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RESEARCH ARTICLE

SUSTAINABLE AND INTEGRATED SOLID WASTE MANAGEMENT PRACTICE FOR INDIAN CITIES

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ABSTRACT

Today, one of the major environmental problems being faced by Indian cities and towns relate to management and handling of municipal solid waste (MSW). Economic growth, urbanization and rising standards of living in cities have led to an increase in the quantity and complexity of the solid waste generated. This study aims to explore an alternative approach to the management of the municipal solid waste (MSW), through effective waste to energy, Public Private Partnership (PPP) approach, "5Rs" concept and the use of a specific technology that is able to meet the social, economic and environmental needs of the society.

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INTRODUCTION

Rapid population growth, living standard of people, urbanization and industrialization result in increased generation of solid waste in urban as well as rural areas of the country (Patil *et al*. 2014, Choudhury, 2014). The quantity of waste generated in Indian cities reported to be in the range of 0.2 - 0.6 kg/capita/day as per the "manual on solid waste management" prepared by Central Public health & Environment Engineering Organization (CPHEEO), Ministry of Urban Development, Govt. of India. Waste, garbage, trash, junk, debris and refuse are all names given to the "Stuff" that is no longer useful in its current form (Nkwachukwu *et al*. 2010, Gogoi 2013). Globalization and urbanization is also responsible for the improper management of municipal solid waste (Eric achankong, 2003, Pai *et al*., 2014). As per information received from State Pollution Control Boards/ Pollution Control Committees (in between the year 2009-12), 1,27,486 TPD (Tons per day) municipal solid waste is generated in the Country during 2011-12. Out of which, 89,334 TPD (70%) of MSW is collected and 15,881 TPD (12.45%) is processed or treated. The state-wise generation of municipal solid waste in India is given in table I (Status report on MSWM, CPCB). Solid waste in urban areas is generated by domestic sources, street sweeping, hospitals, commercial and industrial activities. Only a fraction of this solid waste is collected and disposed off at designated sites. The remaining uncollected solid waste is left on the streets, roadsides and drainages. They run into waterways when it rains and this has resulted in several outbreaks of cholera and other diseases associated with improperly disposed solid waste (Edema *et al*., 2012, Steven and Daniel 2014). Solid waste generation rates in India are given in table II (Apte *et al*., 2013). Many cities in developing countries face serious environmental degradation and health risks due to the unscientific MSWM system (Sankoh *et al*., 2013, Jha *et al*., 2007, Walling *et al*. 2004, Khan 2014, Rana *et al*. 2015, Maity *et al*., 2012, Kumar S, Samson 2014). The choice of waste management methods depends on several factors including the waste stream, equipment capacity and finance. The organic component of solid waste that is generated may not be too much of a problem (depending on the disposal option) as it is biodegradable, but the inorganic components are quite problematic because they

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are non-biodegradable and therefore can remain in the environment for a considerable length of time causing severe problems (Quartey *et al*., 2015). To efficiently manage the municipal solid waste system, computerized system i.e. GIS, RFID are used for municipal services in different countries (Verma and Bhonde 2014, Wyld 2010). In high consumption cities in the industrialized world, large amounts of paper waste, medical waste, over-packaging, food waste, and e-waste are all causing particular socio-economic and environmental problems. "Zero waste" means designing and managing products and processes systematically to avoid and reduce the waste and materials, and to conserve and recover all resources from waste streams (Zaman and Lehmann 2011, Harish, 2012). Integrated municipal solid waste management (MSWM) includes basic activities like generation, collection, transport, separation, recycling and disposal that are essential components of any efficient system (Goel, 2008).

TABLE II: WASTE GENERATION RATES IN INDIA

Population	Waste Generation Rate kg/capita/day
Cities with a population < 0.1 million (8 cities)	0.17-0.54
Cities with a population of 0.1–0.5 million (11 cities)	0.22-0.59
Cities with a population of 1–2 million (16 cities)	0.19-0.53
Cities with a population > 2 million (13 cities)	0.22-0.62

Technologies available for Sustainable processing, treatment and disposal of solid waste

To prevent any environmental problem and to make the city a healthy city from economical and ecological view point, there is an urgent need for a well- defined strategic waste management plan and a strong implementation of same (Singh *et al*., 2014).

Table I. MunicipalSolid Waste Generation in India (State-wise)

S. No	Name of the State / UT	(a) Municipal solid Waste MT/ day 1999-2000			(b) Municipal solid Waste MT/ day (2009-12)
		Class – I cities	Class – II Towns	Total	
1.	Andaman & Nicobar	-	-	-	50
2.	Andhra Pradesh	3943	433	4376	11500
3.	Arunachal Pradesh	-	-	-	93.802
4.	Assam	196	89	285	1146.28
5.	Bihar	1479	340	1819	1670
6.	Chandigarh	200	-	200	380
7.	Chhattisgarh	-	-	-	1167
8.	Daman Diu & Dadra	-	-	-	41
9.	Delhi	4000	-	4000	7384
10.	Goa	-	-	-	193
11.	Gujarat	-	-	-	7378.775
12.	Haryana	3805	427	4232	536.85
13.	Himachal Pradesh	623	102	725	304.3
14.	Jammu & Kashmir	35	-	35	1792
15.	Jharkhand	-	-	-	1710
16.	Karnataka	3118	160	3278	6500
17.	Kerala	1220	78	1298	8338
18.	Lakshadweep	-	-	-	21
19.	Maharashtra	8589	510	9099	19.204
20.	Manipur	40	-	40	112.9
21.	Meghalaya	35	-	35	284.6
22.	Mizoram	46	-	46	4742
23.	Madhya Pradesh	2286	398	2684	4500
24.	Nagaland	-	-	-	187.6
25.	Orissa	646	9	655	2239.2
26.	Puducherry	60	9	69	380
27.	Punjab	1001	265	1266	2793.5
28.	Rajasthan	1768	198	1966	5037.3
29.	Sikkim	-	-	-	40
30.	Tamil Nadu	5021	382	5403	12504
31.	Tripura	33	-	33	360
32.	Uttar Pradesh	5515	445	5960	11.585
33.	Uttaranchal	-	-	-	752
34.	West Bengal	4475	146	4621	12557
	Total	48134	3991	52125	127485.107

Source: Based on CPCB's study conducted through;
a)EPTRI
b)As reported by SPCBs / PCCs (during 2009-12).

Vermi - composting

Vermi - composting involves stabilization of organic waste through the joint action of earthworms and aerobic microorganisms (Sharholy *et al*., 2008). Composting is an attractive alternative of MSW recycling. Application of MSW compost in agricultural field can directly alter soil physicochemical properties as well as promote plant growth (Bundela *et al*., 2010). It is to be ensured that toxic material does not enter the chain which if present could kill the earthworms. "Vermiculture Movement" is going on in India with multiple objectives of community waste management, highly economical way of crop production, which re-places the costly chemical fertilizers, and poverty eradication programs in villages (Adhikary, 2012).

Production of Refuse Derived Fuel (RDF)

The main purpose of the refuse derived fuel (RDF) method is to produce and improved solid fuel or pellets from MSW. The RDF pellets can be conveniently stored and transported long distances and can be used as a coal substitute at a lower price. As pelletization involves significant MSW sorting operations, it provides a greater opportunity to remove environmentally harmful materials from the incoming waste prior to combustion (Asnani, 2006).

Waste to Energy (W t E)

Waste to energy (WtE) provides a solution towards complying with government regulations, and achieving integrated solid waste management (Singh *et al*., 2014, Kehinde *et al*., 2014). WtE is a reestablishing itself as an attractive technology option to promote low carbon growth among other renewable energy technologies (Amoo and Fagbenle, 2013, Karajgi *et al*., 2012, Nwofe 2015).

Plasma Gasification

Plasma gasification represents a clean and efficient option to convert various feed stocks into energy in an environmentally responsible manner. In plasma gasification process, heat nearly as hot as the sun's surface is used to break down the molecular structure of any carbon – containing materials and convert them into product gas that can be used to generate power, liquid fuels or other sustainable sources of energy. Plasma gasification plants are more economical because the plant's inorganic byproduct can be sold to the market as bricks and concrete aggregate. The plants also produce up to 50% more electricity than other gasification technologies (Anyaegbunam, 2013, Khongkrapan *et al*., 2013).

"5Rs" Concept

The "5Rs" model is a useful strategy for efficient and effective management of solid waste (Kenneth peprah *et al*. 2015). 5R represents five different practice for sustainable waste management system.

Reduce - The principle is to reduce the amount of material required to deliver one unit product without sacrificing its utility or quality. The aim of waste reduction is to eliminate waste before it is produced and to reduce both the quantity and toxicity of waste.

Reuse - Reusing of solid waste involves the principle of 'used ones as substitutes' considering solid waste as 'treasure not trash' and 'resource not refuse' (Bhanu and Kumar, 2014).

Recycling - Recycling involves separating different components of waste and reprocessing them into new products (Pappu *et al*., 2007).

Recovery - Recovery is a means of recovering energy or materials, without any pre-processing, from wastes that cannot be used for something else.

Residual management- Residual management is the final treatment and/or disposal of a waste that cannot be used in any other way. Within Canterbury residual management of solid waste is normally disposal within a landfill.

Public Private Partnership (PPP)

Solid waste management offers many opportunities for private sector participation. Small-scale service providers offer several advantages, including low-cost, labor-intensive approaches and greater community participation, which encourages better collection and source separation (Hoornweg and Giannelli, 2007). The engineered disposal facility is proposed to be developed on PPP model. The scientific disposal of the municipal waste will mitigate the environmental hazards associated with open dumping (Bharti *et al*., 2014, Das and Bhattacharyya, 2013).

Gap Filling Technology

The biodrying is a relatively new sustainable technology for MSW treatment, which is successfully implemented in many developed countries, which seem to reduce the socio-economic limitations of the existing technology. Biodrying process is an aerobic convective evaporation process which reduces the moisture content of the waste, with minimum aerobic degradation. In biodrying process, the moisture content of waste is reduced to about 30 to 45 % and hence sorting and storage issues can be reduced to great extent besides the overloading of landfill can be reduced. The output from biodrying process can recover heat if used in incinerators (Pawels and Tom, 2013).

Rules and Regulations

India is the first country that has made constitutional provisions for protection and improvement of the environment. The central government has enacted various laws to regulate various kinds of waste generated in the country. The Environment Protection Act (EPA), 1986 is the umbrella act that pertains to management of wastes in the country. Ministry of Environment and Forests (MoEF) has enacted rules under EPA that governs the management of all kinds of waste in India (Mane ashish vilas, 2015, Kumar and Pandit 2013, Kumar 2010).

- Municipal solid waste (Management and Handling) Rules, 2000 (Yadav and Devi, 2009)
- Electronic waste (Management and Handling) Rules, 2010
- Biomedical waste (Management and Handling) Rules, 1998
- Hazardous waste (Management and Handling) Rules, 1989 (Dutta *et al*., 2006)
- Plastic waste management Rules, 2011

Conclusion

Sustainable and integrated SWM minimizes resource use and environmental impact. It is conducted in an environmentally conscientious manner that conserves natural resources and recovers waste where appropriate. For all equipment required by the service, including vehicles, machines, and parts, sustainable and integrated SWM encourages the use of indigenous manufacturing capacity. It also provides incentives for waste minimization, recycling, and resource recovery at source or as near to the source as possible. Sustainable and integrated SWM optimizes segregation of recyclable materials at the source of waste generation and encourages the development of markets for recyclable materials in major centers of waste generation, including incentives for increased industrial demand for secondary materials as feedstock. Sustainable and integrated SWM provides economical service delivery and establishes cost-recovery mechanisms for long-term sustainability. So, paradigm shift from conventional waste management practices to Integrated Solid Waste Management (ISWM) is essential for cities in order to effectively manage the waste stream.

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