

Opportunity and Challenges of Municipal Waste Disposal in India

Neeraj Kumar Patel

*Energy Centre Maulana Azad National Technology, Bhopal-
462051, India*

Prashant Baredar

*Energy Centre Maulana Azad National Technology, Bhopal-
462051, India*

Abstract

The collection and treatment of municipal solid waste have become an intense problem due to speed up economic development, fast urbanization, cumulatively increased population and industrialization. Increased attention has been given by the government in recent years to handle this problem in a safe and hygienic manner. The purpose of this paper is to review the collection of municipal solid waste (MSW) and landfill deposition. Unscientific landfills leads to deterioration in air quality, public health, etc. Every landfill is an environment hazard and the dump yards have become breeding grounds for dengue, malaria and water-borne diseases. There are concerns over medical consequences from landfill sites and older incinerators, including cancer, mortality, birth defects and low birth weight. Ozone-depleting substances released from discarded electronic appliances and building materials (e.g. foams), as well as industrial waste practices, contribute to ozone-layer depletion.

Keywords: Landfill, Municipal Solid Waste, Transportation, Incineration

I. INTRODUCTION

Increase in rapid population, economic growth, and city size incessant expanding, municipal solid waste (MSW) is growing more and more, confine a big challenge to the urban living environment and the sustainable development of society. The per capita MSW growth in India ranges from 0.2 to 0.5 kg/day and amount of per capita MSW generated in India is increasing at a rate of 11.33% annually (Pappu et al., 2007; Shekdar, 2009). UNECA (2009) have also reported that with growing urbanization, and continuous increase consumerism the quantities of urban solid waste will continue to increase and also become more intricate. As per census 2011, India has population of over 1.21 billion where 31.2% contains the urban population. Alone urban India generates about 48 million ton of municipal solid waste (MSW) annually which is estimated to increase up to 250 million ton by year 2047. (Sharholi et al., 2007; CPCB, 2000). In these fields, municipal authorities are accountability for waste management that includes collection, segregation, transportation, and dumping of solid waste, however these methods are often unscientific and chaotic and remains one of the chief challenge for the authorities. The management of municipal waste problem is getting more severe due to various reasons like bad land use and infrastructure, poor technical and less financial capacity, lack of enforcement of regulations, poor coordination between authorities, deficient policies and no political priorities (Kumar et al. 2009). Hence, despite the legislations, waste collected by the authorities is deposits in the outer part of the city in an unscientific manner where the waste adversely affects the human health and environment (Mor et al. 2006a,b; Kaur et al., 2015; Chattopadhyay et al., 2009; Contreras et al., 2008). After that landfill gas emissions from conventional solid waste collection in developing countries are also effectively contributing to global climate change (Tan et al., 2014). Traditional land filling is less and less attention for these cities due to its disadvantages of less efficient energy recovery and more greenhouse gas emission in comparison to the popular incineration means to treat the MSW (Han, Long, Li, & Qian, 2010). From another energy saving methods, the need of the waste-to-energy technologies is expected to increase five times in less than 10 years (Pike_Research, 2012). On the other hand, waste incineration can minimize its mass by up to 90%, hence effectively decreases the need of landfills and final disposal. It can also be utilised on to provide more cost-effective waste management regimes by reducing the number of the trips over long distances after the incineration and optimization the MSW collection strategy from the waste generation points to the incineration plants.

II. CATEGORIES OF SOLID WASTE MANAGEMENT OF MUNICIPAL SOLID WASTE

Categories of Solid Waste Management of municipal solid waste is related with the control of generation, storage, collection, transfer and transportation, treatment, and dumping of solid wastes in such a way so that is in accord with the best principles of peoples health, economics, engineering conservation, aesthetics, and other environmental prospectss. In its scope, it consists of all administrative, financial, legal, planning and engineering functions related to the whole spectrum of solution to problems of solid waste thrust upon the society by its inhabitants (Tchobanaglou, et al, 1997). Municipal solid waste can be categorized based on source as shown in table 1.

Table – 1
Solid Waste categories based on source

Source	Typical facilities, activities, or locations where wastes are generated	Types of Solid waste
Agricultural	Field and row crops, orchards, vineyards, dairies, feedlots, farms, etc	Spoiled food wastes, agricultural wastes, rubbish, and hazardous wastes
Industrial	Construction, fabrication, light and heavy manufacturing, refineries, chemical plants, power plants, demolition, etc.	Industrial process wastes, scrap materials, etc.; nonindustrial waste including food waste, rubbish, ashes, demolition and construction wastes, special wastes, and hazardous waste.
Commercial and Institutional	Stores, restaurants, markets, office buildings, hotels, auto repair shops,	Paper, cardboard, plastics, wood, food wastes, glass, metal wastes, ashes, special wastes, etc.
Municipal solid waste	Includes residential, commercial and institutions	Special waste, rubbish, general waste, paper, plastics, metals, food waste, etc.

Source: (Hester, R. E and Harrison, R. M., 2002)

A. Municipal Solid Waste

The name municipal solid waste (MSW) is generally assumed to include all of the waste generated in a society, from the exception of waste generated by municipal services, treatment plants, industrial and agricultural processes (Tchobanoglous, G and Kreith, F., 2002). In the urban prospects the term municipal solid wastes is of special relevance . The term includes to all wastes collected and controlled by the municipality and consists of most diverse categories of wastes. It includes of wastes from several different sources such as, domestic wastes, commercial wastes, institutional wastes and building materials wastes.

B. Types of Municipal Solid Waste

Municipal solid waste is a category of solid waste generated from society, commercial and agricultural operations. This comprises wastes from households, stores, offices, and other non-manufacturing operations. The source of municipal solid waste is shown below in table 2.

Table – 2
The sources of municipal solid waste

Sources	Examples
Residential	Single family homes, duplexes, town houses, apartments
Commercial	Office buildings, shopping malls, warehouses, hotels, airports, restaurants
Institutional	Schools, medical facilities, prisons
Industrial	Packaging of components, office wastes, lunchroom and restroom wastes (but not industrial process wastes)

Source (Tchobanoglous, G and Kreith, F., 2002)

III. MSW GENERATIONS

To make effective MSW management system information regarding the quantity and composition of solid waste is necessary, as combination and quantity of waste is influenced by a number of factors consisting living standards, whether condition, art of living, source of generation and the social economic conditions of the place (Sharholly et al. 2007). Union Territories like Delhi and Pondicherry generate 7012 TPD (ton per day) and 371 TPD of MSW respectively while Chandigarh generates approximately 351 TPD of MSW. An overview of composition of major fractions of solid waste of three UT's is given in fig.1. Chandigarh has 47 sectors and MSW generation rates varies from 2.51 TPD to 5.3 TPD having per capita waste generation rate of 0.382 kg/day. The major composition of MSW generated in city is organic in nature that contributes around 45 to 56% of the total wastes followed by combustibles that account for 21 to 31% and remaining inert (Mor et al., 2013). High fraction of organic waste material indicates high moisture content in the waste samples (average 53.43%).

Table – 3
Municipal solid waste generation rates in deferent cities in India

Sample no.	Name of city	Population (as per 2001 census)	Area (Km ²)	Waste quantity (TPD)	Waste generation rate (kg/ (cap - day))	Compostables (%)	Recyclables (%)	C/N ratio	HCV (Kcal/ kg)	Moisture (%)
1.	Kavaratti	10119	4	3	0.30	46.01	27.20	18.04	2242	25
2.	Shillong	132867	10	45	0.34	62.54	17.27	28.86	2736	63
3.	Shimla	142555	20	39	0.27	43.02	36.04	23.76	2572	60
4.	Agartala	18998	63	77	0.40	58.57	13.08	30.02	2427	60
5.	Gandhinagar	193985	57	44	0.22	34.30	13.20	36.05	698	24
6.	Dhanbad	199258	24	77	0.39	46.93	16.16	18.22	591	50
7.	Pondicherry	220805	19	130	0.59	46.96	24.29	36.86	1846	54
8.	Imphal	221492	34	43	0.19	60.00	18.51	22.34	3706	40
9.	Aizwal	228280	117	57	0.25	54.24	20.97	27.45	3766	43
10.	Jammu	309959	102	215	0.58	51.51	21.08	26.79	1782	40
11.	Dehradun	424674	67	131	0.31	51.37	19.58	25.90	2445	60
12.	Assansol	475439	127	207	0.44	50.33	14.21	14.08	1156	54
13.	Kochi	595375	98	400	0.67	57.34	19.36	18.22	591	50
14.	Raipur	605747	56	184	0.30	51.40	16.31	223.50	1273	29
15.	Bhubaneswar	648032	135	234	0.36	49.81	12.09	20.57	742	59
16.	Tiruvananthapuram	744983	142	171	0.23	72.96	14.36	35.19	2378	60
17.	Chandigarh	808515	114	326	0.40	57.18	10.91	20.52	1408	64
18.	Gurwahati	809895	218	166	0.20	53.69	23.28	17.71	1519	61
19.	Ranchi	847093	224	208	0.25	51.49	9.86	20.23	1060	49
20.	Vijaywada	851282	58	374	0.44	59.43	17.40	33.90	1910	46
21.	Srinagar	898440	341	428	0.48	61.77	17.76	22.46	1204	61
22.	Madurai	928808	52	275	0.30	55.32	17.25	32.69	1813	46
23.	Coimbatore	930882	107	530	0.57	50.06	15.52	45.83	2381	54
24.	Jabalpur	932484	134	216	0.23	58.07	16.61	28.22	2051	35
25.	Amritsar	960862	77	438	0.45	65.02	13.94	30.69	1836	61
26.	Kajkot	967476	105	207	0.21	41.50	11.20	52.56	687	17
27.	Allahabad	975393	71	509	0.52	35.49	19.22	19.00	1180	18
28.	Vishakhapatnam	982904	110	584	0.59	45.96	24.20	41.70	1802	53
29.	Faridabad	1055938	216	448	0.42	42.00	23.31	18.58	1319	34
30.	Meerut	1068772	142	490	0.46	54.54	10.96	19.24	1089	32
31.	Nashik	1077236	269	200	0.19	39.52	25.11	37.20	2762	62
32.	Varanasi	1091918	80	425	0.39	45.18	17.23	19.40	804	44
33.	Jamshedpur	1104713	64	338	0.31	43.36	15.69	19.69	1009	48
34.	Agra	1275135	140	654	0.51	46.38	15.79	21.56	520	28
35.	Vadodara	1306227	240	357	0.27	47.43	14.50	40.34	1781	25
36.	Patna	1366444	107	511	0.37	51.96	12.57	18.62	819	36
37.	Ludhiyana	1398467	159	735	0.53	49.80	19.32	52.17	2559	65
38.	Mumbai	1437354	286	574	0.40	52.44	22.33	21.58	1421	43
39.	Indore	1474968	130	557	0.38	48.97	12.57	29.30	1437	31
40.	Nagpur	2052006	218	504	0.25	47.41	15.53	26.37	2032	41
41.	Lucknow	2185927	310	475	0.22	47.41	15.53	21.41	1557	60
42.	Jaipur	2322575	518	904	0.39	45.50	22.10	43.29	834	21
42.	Surat	2433835	112	1000	0.41	56.87	11.21	42.16	990	51
44.	Pune	2538473	244	1175	0.46	62.44	16.66	35.54	2531	63
45.	Kanpur	2551337	267	1100	0.43	47.52	11.93	27.64	1571	46
46.	Ahmedabad	3520085	191	1302	0.37	40.81	11.05	29.64	1180	32
47.	Hyderabad	3843585	169	2187	0.57	54.20	21.60	25.90	1969	46
48.	Bangalore	4301326	226	1669	0.39	51.84	22.43	35.12	2386	55
49.	Chennai	4343645	174	3036	0.62	41.34	16.34	29.25	2594	47
50.	Kolkata	4572876	187	2653	0.56	50.56	11.48	31.81	1201	46
51.	Delhi	10306452	1483	5922	0.57	54.42	15.52	34.87	1802	49
52.	Greater Mumbai	11978450	437	5320	0.45	62.44	16.66	39.04	1786	54

Source: Status of MSW generation, collection, treatment and disposal in cities (CPCB, 2005)

A. MSW Collection Practices

The area of waste storage and type of waste containers are mainly dependent on frequency and method of solid waste collection. MSW (both inorganic and organic fraction) generated in the city is normally stored in the common bins without any segregation and same type of methods are also followed in other countries (Alam et al. 2008). In the past, MSW was thrown in here and there like “haudies” that were constructed in the back lanes of the residential or commercial areas. However, now Municipal Counselling Committee (MCC) has initiated DtDC, which is also imperative as per direction of MSW Rules, 2000. The private sectors such as RWA also support the DtDC of waste in specific sectors and MCC has been given cycle carts to the each sector for them. Individual waste collectors are also involved and charge a fee of 45 to 60 per month per house for the collection of waste.

These solid waste collectors at initial stage (informally) separation of waste into organics, paper, glass, plastics and metals and then waste is transferred to ‘Collection-cum-transfer stations or Sehaj Safai Kendra’s’ (SSK’s) established over an area of 65 x 45 sq.ft. MCC proposed construction of 132 SSKs in Chandigarh to make it a ‘Bin-free city’ but currently only 31 SSKs are located in different sectors of the city and are operational. SSK’s has storage and separation facility of waste having two types of bins i.e. for MSW and for collecting other waste like horticulture waste. Where SSK’s does not exist at present, collection bins have also

been placed at specified areas for collection of the solid waste. Mechanical street sweeping machine are also in practice for cleaning the streets and the roads.

The collection efficiencies of various states given in figure 1

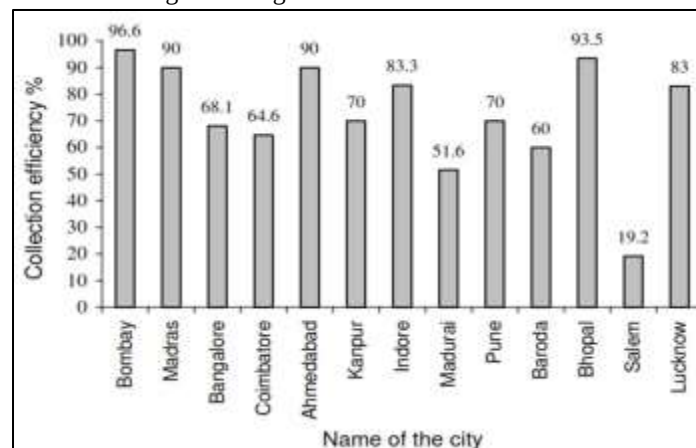


Fig. 1: Collection Efficiencies of various states

Source: Gupta et al., 1998; Khan, 1994; Maudgal, 1995

B. MSW Storage

As detailed in fig.2, around 930 collection bins are placed at several collection points and SSKs having capacity of 4.5 m³ - 6.5 m³. Compared to Chandigarh, majority of the hauled containers in Delhi have the capacity of 1 to 4 m³ (Talyan et al. 2008). According MSW legislations containers should be made of light recyclable material should have appropriate size, corrosion resistant, durable, strong, and covered ability to resist stray animals. The collection efficiency of solid municipal waste in Chandigarh is approximately 70 to 80%. Although as per MSW legislation MSW should be collected per day but it has been seen that in some areas, solid waste bins are not collected daily. They are collected either after 2 to 4 days or until the bin is overflowed. Municipal solid waste remains at the collection points for longer time and helps for a breeding ground for pests, flies and stray animals and spillages of waste causes pungent smell in the area. Apart from this, different locations in the city mainly the slum areas and surrounding low income sectors the number of waste collection bins are either zero or are less in number leading to littering of solid waste in the surrounding area.

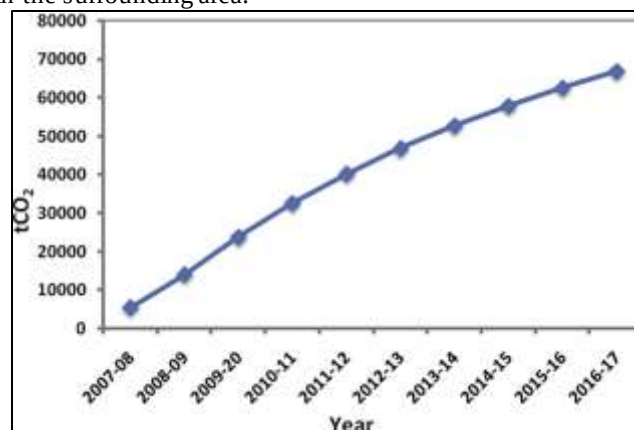


Fig. 2: Annual estimation of emission reductions in tCO₂ through CDM.

C. Transportation of MSW

The municipal solid waste collected from SSK's and other collection centre is transported either to dumping ground or to the processing unit located in outer area of city (Sector-38), Chandigarh. Maximum budget of MCC is available for collection and transportation, where it comprises salaries of human resources, maintenance, fuel and procurement of vehicles (CDPR, 2010), thus, there is a need to critically observe the expenditure on manpower, vehicles and other resources to improve efficiency of solid waste management. Further transportation routes may be improved to save energy and fuel consumption from collection point to landfill site. The horticulture waste is transported using trolleys with carrying capacity of 1.0 to 1.5 T of municipal solid waste and it is densities using the compactor. The dumper placers are also in use which has capacity of 2.5 to 3 T. In Kolkata, on average 310 vehicles are used for waste transportation, where 60% of the vehicles are privately owned. (Chattopadhyay et al. 2009)

D. Disposal of MSW

Kumar et al. (2009) concluded that per day disposal of municipal solid waste is imperative due to the presence of high degradable fraction of municipal solid waste which could cause nuisance. The landfill site situated in Sector 38 is spread over an area of 19.4 ha. Earlier, all types of solid waste consisting, industrial, biomedical, slaughterhouse and municipal solid waste were dumped on this landfill site. The management and handling Rules, 2000, Biomedical Waste (Management and Handling) Rules, 1998, Waste (Management, Handling and Trans-boundary Movement) Rules, 1989 and E-waste (Management and Handling) Rules, 2011] only the inert parts and remains of waste processing (organics) are permitted to dispose off. The solid waste is disposed on the dumping site by the transporting vehicles and reducing the volume with the help of Bulldozer and covered with a soil. The effective micro-organism solution is sprayed on the solid waste before compacting it to prevent pungent smell and helps in breeding of flies and pests. However, landfill site is over 30 years old and has no method of leach ate and proper gas collection systems. Therefore, it has threat to surface and ground water aquifer because of the generation and permeation of leach ate in the soil. This is requirements the periodic monitoring of ground water quality and need to identify remedies to reduce the adverse impact of open landfill site. Emission of landfill gases (LFGs) at the dumping site can be clearly observed causing pungent smell and affecting the health of the workers who working in the vicinity of the landfill site. However no scientific observations for the right quantity of green house gases produced are made to test the concentration of these LFGs.

Per capita generation, disposal and collection efficiency of MSW for Indian state in table 4

Table - 4

Per capita generation, disposal and collection efficiency of MSW for Indian state in table 4

State	Per capita generation (g/cap/day)	Per capita disposal (g/cap/day)	Collection efficiency (%)
India (sample average)	377	273	72
Andhra Pradesh	346	247	74
Bihar	411	242	59
Gujarat	297	182	61
Haryana	326	268	82
Karnataka	292	234	80
Kerala	246	201	82
Madhya Pradesh	229	167	73
Maharashtra	450	322	72
Orissa	301	184	61
Punjab	502	354	71
Rajasthan	516	322	62
Tamil Nadu	294	216	73
Uttar Pradesh	439	341	78
West Bengal	158	117	74

Source: Nema 2004

E. Restoration and Maintenance of Dumping Site

The method for rehabilitating or restoring a landfill into a sustainable dumping site is a systematic activity, which rely on the risk posed by each landfill site and its financial criteria (Rushbrook, 2001). Considering the environmental implications of landfill site MCC has started the conversion of fraction of dumping site into the sanitary landfill and its restoration. Out of 19.45 hec in the starting only 3.2 hec has been converted into sanitary landfill on trial basis. The sanitary landfill is constructing with proper linear system, leach ate collection system and proper gas collection system. By reclaiming area of existing landfill site and the development of a sanitary landfill site would be used for disposal of inert materials and terminates from the processing plants. However, it was seen that the sanitary landfill is not functional and the solid waste is still dumped in the nearby unlined landfill site.

IV. MSW PROCESSING AND MINIMIZATION

Sharholly et al. (2007) concluded that different types of waste treatment technologies like composting, incineration, bio-methanation and pelletisation are being adopted in the country, but their sustainability might be a management issue due to high uncertainty in the solid waste fraction. The present studies have stated that accepting integrating waste treatment technologies like composting with effective source separation for organic fraction, waste recovery or recycling would help for achieving economic, social and environmental benefits (Herva et al., 2014; Dangi et al., 2013; Tan et al., 2014). Chandigarh, does not have a very large scale composting sites or plants but RDF plant is operational since 2008. The plant has the capability to convert 500T of waste daily into RDF and it the first kind of in the north part of India. The treatment of solid waste at plant comprises segregation, homogenization, drying, and the volume and size reduction.

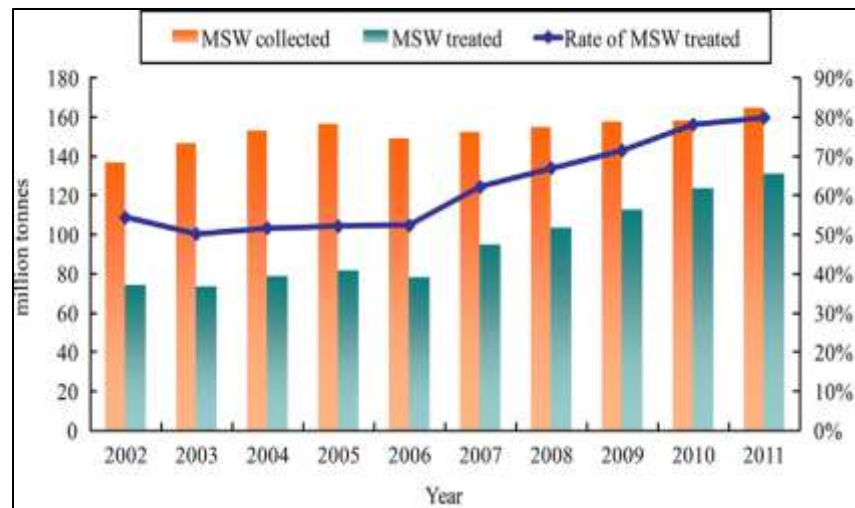


Fig. 3: The situation of MSW management in India from 2002 to 2011.

A. Potential of Carbon Credits under CDM

According to IPCC, (1996) methane emission from the degradation and landfill disposal of solid waste contributes 3 to 19% of the anthropogenic sources in the world. Emission from the MSW can be minimized by following integrated methods like MSW composting, conversion to RDF, bio methanation, collecting landfill gases. Besides, the environmental benefits, the waste sector in India has tremendous potential to earn Carbon Credits under clean development mechanism (CDM). CDM reckoned waste treatment projects help in improving the Carbon Credits leading to sustainable investment. If the total MSW dumped in Chandigarh is deviated from landfill to RDF plant and few options for the treatment of organic fraction of solid municipal waste is available, it would lead to reduction of 5452 tCO₂ emission every year. In the period of ten year; the total reductions will be 66868 tCO₂ as illustrated in Fig. 3 and has potential to earn carbon credits (CDM, 2007).

B. Recycling Potential

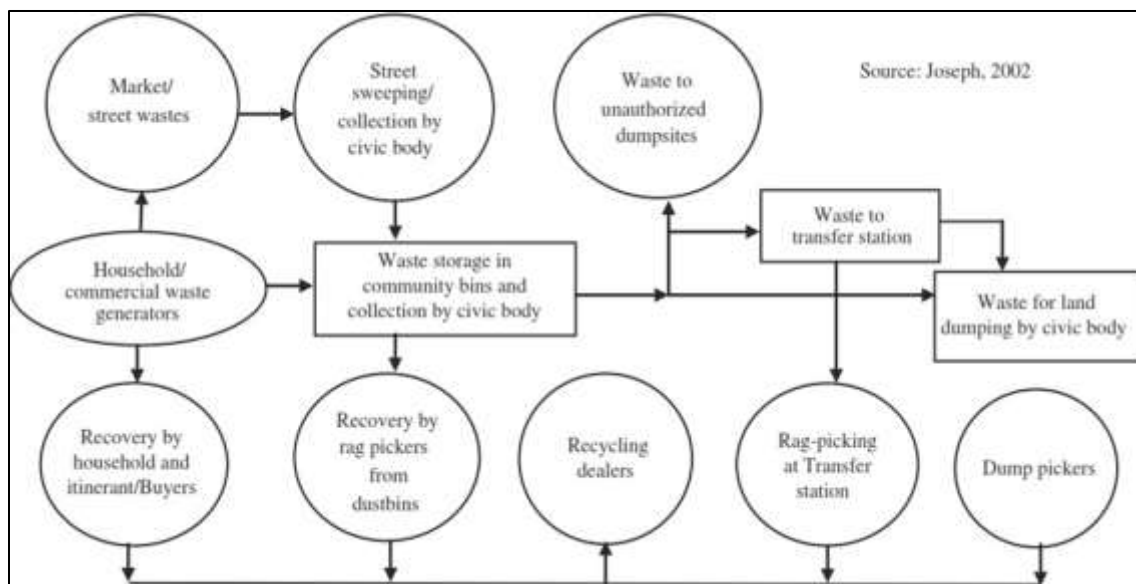


Fig. 4: Schematic flow chart of common MSW management

As explained above that no formal solid waste segregation is practiced in the city by municipal authority, majority of the recyclables present in the MSW are informally collected by the solid waste collectors from the sources where solid waste generated, which they sell to recycling dealers and earn money. Further, rag pickers play a crucial role in the management of solid waste as they are well experienced in segregation of municipal solid wastes. Aggarwal et al. (2005) reported that 17% of recyclables in Delhi are picked up by the rag pickers from different areas of society. The municipal solid waste pickers commonly collect and recover high recycle value items such as paper, glass, leather, plastic, scrap metals by informal activities either from the collection points or from the dumping site. There are almost 100 to 300 rag picker engaged in the Chandigarh city for scavenging the recyclable materials and segregates the useful fraction from waste to earn money. The segregated recyclables are sold to the local dealers who further sell it to recycling units located in Jalandhar and Delhi as there is no recycling unit is

functional in Chandigarh. The common recycling is not given much weightage in the city as the private stakeholders are already working to segregate recyclables from the mixed municipal solid waste fraction at the collection point. However this anfractuosity is tremendously affecting both the sectors where formal segregation is affecting the product of the processing plant and on the other hand processing of recyclables by the plant is affecting the livelihood of so many informal rag picker workers. There is a requirement to generate the optimal scenario that would be able to fulfil the demands of both the sectors. There are no such information are available on the amount of valuable recyclables like cans, high quality plastics, metal, bottles etc. informally collected by the worker of municipal solid waste handlers.

V. MANAGING THE CHALLENGES AND PROSPECTS FOR OTHER CITIES

According to overall assessment, the current study proposes a municipal solid waste management plan for better management in Chandigarh (Fig. 4). Further, below are some recommendations which would be helpful to improve the existing municipal solid waste management practices in the city and could also be adopted by other cities in India and other developing countries. Segregation of municipal solid waste at source leads to subsequent minimization of waste that reaches the landfill site which is situated outskirts of city. It is proposed that municipal solid waste should be segregated at the starting point of source using colour coded bins into different fractions such as combustible, compostable and other fractions as shown in Fig. 4. The community or household side composting should be encouraged for biodegradable fraction (including dry leaves, papers and urban forestry) of municipal solid waste. This will not only minimize the burden to transport large quantity of municipal solid waste but also helps in reducing the carbon emissions in effectively manners. The informal waste handlers or workers collect specific types of wastes such as bottles, plastics and cardboard paper etc. They could be formally part of any type of waste segregation system e.g. by employing them in the RDF processing plant and paying suitable wages according to rule and also provide other facilities like free medical, free training etc.

The physical characteristics of MSW in metro cities are presented in Table 5.

Table - 5

The physical characteristics of MSW in metro cities are presented

Characteristics (% by weight)								
Name of metrocity	Paper	Textile	Leather	Plastic	Metals	Glass	Ash, fine earth and others	Compostable matter
Ahmedabad	6.0	1.0	–	3.0	–	–	50.0	40.00
Banglore	8.0	5.0	–	6.0	3.0	6.0	27.0	45.00
Bhopal	10.0	5.0	2.0	2.0	–	1.0	35.0	45.00
Mumbai	10.0	3.6	0.2	2.0	–	0.2	44.0	40.00
Calcutta	10.0	3.0	1.0	8.0	–	3.0	35.0	40.00
Coimbatore	5.0	9.0	–	1.0	–	–	50.0	35.00
Delhi	6.6	4.0	0.6	1.5	2.5	1.2	51.5	31.78
Hyderabad	7.0	1.7	–	1.3	–	–	50.0	40.00
Indore	5.0	2.0	–	1.0	–	–	49.0	43.00
Jaipur	6.0	2.0	–	1.0	–	2.0	47.0	42.00
Kanpur	5.0	1.0	5.0	1.5	–	–	52.5	40.00
Kochi	4.9	–	–	1.1	–	–	36.0	58.00
Lucknow	4.0	2.0	–	4.0	1.0	–	49.0	40.00
Ludhiana	3.0	5.0	–	3.0	–	–	30.0	40.00
Madras	10.0	5.0	5.0	3.0	–	–	33.0	44.00
Madurai	5.0	1.0	–	3.0	–	–	46.0	45.00
Nagpur	4.5	7.0	1.9	1.25	0.35	1.2	53.4	30.40
Patna	4.0	5.0	2.0	6.0	1.0	2.0	35.0	45.00
Pune	5.0	–	–	5.0	–	10.0	15.0	55.00
Surat	4.0	5.0	–	3.0	–	3.0	45.0	40.00
Vadodara	4.0	–	–	7.0	–	–	49.0	40.00
Varanasi	3.0	4.0	–	10.0	–	–	35.0	48.00
Visakhapatnam	3.0	2.0	–	5.0	–	5.0	50	35.00
Average	5.7	3.5	0.8	3.9	1.9	2.1	40.3	41.80

Source: Status of solid waste generation, collection, treatment and disposal in metro cities, (CPCB, 2000).

VI. PRINCIPLES OF DECOMPOSITION IN A LANDFILL

The word "sanitary landfill" was first introduced in the 1930s to refer to the compacting of solid waste materials. Initially adopted by New York City and, California, the sanitary landfill used heavy earth-moving equipment to compress municipal solid waste materials and then bury them in soil. The practice of burring solid waste was practicing in Greek civilization over more than 2,000 years ago, but the Greeks did it without compacting or reducing the volume of the waste.

Municipal solid waste deposited in landfills in absence of oxygen which decompose by a combination of chemical, biological and physical processes. This type of processes to produce two main by products: biogas and leachate. It is important to say that in Mexico as in many other developing countries, the lack of jobs force many people to manually recycle municipal solid waste. This fact means cardboard, textiles, wood, metal and plastic are removed from MSW, so that, at the end of this recycling process, the organic material content of MSW is over 85 %. Table 6 indicates the typical data on characteristics of leachate reported by

Bagchi (1994), Tchobanoglous et al. (1993) and Oweis and Khera (1990). Data on leachate quality has not been published in India. However, studies conducted by Indian Institute of Technology, Delhi, NEERI, Nagpur, and some State Pollution Control Boards have shown ground water contamination potential beneath sanitary landfills.

Table – 6
Typical Constituents of Leachate from MSW Landfills

Constituent		Range (mg/l)	
Type	Parameter	Minimum	Maximum
Physical	pH	3.7	8.9
	Turbidity	30JTU	500JTU
	Conductivity	480 mho/cm	72500 mho/cm
Inorganic	Total Suspended Solids	2	170900
	Total Dissolved Solids	725	55000
	Chloride	2	11375
	Sulphate	0	1850
	Hardness	300	225000
	Alkalinity	0	20350
	Total Kjeldahl Nitrogen	2	3320
	Sodium	2	6010
	Potassium	0	3200
	Calcium	3	3000
	Magnesium	4	1500
	Lead	0	17.2
	Copper	0	9.0
	Arsenic	0	70.2
	Mercury	0	3.0
	Cyanide	0	6.0
Organic	COD	50	99000
	TOC	0	45000
	Acetone	170	11000
	Benzene	2	410

Source: Bagchi (1994), Tchobanoglous et.al. (1993) and Oweis and Khera (1990). Range of constituents Observed from different landfills

A. Estimation of Landfill Gas Quality and Quantity

The potential volume of landfill gas generation can be estimated to be 200 to 300m³. per tonne of municipal waste. 50 to 75 percent of this gas can be recovered in mixed waste landfills using well-functioning recovery systems. The recovery time is difficult to predict and may vary from 10 to 20 years or even more. The typical constituent of municipal landfill gas is shown below.

Table – 7
Typical Constituents of Municipal Landfill Gas

Constituent	Range (Percentage or Concentration)
Major Constituents	
Methane	30 to 60 %
Carbon Dioxide	34 to 60 %
Nitrogen	1 to 21 %
Oxygen	0.1 to 2 %
Hydrogen Sulphide	0 to 1 %
Carbon Monoxide	0 to 0.2 %
Hydrogen	0 to 0.2 %
Ammonia	0.1 to 1 %
Trace Constituents	
Acetone	0 to 240 ppm
Benzene	0 to 39 ppm
Vinyl Chloride	0 to 44 ppm
Toluene	8 to 280 ppm
Chloroform	0 to 12 ppm
Dichloromethane	1 to 620 ppm
Diethylene Chloride	0 to 20 ppm
Vinyl Acetate	0 to 240 ppm
Trichloroethane	0 to 13 ppm
Perchloroethane	0 to 19 ppm
Others	Variable

Source: CPCB (2008)

Gas outputs of 10 to 20 m³ per hour (corresponding to 60 to 100 KW of energy) have been noted in wells of 16 to 21 cm diameter drilled 11 m into waste at spacing of 31 to 70 m. For 1 MW yield from a landfill site, 15 to 20 such type of wells are required. Recovery of landfill gas from shallow depth landfills is more complicated than from landfill of depths more than 5m.

B. Landfill Gas Management

The gas management strategies must follow one of the following three plans:

- Controlled collection and treatment/reuse
- Controlled passive venting
- Uncontrolled release

For all the MSW landfills, controlled passive venting is recommended. Simply for small (less than 100 tons per day), shallow (less than 5 m deep) and distantly located landfills, should uncontrolled release be approved. Landfill gas tracking will be adopted at all sites and remedial measure (such as flaring) undertaken if the gas concentrations are above acceptable limits.

C. Design of Environmental Monitoring System

The purpose of an environmental monitoring arrangement is -

- To find out whether a landfill is performing as designed.
- To make sure that the landfill is meeting the requirements to the regulatory environmental standards.

Monitoring at a landfill site is performed in four types

- In the unsaturated subsurface zone (vadose zone) beneath and around the landfill.
- On and surrounded by the landfill.
- In the atmosphere/bordering air above and around the landfill.
- In the under groundwater (saturated) zone beneath and around the landfill.

The process of land filling is shown below in figure 5.



Fig 5: Land filling method

VII. COMPOSTING

The organic substance of municipal solid waste (MSW) tends to decompose primary to various smells and odour issues. To make sure a protected disposal of the MSW it is desirable to decrease its pollution potential and numerous processing systems are planned for this purpose. Composting is the decomposition of organic stuff by microorganism in warm moist, aerobic and anaerobic environment. Composting of MSW is, as a result, the most simple and economical technology for operating the organic fraction of MSW (Asnani, 2006).

Composting can be processed in two ways i.e., aerobically and anaerobically. Throughout aerobic composting aerobic microorganisms oxidize organic compounds to Carbon dioxide, Nitrite and Nitrate. In anaerobic process, the anaerobic microorganisms, even as metabolizing the nutrients, break down the organic compounds through a process of reduction. An anaerobic process is a reduction process and the concluding result is subjected to some minor oxidation when applied to land (CPHEEO, 2000).

A. Vermi-Composting

Vermi composting is a scheme for moulding organic waste into nutrient rich soil because it is processed by worms. It can't truly be described as a sort of composting, which is a heat producing procedure that would in fact kill worms; whereas vermin composting should set up environment in which worms can thrive and reproduce. The worms progression organic waste excreting them as organic substance rich, stable, and plant-available nutrients that look like tiny textured soil. It is the natural organic manure formed from the excreta of earthworms fed on systematically semi-decomposed organic waste (Ansani, 2006). Vermi composting amenities have already entered household and manufacturing marketing in countries like Germany, USA, Italy, Japan and Japan. It is now time for India to think about vermin technology commercially (Aalok et al., 2008).

B. Bio-Methanation

The bio methanation is the procedure of alteration of organic matter in wastes to methane and manure by microbial act in the absence of air during the process known as anaerobic digestion. Solid wastes from agro-based system have high organic content and therefore its handling by the method of bio-methanation is the viable as it generates useful products similar to biogas and enriched manure. The bio methanation method is a two stage process consisting of acidification and methanation (CPCB, 2007).

The five MW MSW based power project was established at Lucknow in November 2003, based on fast rate bio methanation technique. Initially it was executed by Asia Bio-energy Ltd, Chennai on BOOM (Build, Own, Operate and Maintenance) foundation. Plant is planned to take care of nearly 500–600 tons of MSW daily from Lucknow City (Axelsson and Kvarnstrom, 2010).

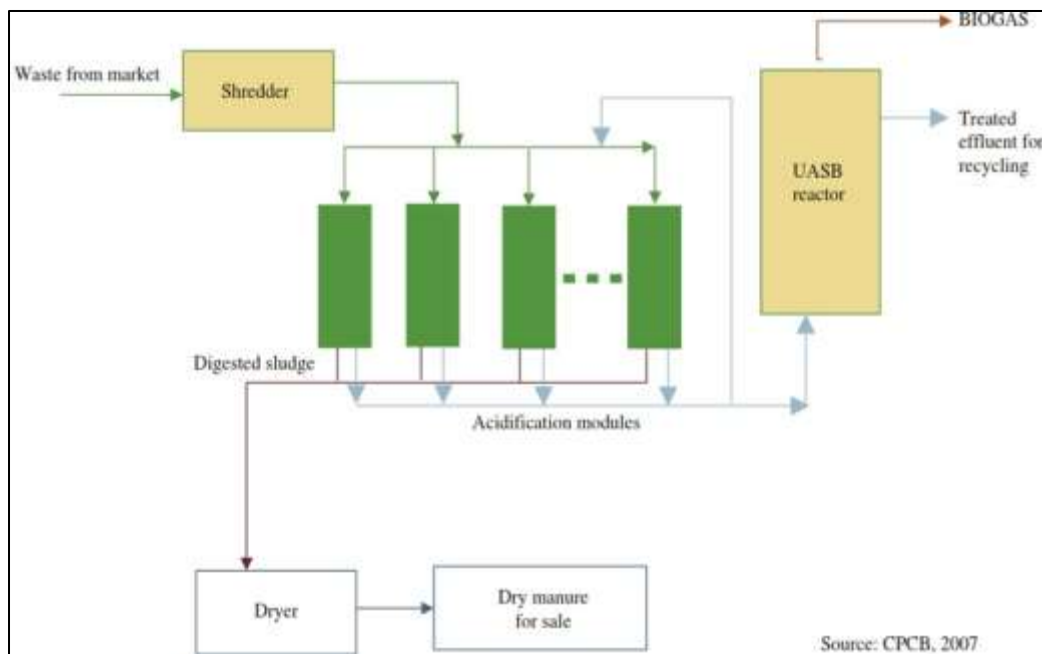


Fig. 6: Acidification and methanation phase

C. Incineration

The incineration processes completed in the presence of air and at the temperature of 850°C and waste are transformed in to carbon dioxide, non-combustible materials and water with solid residue i.e., bottomash (Zaman, 2009; DEFRA, 2007).

Indian cities have, incineration has generally limited to hospital and other biological wastes. It might be due to the high organic material (40%–60%), high moisture content (40%–60%) and little calorific value content (800–1100 kcal/kg) in solid waste (Rajput et al., 2009; Kansal, 2002; Joardar, 2000; Bhide and Shekdar, 1998).

An incinerator has the capability of producing 3.80MW energy from 300 ton per day. MSW was installed at Timarpur, Delhi in the year 1987. It could not function successfully due to low net calorific value of MSW. The plant is lying idle and the investment is wasted (Ansani, 2006).

VIII. CONCLUSION

In this paper, we have discussed waste collection, segregation and transportation problem arising when planning an efficient waste management system. In waste management, we have studied the problem of waste collection and transportation in a city where sources are scattered by heterogeneous way. I have proposed heuristic solution for optimal waste collection and transportation problem. The introduced method computes bonzer municipal solid waste collection and transportation path at each stage. This helps bring down waste collection and transportation costs, which have been rising and have become a main factor for concern for policymakers. This paper is the first to propose such an allocation model that catches on the volume reduction

capability of incineration plants to make for a more cost efficient waste collection regime. The government and local authorities have a necessary role to play by not only building capacities but designing an effective MSW collection policy modified and rearranged to the unique characteristics of the country. Municipal solid waste management in India and in other developing countries are limited to the collection, transport and disposal like other developing countries. Mainly of those countries are grappling with the task of designing an efficient, sustainable politically acceptable and physically realizable solid waste policy, taking into consideration monitored collection, cost effective transportation, treatment costs, dumping tipping fees and as well as environmental issues that will affect the different type disposal methods. This paper revealed an articulate image of the present situation in MSW collection area under the perspective of the citizens and measures that could extricate waste management strategies failures. Awareness, art of living and capacity to differentiate between hazardous and non-hazardous municipal solid waste is comparatively low presenting to local authorities with the challenge to educate citizens and bestrew sustainable measures and exercises aiming to; (a) reinforce environmental sustainability, public health, family care and children safety and (b) exercise the doctrines of waste management: reduction and segregation at the source, reuse, minimize the generation and commitment to participate in recycling schemes. Finally, the study concluded that the lack of resources such as infrastructure, suitable planning and data, financing and uninteresting leadership, are the key constraint in MSWM. The raising of service stress combined with the lack of funds for municipalities are putting a huge damage on the existing MSWM process.

REFERENCES

- [1] Aggarwal, A., Singhmar, A., Kulshrestha, M., Mittal, A.K., 2005. Municipal solid waste recycling and associated markets in Delhi, India. *Resour. Conserv. Recycl.* 44 (1), 73e90.
- [2] Alam, R., Chowdhury, M.A.I., Hasan, G.M.J., Karanjit, B., Shrestha, L.R., 2008. Generation, storage, collection and transportation of municipal solid waste a case study in the city of Kathmandu, capital of Nepal. *Waste Manag.* 28, 1088e1097. CPCC, 2013. Chandigarh Pollution Control Committee Report. http://chandigarh.gov.in/dept_cpcc.htm.
- [3] Central Pollution Control Board (CPCB), 2000. Status of Municipal Solid Waste Generation, Collection Treatment, and Disposal in Class 1 Cities.
- [4] Central Pollution Control Board, Ministry of Environment and Forests, Government of India, New Delhi.
- [5] CDM, 2007. Clean Development Mechanism Simplified Project Design Document for Small-scale Project Activities. CDM: UNFCCC. CDPR, City Development Plan Report of 'Chandigarh', 2010. Chandigarh Administration. Jawahar Lal Nehru Urban Renewable Mission. Ministry of Urban Development, GOI, pp. 50e110.
- [6] Chattopadhyay, S., Dutta, A., Ray, S., 2009. Municipal solid waste management in Kolkata, India a review. *Waste Manag.* 29, 1449e1458.
- [7] Contreras, F., Hanaki, K., Aramaki, T., Connors, S., 2008. Application of analytical hierarchy process to analyze stakeholders preferences for municipal solid waste management plans, Boston, USA. *Resour. Conserv. Recycl.* 52, 979e991.
- [8] Dangi, M.B., Urynowicz, M.A., Belbase, S., 2013. Characterization, generation, and management of household solid waste in Tulsipur, Nepal. *Habitat Int.* 40, 65e72.
- [9] Nema, A.K., 2004. Collection and transport of municipal solid waste. In: *Training Program on Solid Waste Management*. Springer, Delhi, India.
- [10] Lund Herbert, F. "The Mac Graw Hill Recycling Handbook" Mac Graw Hill, USA, 1993
- [11] Miller and Rupnow "Survey on Landfill Methane Recovery" Future Technology Surveys, Inc. USA, 1992
- [12] Tchobanoglous, Theisen and Vigil, "Integrated Solid Waste Management" Mac Graw Hill, USA, 199.
- [13] Zhang Yazun, Zhang Lei, Zhang Fan, "The present status of treatment for municipal solid wastes and its development trend", *AUGU OF EMCC*, vol. 17, pp. 9-11, 2007.
- [14] Yang Hongyi, Lu Yingfang, "The Treatment and Disposal of MSW", Beijing: China Environmental Science Press, 2006, pp.75-75.
- [15] USEPA, "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2003", 2005.
- [16] Rathi, S., 2006. Alternative approaches for better municipal solid waste management in Mumbai, India. *Journal of Waste Management* 26 (10), 1192-1200.
- [17] Zhang ZY, "Study on compressibility and settlement of landfill for municipal solid waste," Ph. D. Thesis. 2005, Zhejiang University, China.
- [18] Shannigrahi, A.S., Chatterjee, N., Olaniya, M.S., 1997. Physico-chemical characteristics of municipal solid wastes in mega city. *Indian Journal of Environmental Protection* 17 (7), 527-529.
- [19] G. F. Lee and R. A. Jones, "Municipal Solid Waste Management: Long-Term Public Health and Environmental Protection," in *NWWA National Outdoor Action Conference on Landfills and Groundwater Quality*, Las Vegas, Nevada, 1991.
- [20] Reddy, S., Galab, S., 1998. An Integrated Economic and Environmental Assessment of Solid Waste Management in India - the Case of Hyderabad, India.
- [21] Sharholi, M., Ahmad, K., Mahmood, G., Trivedi, R.C., 2005. Analysis of municipal solid waste management systems in Delhi - a review. In: *Book of Proceedings for the second International Congress of Chemistry and Environment*, Indore, India, pp. 773777.
- [22] Kansal, A., 2002. Solid waste management strategies for India. *Indian Journal of Environmental Protection* 22 (4), 444-448.
- [23] C. Ofori-Boateng, K. T. Lee and M. Mensah, "The prospects of electricity generation from municipal solid waste (MSW) in Ghana: A better waste management option," *Journal of Fuel Processing Technology*, vol. 110, pp. 94-102, 2013.
- [24] Ketibuah, E., Asase, M., Yussif, S., Mensah, M. Y., Fischer, K., 2004. Comparative analysis of household waste in the cities of Stuttgart and Kumasi - Options of waste recycling and treatment in Kumasi. In: *Proceedings of the 19th International CODATA Conference Berlin, Germany*, 7-10 November.
- [25] Ranjith, K.A., 2012. Sustainable solid waste management in India, A thesis submitted to the Department of Earth and Environmental Engineering, in partial fulfillment of the requirement for the degree of MSc in Earth Resource Engineering, Fu Foundation School of Engineering and Applied Science, Columbia University.
- [26] Amponsah, S.K., Salhi, S., 2004. The investigation of a class of capacitated arc routing problems: the collection of garbage in developing countries. *Waste Manage.* 24 (7), 711-721.
- [27] Rada, E.C., Grigoriu, M., Ragazzi, M., Fedrizzi, P., 2010. Web oriented technologies and equipments for MSW collection. In: *Proceedings of International Conference Risk Management, Assessment and Mitigation - RIMA'10*, pp. 150-153.
- [28] Rabbani, M., Sadri, H., Rafiei, H., 2014. Vehicle-routing in a multimodal transportation system used in waste collection. In: *IMSS 2014 - 9th International Symposium on Intelligent Manufacturing and Service Systems*, pp. 203-212.
- [29] Srivastava, P.K., Kushreshtha, K., Mohanty, C.S., Pushpangadan, P., Singh, A., 2005. Stakeholder-based SWOT analysis for successful municipal solid waste management in Lucknow, India. *Journal of Waste Management* 25 (5), 531-537.
- [30] Valkenburg, C., Walton, C.W., Thompson, B.L., Gerber, M.A., Jones, S., Stevens, D.J., 2008. Municipal solid waste (MSW) to liquid fuels synthesis, Volume 1: Availability of feedstock and Technol. PNNL 18144, Pacific Northwest National Laboratory, Richland,
- [31] Hiremath RB, Kumar B, Balachandra P, Ravindranath NH, Raghunandan BN. Decentralized renewable energy: scope, relevance and applications in the Indian context. *Energy Sustainable Dev* 2008;13:4.

- [32] Sudha P. Plantation forestry; land availability and bio-mass production potential in Asia. Report submitted to ARPEEC, Sida, Energy Program, AIT, Bangkok; 1996.
- [33] MNRE. Biomass power and cogeneration programme of the Ministry of New and Renewable Energy. Government of India 2013.
- [34] Souza, Samuel Nelson M, Werncke Ivan, Marques Cleber Aimoni, Baricatti Reinaldo A, Santos Reginaldo F, et al. Electric energy micro-production in a rural property using biogas as primary source. *Renewable Sustainable Energy Rev* 2013;28:385–91.
- [35] Singh Y. Waste biomass to energy, environment and waste management, <[www.wealthywaste.com/waste biomass-to-energy](http://www.wealthywaste.com/waste-biomass-to-energy)>; 1 October, 2008.
- [36] Dayal, G., 1994. Solid wastes: sources, implications and management. *Indian Journal of Environmental Protection* 14 (9), 669–677.
- [37] Singh RP, Tyagi VV, Allen T, Ibrahim MH, Kothari R. An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario. *Renew Sustainable Energy Rev* 2011;15:4797–808.
- [38] Intergovernmental Panel on Climate Change (IPCC). Fourth Assessment Report: Climate Change – Working Group III Mitigating Climate Change. Chapter 10: Waste management. Geneva: IPCC; 2007.
- [39] Centre for People and Environment (CPE). Landfill recovery and use in Nigeria: a report prepared for US Environmental Protection Agency. Washington, DC, Ibadan: CPE; 2010.
- [40] Babayemi JO, Dauda KT. Evaluation of solid waste generation, categories and disposal options in developing countries: a case study of Nigeria. *J Appl Sci Environ Manag* 2009;13(3):83–8.
- [41] Adewumi IK, Ogedengbe MO, Adepetu JA, Fabiyi YL. Planning organic fertilizer industries for municipal solid wastes management. *J Appl Sci Res* 2005;1(3): 285–91.
- [42] Ngoc UN, Schnitzer H. Sustainable solutions for solid waste management in Southeast Asian countries. *Waste Management* 2009;29:1982–95.
- [43] Sharifah ASAK, Abidin HZ, Sulaiman MR, Khoo KH, Ali H. Combustion characteristics of Malaysian municipal solid waste and predictions of air flow in a rotary kiln incinerator. *Journal of Material Cycles and Waste Management* 2008;10:116–23.
- [44] Sharifah ASAK, Sulaiman MR, Ibrahim R, Husain M. Municipal solid waste treatment in selected Malaysian islands. In: *Proceedings of seminar on appropriate waste management for establishing zero discharge system*. Kyoto: Japan; 2002.
- [45] Periathamby A, Hamid FS, Khidzir K. Evolution of solid waste management in Malaysia: impacts and implications of the solid waste bill. *Journal of Materials Cycles and Waste Management* 2007;11:96–103.
- [46] Ambulkar, A.R., Shekdar, A.V., 2004. Prospects of biomethanation technology in Indian context: a pragmatic approach. *Journal of Resources, Conservation and Recycling* 40 (2), 111–128.
- [47] UNEP. Municipal solid waste: is it garbage or gold? Available at: http://www.unep.org/pdf/UNEP_GEAS_oct_2013.pdf.