Smart Dustbins: An Approach for Sustainable Solid Waste Management in Smart Cities

A. C. Sati and K. Sudhakar

Abstract Solid waste management is a challenging problem in today's world because of increasing population and changing lifestyle. The solid waste does not only create cleanness issue but also environmental issues. In this paper, we discuss the characteristics and existing status of municipal solid waste, generation and collection in Indian cities and with the help of the collected data we propose a model for sustainable solid waste management for the smart cities, which includes door-to-door, smart collection of waste and smart dustbin approach. Finally, the advantages and the challenges in implementation of the model are also discussed.

Keywords Solid waste management · Smart dustbins
Smart waste collection system

Introduction

India is the second largest country in the world, with a population of 1.21 billion. India is facing a sharp contrast between its increasing urban population and available services and resources. Solid waste management (SWM) is one such service where India has an enormous gap to fill. Proper municipal solid waste (MSW) disposal systems to address the burgeoning amount of wastes are absent. The current SWM services are inefficient, incur heavy expenditure and are so low as to be a potential threat to the public health and environmental quality (Annepu 2012). Improper solid waste management deteriorates public health, causes environmental pollution (Sharholy et al. 2008), accelerates natural resources degradation, causes climate change and greatly impacts the quality of life of citizens

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(Jha et al. 2007). This paper is an attempt to propose a model for sustainable solid waste management for the smart cities, which includes door-to-door, smart collection of waste and smart dustbin approach.

Characterization of Municipal Solid Waste

Municipal solid waste (MSW) is defined as the waste which comes from residential areas, government and private offices, shops and public places (i.e., airports, railway stations, bus stands and public parks), but solid waste does not include construction waste, industrial waste or sewage waste (Keisham and Paul 2015). Table 1 shows the variety of waste generated from different sources of municipal solid waste.

Characterization of waste is necessary to know changing trends in composition of waste. Based on composition/characterization of waste, appropriate waste collection system, transportation, processing and disposal technologies could be selected. According to the studies done by CPCB and NEERI (Waste Generation and Composition 2014), the waste characterization in 20 cities is indicated in Table 2.

Solid Waste Management: Present Status in India

Collection, transportation and disposal are three essential steps in the solid waste management. The first key step in this process is collection of waste, which also designates the collection efficiency of any city. In India, inefficient collection and

Table 1 Sources and types of municipal solid waste (Division of Technology, Industry and Economics 2015)

Sources	Typical waste generators	Types of solid waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, glass, metals, ashes, special wastes (bulky items, consumer electronics, batteries, oil and tires) and household hazardous wastes
Commercial	Stores, hotels, restaurants, markets and office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes and hazardous wastes
Institutional	Schools, government center, hospitals and prisons	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes and hazardous wastes
Municipal services	Street cleaning, landscaping, parks, beaches and recreational areas	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches and other recreational areas

Table 2 Solid waste composition of 20 major cities in India (Waste Generation and Composition 2014)

S. No.	Name of City	Compostable (%)	Recyclables (%)	C/N Ratio	HCV (Kcal/Kg)	Moisture (%)
1	Agra	46.38	15.79	21.56	520	28
2	Ahmedabad	40.81	11.65	29.64	1180	32
3	Allahabad	35.49	19.22	19	1180	18
4	Bangalore	51.84	22.43	35.12	2386	55
5	Bhopal	52.44	22.33	21.58	1421	43
6	Chandigarh	57.18	10.91	20.52	1408	64
7	Chennai	41.34	16.34	29.25	2594	47
8	Delhi	54.42	15.52	34.87	1802	49
9	Guwahati	53.69	23.28	17.71	1519	61
10	Hyderabad	54.2	21.6	25.9	1969	46
11	Jaipur	45.5	12.1	43.29	834	21
12	Jammu	51.51	21.08	26.79	1782	40
13	Kanpur	47.52	11.93	27.64	1571	46
14	Nagpur	47.41	15.53	26.37	2632	41
15	Patna	51.96	12.57	18.62	819	36
16	Pune	62.44	16.66	35.54	2531	63
17	Thiruvananthapuram	72.96	14.36	35.19	2378	60
18	Varanasi	45.18	17.23	19.4	804	44
19	Vijayawada	59.43	17.4	33.9	1910	46
20	Visakhapatnam	45.96	24.2	41.7	1602	53

inappropriate final disposal of MSW are two of the major problems faced in municipal solid waste management system (Keisham and Paul 2015). Various collection system deployed by the municipalities collects less than 50% of the total waste generated, which results in scattering of waste in open dumps or waste disposal in unplanned manner or open burning of the waste, leading to the environmental and health issues (Sharholy et al. 2008).

In India, about 0.1 million tons of municipal solid waste generated every day, which is approximately 36.5 million tons per year. The per capita waste generation in Indian cities lies from 200 to 600 g/day, which is increasing at a rate of about 1.3% per year in India (Department of Economic Affairs 2009). Table 3 depicts the total and per capita solid waste generation in 20 major cities in India.

In Indian context, the municipal solid waste is generally stored in rectangular-shaped bins made up of metal or plastics, which are neither in closed condition nor emptied regularly, leading to wicked smell and other environmental and health-related concerns. On the other hand, for municipalities it is very difficult to estimate the real-time data of the waste container (Intelligent Waste Management BURBA 2015). At most of the places, the number of bins is inadequate in size and quantity, resulting in scattering of waste, which causes choking of drains (Sunil Kumar and Bhattacharyya 2009). All cities, regardless their size, their

Table 3 Municipal solid waste generation of 20 major cities in India (Waste Generation and Composition 2014)

S. No.	Name of city	Population	Area (km^2)	Waste quantity (TPD)	Waste generation rate (kg/c/day)
1	Agra	1,275,135	140	654	0.51
2	Ahmedabad	3,520,085	191	1302	0.37
3	Allahabad	975,393	71	509	0.52
4	Bangalore	4,301,326	226	1669	0.39
5	Bhopal	1,437,354	286	574	0.4
6	Chandigarh	808,515	114	326	0.4
7	Chennai	4,343,645	174	3036	0.62
8	Delhi	10,306,452	1483	5922	0.57
9	Guwahati	809,895	218	166	0.2
10	Hyderabad	3,843,585	169	2187	0.57
11	Jaipur	2,322,575	518	904	0.39
12	Jammu	369,959	102	215	0.58
13	Kanpur	2,551,337	267	1100	0.43
14	Nagpur	2,052,066	218	504	0.25
15	Patna	1,366,444	107	511	0.37
16	Pune	2,538,473	244	1175	0.46
17	Thiruvananthapuram	744,983	142	171	0.23
18	Varanasi	1,091,918	80	425	0.39
19	Vijayawada	851,282	58	374	0.44
20	Vishakhapatnam	982,904	110	584	0.59

Source CPCB, Government of India (2004–2009)

geographical location or their economic level, spend huge amount of money every year for waste collection rather than its management (Bandyopadhyay 2015). The urban local bodies spend approximately Rs. 500–1500 per ton on collection, transportation, treatment and disposal of solid waste. About 60–70% of the total amount is spent on collection, 20–30% on transportation and less than 5% on final disposal. Out of the total municipal waste collected, on an average 94% is dumped on land and only 5% is composted (Keisham and Paul 2015).

Smart Cities in India

In India, cities accommodate nearly 31% of India's current population and contribute 63% of GDP. Urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030. This requires comprehensive development of physical, institutional, social and economic infrastructure. All are important in improving the quality of life and attracting people and investment, setting in motion a virtuous cycle of growth and development. Development of smart cities is a step in that direction. Recently Indian Government has announced the proposal for 100 smart cities. The Smart Cities Mission is an innovative and new initiative by the Government of India to drive economic growth and improve the quality of life of people by enabling local development and harnessing technology as a means to create smart outcomes for citizens (Smart Cities Mission 2015). Cities which are not clean do not exhibit a smart character. Cities which are clean are perceived to be smart, providing a healthier environment and a better quality of life (Bandyopadhyay 2015). Therefore, municipal solid waste management plays a key role in the development of the smart cities by deploying technology in waste collection and transportation process.

Smart Waste Collection and Smart Dustbin Technique

All activities in the human civilization are accomplished by taking raw materials and energy, as resources, from the nature. The unwanted by-product of all the activities is the waste, as illustrated in Fig. 1. The problem of municipal solid waste

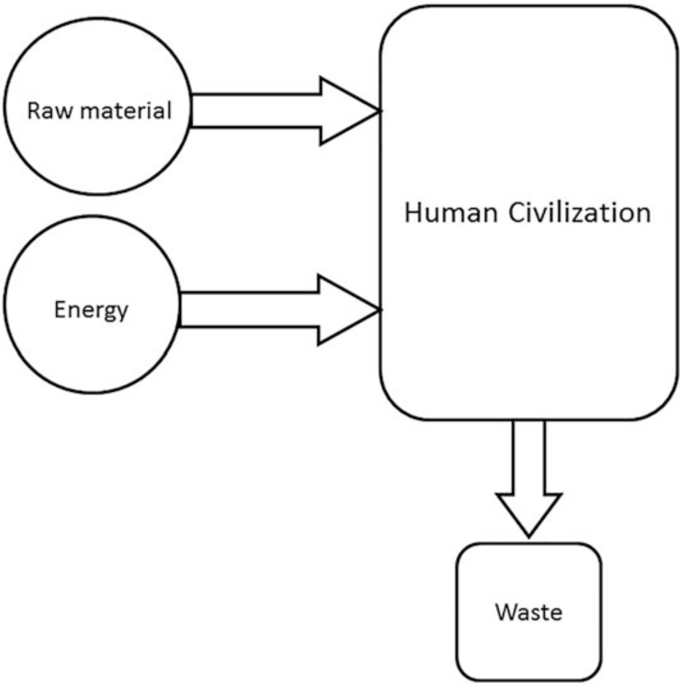

Fig. 1 Block diagram representation of waste generation cycle by human civilization

could be avoided by incorporating sustainable solid waste management model, which converts the whole generated waste back into the resources (i.e., raw materials and energy), as shown in Fig. 2.

In India, the waste collection is done by ULBs (urban local bodies) and the recyclable materials are collected by waste pickers. In the process of waste collection, hardly any technology is used. So this model also includes a proper technological network for waste collection, transportation and their monitoring (Catania and Ventura 2014) using GPS, RFID (Abdoli 2009; Glouche and Couderc 2013) and GSM technology (Bamodu 2013). The smart waste collection unit comprises of a vehicle for the waste transportation and smart dustbin for waste collection. The smart bin contains dedicated chambers for different categories of wastes (i.e., organic, inorganic, inerts etc.). In Fig. 3 H1, H2, H3, stands for House No. 1, House No. 2, etc., are those houses, from where waste has to be collected. For the representation of the model, only seven houses are taken into the consideration. The waste is collected using smart waste collection system from each house. The organic (biodegradable) part of the collected waste is sent to the bio-digester. The recyclable materials are sent to recycling plants, and inerts are sent to WTE (waste-to-energy) plants. The RFID, GSM and GPS technology is incorporated in the waste collection in order to make it easier and more efficient.

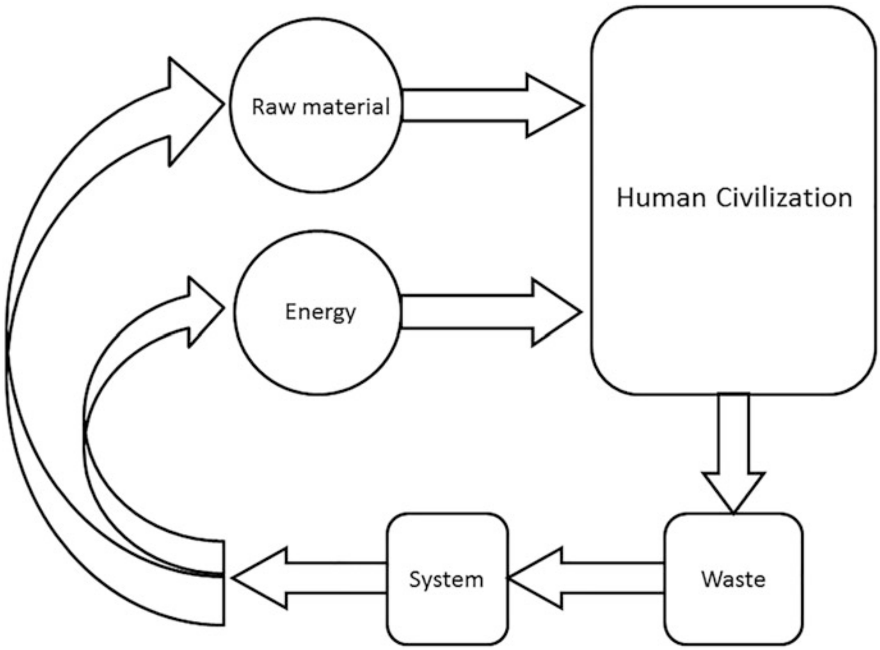

Fig. 2 Solid waste management system with human civilization's waste generation cycle

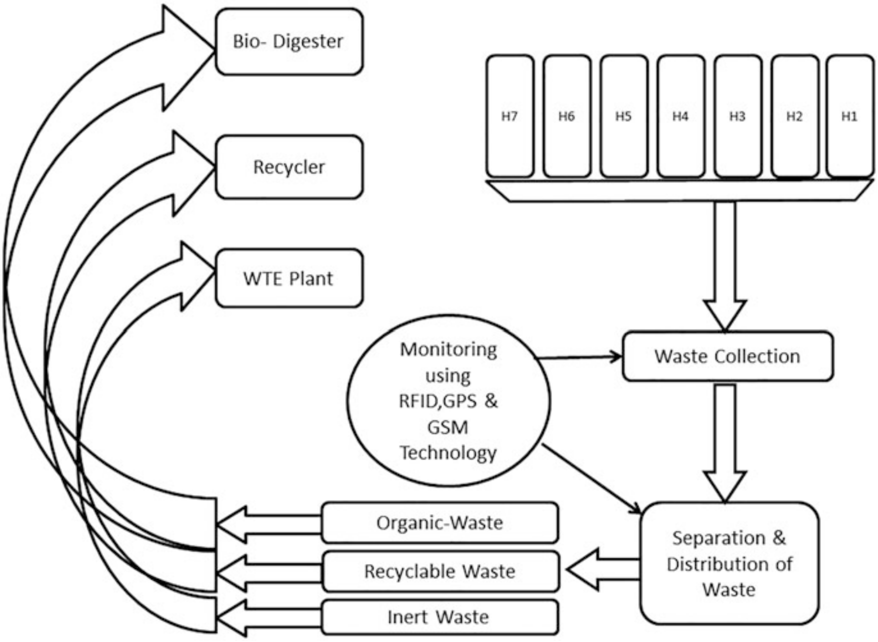

Fig. 3 Block diagram of proposed model for sustainable solid waste management

The model takes the source separation into account, and the organic part of the MSW goes for anaerobic digestion (bio-methanation). The process of anaerobic digestion not only produces biogas (a source of renewable energy) but also the digested slurry, which is a virtuous fertilizer for agricultural use. The other methods for treating organic portion of the MSW (i.e., composting and vermicomposting) are not advised in this model because these methods do not produce any kind of renewable energy, and the composting, practiced in India, is mechanical–biological treatment (MBT) but has been unsuccessful in long run as the quality of the compost produced by the MBT plants was of low grade with high heavy metal concentration and low nutrient value (Annepu 2012). The recyclable portion of the MSW would be sent to recycling plants. The process of recycling would not only conserve our natural resources but it also saves the extra amount of energy, which otherwise would have been wasted in extracting the material from its natural form. This model does consider the modern WTE (waste-to-energy) plants (having pollution control technology, which can dramatically reduce the emission of dioxins and furans (Annepu 2012)) but only for the inert materials or substances which, otherwise, cannot be recycled or used in any other way except for land filling.

Future Perspective

Advantages

With increase in the population and changing lifestyle, the per capita waste generated in India is increasing every year. Table 4 shows the future perspective of population growth and its impact on the generation of municipal solid waste, till 2041.

The studies show that in coming years the amount of waste generated is going to increase tremendously. In order to handle the future scenarios, a systematic technological model for the municipal solid waste management is needed. This model is perceived to have following advantages in relation to the current solid waste management system:

I. A useful and scientific way to handle the big amount of waste.
II. Creation of new employment opportunities in solid waste management sector.
III. The model plays a key role in the development of the smart cities.
IV. The model also reduces the problem of area requirement for the landfill sites by increasing recycling and collection efficiency of solid waste.
V. Reduction in the GHG (green house gases) emission from open dumping and landfill sites.

Challenges:
Challenges in the realization of this model are listed as follows:

I. The segregation of collected waste into biodegradable, non-degradable and inertcategory is the main challenge.
II. Realization of smart door-to-door collection systems.
III. Realization of various types of standalone smart dustbins for different applications, e.g., a small smart dustbin for the public transport buses and railways, so that people would be having an option to keep the waste into the dustbin rather than throwing it outside the buses or trains.

Table 4 Population growth and impact on overall urban waste generation and future predictions until 2041 (Annepu 2012)

Year	Population (millions)	Per capita	Total waste generation (thousand tons/year)
2001	197.3	0.439	31.63
2011	260.1	0.498	47.30
2021	342.8	0.569	71.15
2031	451.8	0.649	107.01
2036	518.6	0.693	131.24
2041	595.4	0.741	160.96

IV. Realization of dustbins of appropriate size and shape to put it in the public place (e.g., at bus stands, railways stations etc.), where people usually through the garbage.
V. Selection of appropriate technological tools for designing the prototype of the smart door-to-door collection system and smart dustbin.
VI. Technological and economic feasibility analysis of the designed prototype in real-time conditions.

Concluding Remarks

The problem with present solid waste management system is that the bins are common for both compostable and non-compostable waste collection, through which it becomes extremely difficult to segregate the variety of collected waste. The solution to this problem is to have smart dustbin and smart door-to-door waste collection systems approach. The study also concludes that the technological interventions in municipal solid waste collection have huge potential, in substantially enhancing the waste collection efficiency, which results in better quality of life, improved cleanliness and reduction in the harmful effect of solid waste on the environment.

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