattopadhyay et al., 2009; Kumar and Goel, 2009; Kumar et al., 2009). Kitchen waste, mainly consisting of food waste, was found to form the major fraction of about 49.5%, consistent with the findings of Sharholy et al. (2008). Source-separated and mixed wastes accounted for 48% and 52%, respectively, of the total waste stream. Kitchen waste was the largest proportion of the source-separated waste stream at 49% (Table 4). The second major fraction was represented by recyclables at 32%; the substantial recyclable portion indicates that the households consume more packaged goods/materials. Several households in the study area have gardens and lawns. Together with the activities of street-sweeping services, tree trimmings/cuttings generated 16% of green wastes. Hazardous wastes accounted for 3% of collected waste, for which there was no recovery facility in and around Puducherry. The compostable materials, which include kitchen (49%) and garden (16%) wastes, are diverted into composting. This data shows that 97% of waste is recoverable if brought under source segregation. If the remaining mixed waste, which comprises 51% of the total waste, is segregated at source it will save a significant amount of the material going into landfill. The quantification of residential solid waste is summarized in Table 4. Low values of relative SD show that the generation rate was consistent throughout the sampling period and variation was negligible. The observed uniform generation rate indicates that residential units generate more or less the same quantity of waste, which was also reflected by the ANOVA.

A two-way ANOVA was performed to test the variation in the mean generation of dry wastes across different months and variation between monthly generation of different waste categories that contributed to mean dry waste, which show that the probability value ($p$-value) associated with between-month variation of dry waste generation is statistically non-significant ($p = 0.11$), while the $p$-value associated with between-category variation ($p = 5.5$) indicates significant variation in monthly generation of each waste category (Table 5). Hence, it can be inferred that the

**Table 4.** Monthly generation of residential solid waste.

| Month | Source-separated wastes | | | | Mixed wastes (kg) | Total |
|---|---|---|---|---|---|---|
| | Kitchen waste (kg) | Recyclable waste (kg) | Garden waste (kg) | Hazardous waste (kg) | | |
| December 2009 | 2054 | 1283 | 685 | 139 | 4321 | 8482 |
| January 2010 | 2034 | 1262 | 676 | 132 | 4298 | 8402 |
| February 2010 | 2040 | 1379 | 642 | 141 | 4521 | 8723 |
| March 2010 | 2120 | 1326 | 632 | 128 | 4428 | 8634 |
| April 2010 | 2078 | 1385 | 681 | 132 | 4478 | 8754 |
| May 2010 | 2029 | 1305 | 653 | 129 | 4380 | 8496 |
| Average | 2059 ± 35 | 1323 ± 50 | 661 ± 22 | 133 ± 6 | 4404 ± 87 | 8582 ± 142 |
| Relative SD (coefficient of variation) | 1.7% | 3.8% | 3.3% | 4.5% | 2.0% | 1.6% |

± represents SD.

**Table 5.** Two-way analysis of variance test of mean waste generation between months and categories.

| Source of variation | SS | df | *MS* | *F* | *p*-value | *F* crit |
|---|---|---|---|---|---|---|
| Month | 20401.3 | 5 | 4,080.26 | 2.077057 | 0.110953 | 2.71089 |
| Category of wastes | 66,691,389 | 4 | 16,672,847 | 8,487.314 | 5.5 | 2.866081 |
| Error | 39,288.87 | 20 | 1,964.443 | | | |
| Total | 66,751,079 | 29 | | | | |

SS, source of variation; df, degrees of freedom; *MS*, mean sum of squares; *F*, *F*-test statistic value; *p*, probability value (*p*-value associated to the *F*-test statistic ); *F* crit, *F* tabulated value.

**Table 6.** Composition of hazardous wastes.

| Month | Composition of hazardous wastes | | | | | |
|---|---|---|---|---|---|---|
| | Household hazardous products | | E-waste | | Sanitary wastes | |
| | Weight (kg) | Percentage (%) | Weight (kg) | Percentage (%) | Weight (kg) | Percentage (%) |
| December 2009 | 73 | 52 | 45 | 32 | 21 | 15 |
| January 2010 | 67 | 51 | 48 | 36 | 17 | 13 |
| February 2010 | 69 | 49 | 56 | 40 | 16 | 11 |
| March 2010 | 61 | 48 | 49 | 38 | 18 | 14 |
| April 2010 | 72 | 54 | 41 | 31 | 19 | 14 |
| May 2010 | 69 | 53 | 42 | 32% | 18 | 14 |
| Average | 68±4 | 51 | 47±5 | 35 | 18±2 | 14 |

± represents SD.

mean dry waste generation is more or less constant, though the quantity of different waste categories that contribute to the observed pattern varies. Otherwise, seasonality in the generation of different types of wastes was not enough to produce a variation in the mean monthly generation of dry waste. The same trend can be observed from the relative SD values (Table 4), showing 1.7–4.5% of deviation from the mean for different waste categories did not produce any significant variation from the mean solid waste generated across months due to the uniform consumption of households.

The composition of hazardous portions in the residential waste stream is presented in Table 6, which indicates the predominance of household hazardous wastes and electronic waste (e-waste).

*Processing: Resource recovery.* Both bio-degradable and non bio-degradable wastes can be recycled into valuable products, and the reuse of discarded items is traditionally conducted by local communities. Some crude resource-recovery techniques were already in practice among the residents. Conventionally, certain categories (paper, metal, glass bottles and certain plastics) were being sold by some of the residents directly to the scrap dealers for some monetary returns. However, certain categories like food and garden wastes, textile, rubber, leather, ceramics, hazardous and sanitary wastes have always been kept out of recovery and were dumped. Shuddham has undertaken secondary segregation of non-biodegradable wastes (except hazardous and sanitary wastes) into recyclable subcategories and composting of biodegradable wastes.

**Table 7.** Details of recyclables and their economic value and earned revenue through recycling.

| Recyclables | December 2009 | January 2010 | February 2010 | March 2010 | April 2010 | May 2010 | Average dry waste recycled (kg/month) | Percentage of dry waste recycled (%) | Market value INR/kg | Average revenue earned/month (Rs) |
|---|---|---|---|---|---|---|---|---|---|---|
| Mixed waste paper | 425 | 437 | 458 | 463 | 472 | 457 | 452 ± 18 | 34 | 2 | 904 |
| Cardboard | 161 | 142 | 152 | 147 | 159 | 141 | 150 ± 8 | 11 | 4.5 | 675 |
| White paper | 227 | 210 | 208 | 201 | 231 | 210 | 214 ± 12 | 16 | 6 | 1287 |
| Books | 30 | 26 | 38 | 29 | 34 | 27 | 31 ± 5 | 2 | 4 | 124 |
| Tamil newspapers | 13 | 11 | 14 | 14 | 16 | 13 | 13 ± 2 | 1 | 4 | 54 |
| English newspapers | 12 | 9 | 11 | 10 | 11 | 13 | 11 ± 1 | 1 | 5 | 55 |
| High-density polyethylene | 23 | 27 | 37 | 32 | 31 | 26 | 29 ± 5 | 2 | 15 | 435 |
| Low-density polyethylene | 157 | 143 | 164 | 159 | 163 | 152 | 156 ± 8 | 12 | 3 | 469 |
| Milk and oil plastics covers | 6 | 6 | 5 | 5 | 6 | 5 | 5 ± 1 | 0.5% | 15 | 82.5 |
| Tablet covers | 6.5 | 4 | 6 | 5 | 5 | 4 | 5 ± 1 | 0.5 | 3 | 15 |
| Polypropylene/ polystyrene | 18 | 32 | 21 | 27 | 28 | 21 | 24 ± 5 | 2 | 3 | 73.5 |
| Polyethylene terephthalate | 31 | 22 | 24 | 32 | 31 | 28 | 28 ± 4 | 2 | 3 | 84 |
| Iron | 17 | 19 | 21 | 21 | 16 | 18 | 19 ± 2 | 1 | 13 | 247 |
| Sheet iron | 23 | 34 | 38 | 32 | 29 | 23 | 30 ± 6 | 2 | 10 | 300 |
| Other metals | 5 | 14 | 12.5 | 9 | 13 | 12 | 11 ± 3 | 1 | 21 | 231 |
| Liquor Bottles | 8 | 7 | 12 | 9 | 11 | 13 | 10 ± 2 | 2 | 2 | 20 |
| Glass | 121 | 119 | 158 | 131 | 129 | 142 | 133 ± 14 | 10 | 1 | 133 |
| Total | 1283 | 1262 | 1379 | 1326 | 1385 | 1305 | 1323 ± 50 | 100 | | 5189 |

± represents SD.

*Resource recovery rate.* The average amount of MSW generated by the residential units in the Raj Bhavan ward was 8582 kg/month, out of which 47% (i.e. 4043 kg) was recovered through active recycling and composting practices. Food waste and dry recyclables were the dominant types (51% and 33%, respectively, as shown in Table 4). Together they make up 84% of the total recovered materials and about 16% of garden waste was recovered by composting. As mentioned above, some portions of wastes were being sold by the residents directly to the local scrap dealers on low returns. This parallel system operating outside the Shuddham system must have altered the actual quantity of recyclables given in Table 7. Before Shuddham was employed in the Raj Bhavan area there was a normal collection and disposal system handled by the municipality with zero recovery rates. Small quantities (3–6%) of paper, cardboard, metal and some plastics materials were recovered through informal recycling by the rag pickers and waste collectors.

*Recycling.* Recycling prevents the wastage of potentially useful materials while reducing dependency on virgin materials and energy consumption as well as large-scale emissions (Farzadkia et al., 2012; Swapan, 2009; Velis and Brunner, 2013). All recyclable items, such as paper, plastics materials, cardboard, metal, glass bottles, etc., were transported to recycling sheds, where sorting was carried out to segregate the waste into different streams. A total of 60–150 kg of recyclable items was generated per day from the study site including residencies, hotels, apartments, schools and government institutions. These recyclable items were further segregated into subcategories and made into bales by the beautifiers. One beautifier could segregate recyclable items at a rate of 15 kg/hour.

When accumulated in bulk, the well-sorted and separated packed subcategories of recyclables were taken to various certified recycling facilities located in and around the Puducherry region. Based on material type and quality of waste, there are specific companies that buy particular categories of waste material. They buy the well-sorted wastes that satisfy their specifications or quality, recycle them into secondary raw materials and sell to other manufacturing units. For instance, 1 kg of printed white paper sells for between INR 12 (US$ 0.90) to INR 14 (US$ 0.22) while plastics go for INR 26 (US$ 0.41) depending on the type and quality. Glass gets INR 2 (US$ 0.03) per kilogram but broken glass gets only INR 1(US$ 0.01). Recycling not only improved the waste management process but also changed the perceptions of people about waste by adding value to it. It also brought economic benefit to those involved in it. The monthly variation and average quantity of residential dry waste recycled for each category, their market value and the revenue earned through the recycling practices are given in Table 7.

The term dry waste refers to all items that are not wet or soiled. It includes all types of paper, cardboard, bottles, metal, etc. The total amount of dry waste recycled within the study area is approximately 1323 ± 50 kg/month.

The relative SD of 4% indicated that there was a maximum of 4% difference (50 kg) from the monthly mean quantity of recyclables recovered at Shuddham, which can be due to monthly difference in resource consumption or waste generation patterns

and operation of parallel scrap dealers. The results obtained from the dry-waste characterization study show that the residential dry waste consisted mainly of paper (66%) followed by plastics materials (19%). There were also significant quantities of glass (11%) and metal (4%) products. For paper waste, mixed waste paper accounted for the largest part of the total (34%), followed by white paper (16%), cardboard (11%), books (2%) and newspapers (2%). The reason for such a high fraction of paper is due to the usage of more paper packaging, daily newspapers, magazine and catalogues.

Many of the used household products and containers were made from plastics. Recently the price advantage of plastics has been recognized by scrap dealers and has encouraged the establishment of more recycling units in and around the Puducherry region. The compositional analysis of plastics wastes showed that low-density polyethylene (LDPE) accounted for the predominant plastics fraction (12%), The remainders included 2% each as high-density polyethylene (HDPE), polypropylene/polystyrene (PP/PS) and polyethylene terephthalate (PET). Glasses (11%) represent the third largest component, consisting of broken and unbroken glass containers (10%) and liquor bottles (2%). The metal fraction (5%) encountered consisted of thin iron (sheet) materials (2%), iron (1%) and other metals such as aluminium, stainless steel and copper (1%).

*Composting.* Composting can be applied to bio-degradable waste such as food waste, leaves from street sweeping, yard trimmings and garden wastes. In this process, organic matter is subjected to partial decomposition to prepare pre-compost, which is consumed by earthworms. The nutrients of the pre-compost are returned in enriched form when converted into a good manure called vermicompost. A simple, low-cost shed was built for the sorting, composting and maturing units for the plant, with drainage, water supply and electrical facilities. In the study site, biodegradable wastes such as food waste, egg, prawn, crab shells and vegetable peelings were carried to the vermi-shed. The biodegradable waste cannot be fed directly to the earthworms due to the presence of complex macro- and micro-element structures. Hence, the waste needs to be shredded and partially composted. The wastes were shredded in a modified plastics shredder and made into paste. The shredded wastes were mixed with cow dung in the ratio of 3:1. An average of 240 kg of three-day-old shredded kitchen waste prepared in this manner was made into a pile on the ground layer, and left for incubation in aerobic conditions for 45 days, until it was partially decomposed. The pile was turned over every day and the moisture level was maintained by adding water. The C/N ratio is maintained at 25:1 by adding cattle manure and sewage sludge as nitrogen sources, and sawdust, wood chips and leaves for enriching the carbon content. The pre-compost was used as a feed for earthworms. Three species of earthworms were used in vermicomposting: *Eisenia foetida* and *Eudrilus eugeniae*, which are exotic, and *Perionyx excavatus*, which is endemic. Before it was introduced in to the vermi tank, the feed had to be checked by making a small sample bed of 1 m × 1 m. If the pre-compost was taken by earthworms it could be introduced in the tanks. After a week, a covering of casting on the top layer was observed. The total composting process lasted for 60 days and the yield was 0.7 kg/kg of input wastes. Figure 4 explains the steps involved in vermi-composting.

The potential market for compost products was the residents, business units and schools in the same community from which the NGO was collecting solid waste. The local community was the primary user, which purchased about 80% of the total compost produced. The compost was bought directly from the production shed at a rate of INR 15 per kilogram for gardening and kitchen gardens. Landscapers and plant nurseries were the other major customers for the Shuddham compost. The revenue generated by selling the compost was sufficient for infrastructure maintenance and also for paying the employees in the composting unit. The quality of the vermi-compost produced has not yet been determined, but the market demand for this product indicates that the customers were satisfied with the compost as a good-quality and cost-effective manure.

*SWOT analysis of NGO performance.* In this section, we separately evaluated the strengths and weaknesses along with the opportunities and threats for this NGO-mediated waste management model to see whether it is advantageous to adopt this model if the threats and weaknesses are mitigable and less significant when compared to the positive aspects of the system (Table 8).

This NGO-supported residential waste management program was successful primarily because it was a grassroots level movement planned and implemented by the local residents themselves with the support of the municipality, who had a clear idea of the needs and priorities of the neighbourhood. From the SWOT analysis it can be seen that the NGO had a strong organizational set up and goal-oriented and environmentally responsible work culture, which are conspicuously absent in solid-waste contractors, operating in parallel in other Puducherry wards. The effort taken for female empowerment, changing the outlook of sanitation workers and occupational safety measures by the NGO are laudable. Another step worth mentioning is the community outreach and educational programs including door-to-door and mass awareness campaigns implemented to encourage the community toward sustainable participation and to keep them informed about the associated benefits. Though the strengths are visibly very desirable in any model program, financial shortsightedness is also prominent, which can be detrimental to the continuation of the initiative. It can be seen that the municipality contract was the major source of funding but it could not be committed to for a long term and thus was not reliable. The NGO has not devised any alternative funding and tried to self-finance the operation through individual donations when official funds were delayed, instead of devising a user fee system. Attempts at partial cost recovery have in effect resulted in additional infrastructure and operational costs. Among the threats, changes in political and bureaucratic leadership/support can be an indirect deciding factor for the smooth functioning of an NGO. But the greatest disadvantage for Shuddham is a lack of knowledge about the treatment and disposal of infectious and hazardous wastes that were being directly dumped. Lessons

(a) Segregated kicthen waste

(b) Kicthen waste being shredded

(c) Pre-preparation of vermicompost

(d) Prepared compost fed to worms

(e) Infrasture of vermi pit

(f) Collecting vermi wash

(g) Collecting vermi casting

**Figure 4.** Processing of Compostable Waste at Shuddham.

**Table 8.** SWOT analysis of NGO performance in the study area.

| | |
|---|---|
| Strengths | 1. Well-defined administrative framework and properly distributed roles and responsibilities brought operational efficiency in all levels of management practices;<br>2. Properly scheduled waste collection encouraged people's participation and cooperation in source segregation practices;<br>3. Women empowerment through professional training and employment. For example, Shuddham trained women to use tricycles for waste collection and safe handling of MSW.<br>4. Brought positive change in perception of local community towards sanitation workers;<br>5. Implemented the concept of resource recovery in MSW management at Puducherry through composting and sale of recyclables. These activities reduced solid waste quantity in open dumps by 47% as well as indiscriminate burning of wastes due to insufficient collection services.<br>6. Practiced partial cost recovery through sale of compost and recyclables, which can be seen as an attempt to bring some financial sustainability;<br>7. Maintained proper records of the entire waste management process for future reference;<br>8. Good impression on residents and tourists alike by keeping the streets litter-free, leaving a good track record. |
| Weaknesses | 1. Lack of technical know-how on management of special categories such as mixed, hazardous, sanitary and e-wastes, leading to their disposal in open dumpsites without adopting secure landfilling;<br>2. Waste minimization strategy becomes limited to zero-bin approach. Door-to-door daily collection facility offered by the NGO did not encourage residents toward waste minimization, rather the reverse. This strategy also had the disadvantage of higher operational cost.<br>3. The NGO could neither charge a user fee for better financial management nor give incentives for recyclables for encouraging source-level segregation;<br>4. The NGO faced challenges in dealing with government officials who changed frequently and alleged attempts to coerce the NGO into paying bribes by withholding payment for municipal services. |
| Opportunities | 1. NGO approach facilitated 'responsible' management of solid waste at the community level;<br>2. Local employees received good practical training in the field of waste management so that later they may use their expertise in a new place/project;<br>3. Empowerment of women from the lowest economic strata;<br>4. Revenue generation through resource recovery and recycling;<br>5. Recycling adds value to waste, reduces the load on natural resources by providing secondary raw materials, promotes growth of small scale industries and generates income and employment;<br>6. Composting encourages organic-based home-gardening practices;<br>7. Sustainable solid-waste management practices improve the quality of living of local community by keeping the town clean and raising their environmental awareness |
| Threats | 1. Financial and bureaucratic uncertainty due to reliance on municipality funding (external funding) as the prime financial source for NGO operation. It was challenging to deal with frequently changing municipality officials and political leadership for timely allotment of funds. Self-financing the higher operational charges (compared to private contract workers) and payment of employees in such occasions have made the survival of this model doubtful unless alternative funding modes are devised.<br>2. The local government was not taking any role in solid management practices except financial support, which resulted in weak collaboration with municipal authorities/other related organizations;<br>3. Failure to gain the confidence of municipal authorities about applying service charge on customers;<br>4. There was no control over solid-waste production due to daily door-to-door collection of waste from the residents and other commercial buildings, which resulted in a higher rate of waste generation per capita. Parallel-operating direct scrap dealers can weaken the resource recovery that was set up at a high running cost with low returns.<br>5. Lack of treatment facility for hazardous, sanitary and e-wastes dilute the differences between conventional MSW management methods of open dumping. |

learnt from Shuddham can be a model for any community-based organizations, civic groups and NGOs, which can succeed if the weaknesses and threats are overcome through a cost-effective, financially viable and technically upgraded waste management program that is capable of operating independently in the region with community support.

## Present status of waste management

The Shuddham NGO was encouraged by the then Member of the Legislative Assembly (MLA) of the Raj Bhavan area (belonging to the then ruling political party) and consequent support from the relevant administrative circles during the study period. However, the subsequent year has witnessed a major political reshuffling when the opposition party took over the legislative assembly, and hence Shuddham had lost the administrative and political support it received previously. Unfortunately, this 'step motherly' syndrome persists all over India in most of the states, irrespective of political parties, deliberately trying to suppress the development projects initiated during the previous regime. Since the mode of funding for MSW collection and disposal was mostly external sources (the

municipality) and less from cost recovery from the residents, the mode of operation was financially unsustainable as we have indicated by the SWOT analysis. Funds were inordinately delayed for eight months during the second phase in 2010, during which Shuddham experienced an acute financial crisis by operating on self-generated funds and partially from the sale of recyclables. During the next financial year (2011–2012), the municipality leased the contract to a new bidder and, subsequently, Shuddham was closed down. The new contractor collected MSW from the community bins only twice/three times a week and disposed of it in the dump yard located at Karuvadikuppam. The residents who used to enjoy efficient sanitation services from Shuddham were unsatisfied by the new poor-quality waste management system and, subsequently, in 2013 the Raj Bhavan Residents Association established a new community waste management organization called Raj Bhavan North Association (RNA) under the supervision of the Shuddham administrators. RNA in essence follows the Shuddham mode of collection and disposal but without any resource recovery operations for cost-effectiveness, since the residents were not willing to pay more for secondary sorting and composting activities. RNA arranges for daily collection of kitchen wastes and for once-or-twice-weekly collection of dry wastes. The operational cost for collection and disposal is being recovered from a reasonable monthly user fee of INR 60 per household, in a self-financing mode. However, RNA could operate only in the North Raj Bhavan area, where most of the residents are associated with the Sri Aurobindo Ashram. Hence, we are of the opinion that for a community-based waste management model to succeed, good organizational and financial inputs with closer cooperation of the community, as well as continuous political and administrative support, are essential requirements. It appears that a community-based co-management model for MSW collection and management would be ideal in the context of rapidly developing countries such as India. This is not only true in the local context but also applicable to all Indian cities, where such synergies and cooperation exist. If the weaknesses, indicated in the SWOT analysis above, are rectified this model can serve as a potential sustainable waste management system at a community level.

## Conclusions

It was found that community participation was at a level of 87% under the NGO-run waste management system in Raj Bhavan ward, with 39% responding positively to the comparatively novel concept of source-segregated collection, which could have been higher if the NGO had continued operation in the study area. At least six out of 17 streets of Raj Bhavan ward had 100% participation in the program, and there were 11 streets with more than 90% participation where the zero-bin strategy, through removal of community bins for litter-free streets, succeeded in its goal. Community outreach and education can be a major tool for increasing the level of participation in the program. When compared to the conventional SWM practices operational in other wards of Puducherry municipality, this NGO-mediated model had the advantage of a well-structured organizational set-up, along with resource recovery operations, for the first time providing the residents with daily door-to-door collection services, and brought a dignified outlook to sanitation workers. The Shuddham approach had a better understanding of the community expectations of the waste management system since it was formed by a group of residents with first-hand negative experience of the conventional inadequate/inefficient system in operation previously. Analysis of the waste generation rate has indicated that the temporal variations within the generation rate of different waste categories are important for assessing the success of the material recovery/diversion rate as well as the adequacy of the waste management methods followed for different waste categories. Organic matter was the dominating fraction, which contributed 65% of the waste stream followed by dry wastes at 32%, with the least fraction being hazardous and infectious wastes (together 3%). Knowledge of the composition of the waste stream is important to frame optimal waste diversion and treatment programs so that the system can operate cost-effectively with higher returns from resource recovery. Shuddham had a recycling rate of 97% of the segregated wastes received. The temporal variation patterns in the residential solid waste generation of dry wastes and subcategories as suggested by the two-way ANOVA and relative SD values indicated that any well-defined waste management system can continue to operate without accounting for large-scale periodic fluctuations in waste quantities in the study area. The SWOT analysis showed that the Shuddham model had several positive elements that were desirable in any waste management program, such as much needed awareness and education, encouragement of source separation, enhancement of the door-to-door collection and utilization of the wastes as a raw material. However, as indicated by the SWOT there were weaknesses and threats that the NGO faced, foremost of which are weak financial support and political uncertainty that have eventually affected the continuation of NGO-mediated MSW management in the region, making it unsustainable. The lack of attention to appropriate technologies for hazardous and infectious wastes management and the lack of an incentive system for segregated collection can be seen as two serious drawbacks of the Shuddham model. However, the positive aspects of such a system in the infant stage certainly overshadows the disadvantages and with suitable modifications can be implemented in many Indian cities that lack a proper solid waste management (collection and disposal) system without waste treatment. The authors propose that a modified Shuddham model, strengthened by scientific waste disposal and treatment techniques, which can minimize the weaknesses of the present model with an independent mode of operation to bypass the threats can be a sustainable waste management model for the region. The proposed system is suggested to have alternative fund generation methods through a user fee, incentives for increased user participation, donations from industrial and commercial firms towards environmental commitment, and sale of recyclables and compost. Prudent investment should be made in infrastructure and the labour force according to the proportion of

waste categories in the waste steam. The modified model is suggested to conduct community outreach not only for increasing participation, but also for the purpose of waste minimization practices. Such a modified Shuddham model can function as a sustainable and environmentally responsible solid-waste management system needed to keep Indian cities clean and green.

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