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REVIEW PAPER

Urban solid waste management in the developing world with emphasis on India: challenges and opportunities

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Abstract Management of municipal solid waste is a global problem and is faced by all developing countries. The rapid pace of increase in population, economic growth, urbanization and industrialization is coupled with accelerated solid waste generation. In most of the developing countries wastes are either scattered in urban centers or disposed off unplanned in low lying areas or open dumps. The lack of infrastructure for collection, transportation, treatment and disposal of solid waste, proper solid waste management planning, insufficient financial resources, technical expertise and public attitude have made the situation exasperating due to which several environmental and health related problems are increasing. Though, there are many negative issues related to solid waste, it also provides many opportunities that not only mitigates its negative impact but also helps in meeting the demand for energy and employment generation as well as in soil health improvement. Keeping in mind the present situation the current review was planned with the objective to overlook the challenges and opportunities faced during urban solid waste management in developing countries like India.

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1 Introduction

The generation of solid waste is an important byproduct of socio-economic activities. The definition of solid waste varies among countries. Generally, waste generated from industrial sector, commercial, domestic, institutional and municipal services are included in municipal solid waste (MSW). The ever rising population, along with rapid urbanization and industrialization directly affects the amount of urban and MSW generated (Singh and Sharma 2002; Minghua et al. 2009). Presently, waste is generated faster than other environmental pollutants, including greenhouse gases (GHGs) (Hoornweg et al. 2013). Being the world's second most populous country the level of urbanization in India, has increased from 27.81 % in 2001 to 31.16 % in 2011. The ever rising population is putting immense pressure on demand for food, shelter and on other natural resources (Manser and Keeling 1996; Cointreau 2006a, b; Kathiravale and Muhd Yunus 2008).

Municipal solid waste management (MSWM) is one of the most overlooked basic services provided by the Government of India. Generation and characteristics of MSW may vary at the level of country, state, city as well as within different areas of the same city.

MSW generation rates range between 0.3 and 0.6 kg/capita/day in Indian cities and annual increase in MSW generation (volume) is estimated as 1.33 % per capita (Pattnaik and Reddy 2010). Municipalities, usually responsible for managing MSW in developing countries like India are facing a challenge in providing an effective and dynamic system to the society. They usually fail to attain this due to lack of appropriate collection system, lack of technical expertise and insufficient financial resources (Sujauddin et al. 2008; Guerrero et al. 2013). The municipalities use major chunk of their financial resources on MSW collection (primary and secondary) from different locations in municipal areas and very little is left thereafter for its management (Collivignarelli et al. 2004). In developing countries, the cities barely spend 0.5 % of their per capita gross national productivity (GNP) on services for managing MSW (What a waste 1999). Moreover, political, legal, socio-cultural and institutional factors greatly influence MSWM plan.

Rajendiran et al. (2012) have emphasized the involvement and role of a number of government stakeholders like Ministry of Environment and Forest (MoEF), Ministry of Urban Development (MoUD), Ministry of agriculture, Ministry of New and Renewable Energy and Ministry of Non-Conventional Energy Sources (MNES) in MSWM. Besides, the involvement of formal and informal sector could help MSWM (Sharholy et al. 2008). So there is a need of a holistic approach like integrated solid waste management (ISWM) and steeled effort from all dominion of society, otherwise it will continue to adversely affect all three pillars of sustainability viz. social–environmental–economic.

2 An integrated sustainable waste management approach

Integrated solid waste management (ISWM) is one of the most conventionally accepted approaches for MSWM, which allows a conclusive study of the complex and multi-dimensional waste management system in an integrative manner (WASTE 2004). Tchobanoglous et al. (1993) has defined ISWM as “the selection and application of suitable techniques, technologies and management programs to achieve specific waste management goals and objectives.” The ISWM consists of a hierarchy of a coordinated set of actions in which maximum benefits in comparison to cost input, optimal resource utilization, maximum recovery of reusables and recyclables, environmental and health standards, and social acceptability are achieved. Three main dimensions of ISWM, which are interdependent to each other, are stakeholders (including both formal and informal sectors), elements (including technical aspects of SWM) and aspects (including policies and impacts) (Van de Klundert and Anschütz 2001). UN-HABITAT (2009) had identified three key system elements in ISWM viz. public health, environmental protection and resource management. Prior to designing an ISWM plan for a city, the information about geographical location, climatic condition, population distribution, socio-economic status, data on waste generation and its projections over lifetime of proposed plan, physicochemical characteristics of waste, identification of proposed options and their evaluation for the best, assessment of total cost of plan, assessment of finance and revenue sources and its environmental impact such as GHG emissions should be taken into consideration (Hoornweg and Bhada-Tada 2012). So there is a need to design an ISWM system in such a way that it will maintain balance of social, environmental, health, institutional, technical, financial and legal issues in order to provide sustainability to the system (van de Klundert and Anschütz 2001).

Figure 1 gives an overview of integrated solid waste management system.

3 Generation of municipal solid waste

3.1 Global scenario

The rapid pace of urbanization (migration of people from rural to urban areas) and growing economy have greatly accelerated the MSW generation rate in developing countries (Hassan 2000; Minghua et al. 2009; Singh et al. 2011b). Presently, the volume of waste generated from urban centers of the world is around 1,300 million tonnes per year (1.2 kg/capita/day) which is expected to rise to 2,200 million tonnes per year by 2025 (World Bank 2012). The waste generated from South and East Asia represents 33 % of the world’s total quantity (What a waste 1999). It is anticipated that the MSW generation rate in Asia will reach to 1.8 million tonnes/day by 2025 (What a waste 1999). These estimates are still accurate. The level of urbanization (or percentage of urban population) and

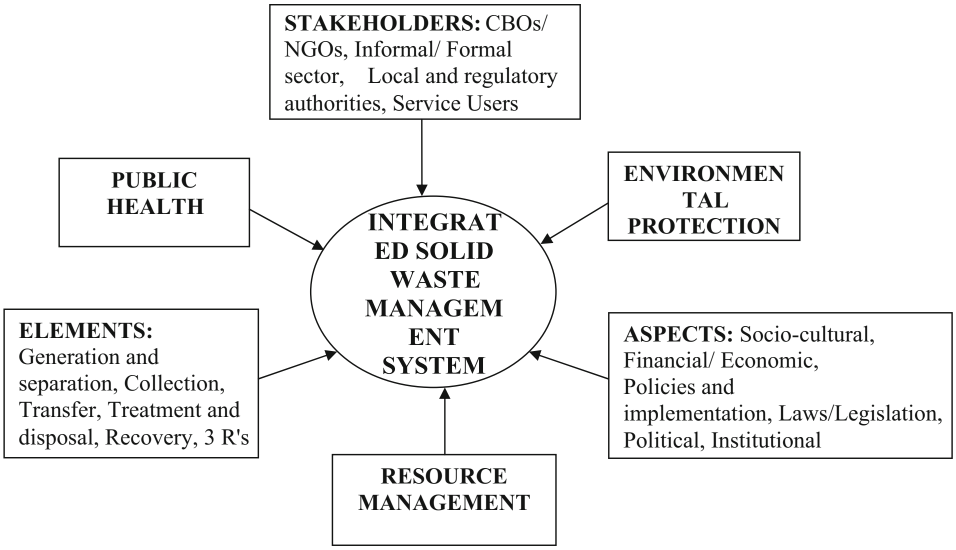

Fig. 1 An Integrated solid waste management system (van de Klundert and Anschütz 2001)

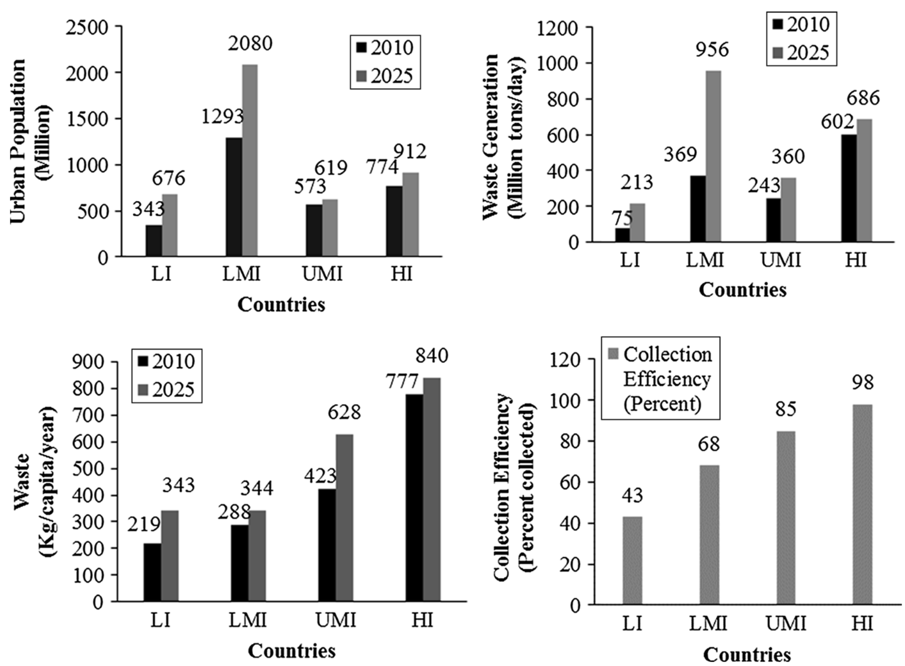

Fig. 2 Urban population, solid waste generation and collection efficiency in different income groups. *LI* low income, *LMI* low middle income, *UMI* upper middle income, *HI* high income

waste generation is the lowest in low income (LI) countries, generating about 219 kg/capita/year in 2010 which is projected to reach to 343 kg/capita/year by 2025 (World Bank 2012) (Fig. 2). The Gross national income (GNI) per capita of a country greatly influences MSW generation rate (What a waste 1999). As we move towards middle income (MI) and high income (HI) economies then we see that with the increase in GNI per capita, the MSW generation per capita also increases. LI economies with low GNI per capita generate less MSW (e.g. Nepal and Bangladesh) in contrast to HI economies which have high GNI per capita and generate large amount of MSW (e.g. Germany, Singapore, Japan etc.). However, the overall waste generation is higher in low middle income (LMI) group than upper middle income (UMI) group (Fig. 2).

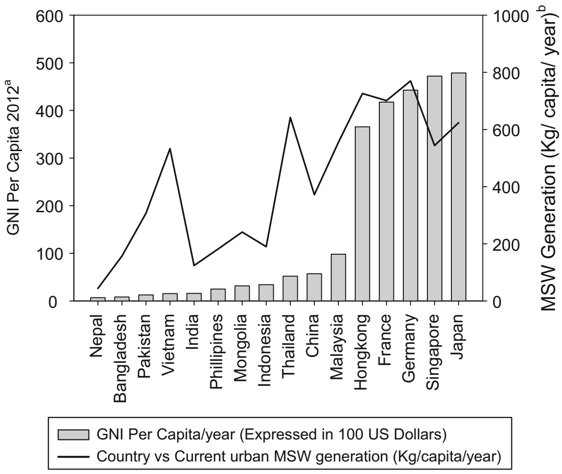

Fig. 3 Relationship between GNI per capita and MSW generation rate. GNI 2012 per capita in US dollars. [a]*Source*: World development indicator database, World Bank (2013). [b]*Source*: Hoornweg and Bhada-Tada (2012)

Table 1 Waste generation rates (kg/capita/day) of selected countries

Countries	Waste generation rates	
	Current	2025
Bangladesh[a]	0.43	0.75
China[a]	1.02	1.70
India[a]	0.34	0.70
Malaysia[a]	1.52	1.90
Nepal[a]	0.12	0.70
Pakistan[a]	0.84	1.05
Phillipines[a]	0.50	0.90
Thailand[a]	1.76	1.95
Vietnam[a]	1.46	1.80

[a] Hoornweg and Bhada-Tada (2012)

This is due to the incorporation of China in LMI group, which accounts for 70 % of the total waste generated in East Asia and the Pacific Region (Hoornweg et al. 2005). Figure 3 shows relationship between GNI per capita and MSW generation rate for different countries.

Collection efficiency largely depends on economic status of a country. In low income countries 80–90 % of total budget for solid waste management (SWM) is spent on collection of waste, yet collection rate is very poor resulting in low collection frequency and efficiency. However, in high income countries, although less than 10 % of total SWM budget is utilized on collection services but still collection frequency and efficiency is very high (more than 90 %) (Hoornweg and Bhada-Tada 2012). A list of per capita MSW generation rate from different countries is shown in Table 1.

As per provisional figures of World Bank (2012), the amount of annual waste generation by the member countries in East Asia and Pacific Region (EAP) is about 270 million tonnes per year (total urban population, TP is 777 million); in OECD (Organization for Economic Co-operation and Development) countries is about 572 million tonnes per year (TP is 729 million); in Middle East and North America (MENA) region is about 63 million tonnes per year (TP is 162 million) and in South Asia region it is about 70 million tonnes per year. (TP is 426 million).

3.2 Indian scenario

India, the second most populous country aiming to attain an industrialized nation status by 2020 has experienced rapid urbanization and industrialization during the last few decades (Sharma and Shah 2005). India has a population of over 1.2 billion which accounts for 17.5 % of the world population (http://censusindia.gov.in). About 31.16 % of the country's population lives in urban areas (Census of India 2011; Sudhir and Gururaja 2012). The continuous population expansion as well as migration from rural to urban areas has resulted in rapid boost in waste generation.

Generally in India MSW is disposed off in low lying areas or open dumps without necessary precautions. Therefore, MSWM is one of the most challenging environmental issues in Indian megacities. In India the current urban MSW production rate is 109,598 tonnes per day (or 0.34 kg/capita/day) and is assumed to reach to 376,639 tonnes per day (or 0.7 kg/capita/day) by 2025 (Hoornweg and Bhada-Tada 2012). The survey of 59 Indian cities, conducted by Central Pollution Control Board (CPCB) (through NEERI) has suggested that about 35,401 tonnes per day MSW was generated from 59 cities during 2004–2005. Thereafter, a survey conducted by the Central Institute of Plastic Engineering and Technology (CIPET) has reported that about 50,592 tonnes per day MSW was generated during 2010–2011 in the same 59 cities. MSW generation in selected Indian cities during 2004–2005 and 2010–2011 is given in Table 2.

Table 2 Municipal solid waste generation in Indian cities (CPCB 2012)

City	Municipal solid waste generation (tonnes per day)	
	2004–2005[a]	2010–2011[b]
Ahmedabad	1,302	2,300
Bangalore	1,699	3,700
Bhopal	574	350
Bhubaneswar	234	400
Chandigarh	326	264
Chennai	3,036	4,500
Dehradun	131	220
Delhi	5,922	6,800
Guwahati	166	204
Indore	557	720
Jammu	215	300
Kanpur	1,100	1,600
Kolkata	2,653	3,670
Lucknow	475	1,200
Mumbai	5,320	6,500
Patna	511	220
Pune	1,175	1,300
Shillong	45	97
Srinagar	428	550
Varanasi	425	450

[a] NEERI, Nagpur (2004–2005)

[b] CIPET (2010–2011)

In India, although more than 90 % of municipality's total budget is spent on collection of waste, yet collection efficiency is very poor about 70–72 % (Nema 2004; CPCB 2012).

4 Composition of municipal solid waste

The composition and characteristics of MSW is greatly influenced by the economic status, living standards, food habits, rituals, literacy rate, type of energy source, climatic and topographical conditions (Jin et al. 2006). A reliable data about generation and composition of solid waste generated is essential for appropriate planning of waste management system (Idris et al. 2004). The economic status of a country is reflected in MSW composition produced. In high income countries the fraction of organic waste is comparatively low as compare to the low income countries (e.g. In Georgia organic waste accounts 39 % of the total MSW which is 62 % in Indonesia (Hoornweg and Bhada-Tada 2012). Apart from that in low and middle income country the waste generated has high moisture content and density. In Europe, MSW composition is different from Asia, comprising household and commercial waste as well as waste generated from public building areas (Eurostat 2003). It does not include sewage sludge and fecal material which is included in Asia. On the other side in Asia, along with waste generated from human settlements and industries, sometimes gets also contaminated with hospital waste due to negligence and unscientific waste management practices leading to more hazardous potential than European cities (Singh et al. 2011a). The relative composition of MSW from low, middle and high income countries is shown in Table 3. It suggests that composition of MSW in low income country is attributed by high percentage of organic matter (40–85 %), high moisture content (40–80 %), high density (250–500 kg/m^3) and low calorific value (CV) (800–1,100 kcal/kg) whereas, high income countries show comparatively low organic matter (20–30 %), low moisture content (5–20 %), low density (100–170 kg/m^3) and high CV (1,500–2,700 kcal/kg). The composition of waste generated in different developing Asian countries is given in Table 4. The organic material accounts for major fraction of waste. The highest amount of organic material was noticed in Indonesia (74 %), which was followed by Kathmandu, Nepal (67.8 %) and China (59 %). Similarly, the composition of waste generated in some selected Indian cities is given in Table 5. Due to continuous increase in level of urbanization and industrialization Indian cities now generate eight times more waste than they generated in 1947 (Sharholy et al. 2008). The characteristics of waste in India show great variation in respect to composition and hazardous nature, when compared to western part of the world (Gupta et al. 1998; Sharholy et al. 2008). The organic waste contributes as major fraction in all cases. The highest amount of organic waste was reported in Mumbai (62 %), which was followed by Chandigarh (57 %). Besides this, moisture content was also high in all cases (except Ahmedabad) ranging between 41 and 64 %. The CV is very low ranging between 742 and 2,632 kcal/kg and the C/N ratio ranging between 18 and 37.

5 Threats

Disposal of solid waste without proper treatment imposes negative effect on different components of environment (soil, water and air), human health and aesthetic value.

5.1 Health impacts

Due to continuous increase in solid waste generation, its ever-changing composition, mismanagement and poor public attitude, people are directly exposed to health risks. According to Giusti (2009), there is direct and indirect association of health impacts with each step of the handling, treatment and disposal methods of waste. In developing countries, the poor attitude of waste generators has made the situation exasperating. They commonly throw their wastes on the roads, which is further scattered by rag pickers in search of recyclables, and animals (cows, dogs, pigs, etc.) looking for food. Hence, waste generated by them clog the drains, creating stagnant water condition which is favorable for insects and mosquitoes breeding responsible for malaria, lymphatic filariasis and other diseases, thus posing risks to human health (Castro et al. 2010). Alvarado-Esquivel (2013) has reported that rag pickers are more vulnerable to toxocariasis. Moreover, open burning, illegal transfer of biomedical and other hazardous waste to dumping site leads to ground water as well as air pollution and other health problems (Kathiravale and Muhd Yunus 2008). Many reviewers have emphasized the correlation between exposure to landfill sites and ill health. People residing or working nearby landfill sites have been reported to have high risk of congenital birth defects, cancers and respiratory illness (Sever 1997; Johnson 1997, 1999; Ray et al. 2005). However, according to the World Health Organization (WHO 2000, 2007), the evidence that links waste landfills and incinerators to health problem particularly cancer, reproductive outcomes and mortality is inadequate. Nevertheless, this is supported by findings of Ray et al. (2005, 2009), who has reported the impairment of lung function of landfill workers of Okhla landfill site, Delhi by 62 % as compared to 27 % of the controls which are of the same age, sex and socio-economic conditions. The landfill workers are more susceptible to tissue damage and cardiovascular diseases due to activation of

Table 3 Relative composition for low, middle and high income country (INTOSA 2002; Cointreau 2006a, b)

Parameters	Low income country	Middle income country	High income country
Organic	40–85	20–65	20–30
Paper	1–10	15–30	15–40
Plastic	1–5	2–6	2–10
Metal	1–5	1–5	3–13
Glass	1–10	1–10	4–10
Rubber, leather etc.	1–5	1–5	2–10
Other	15–60	15–50	2–10
Moisture content (%)	40–80	40–60	5–20
Density (kg/m^3)	250–500	170–330	100–170
Calorific value (kcal/kg)	800–1,100	1,000–1,300	1,500–2,700

Table 4 Composition of MSW in different developing nations

Country	Year	Organic matter	Paper and paperboard	Plastics	Glass/ceramics	Metal	Textile and others	References
Kathmandu (Nepal)	2007	67.8	6.5	0.3	1.3	4.9	19.2	Dangi et al. (2011)
India	2008	42	6.0	4.0	2.0	2.0	44	Shekdar (2009)
China	2002	59.0	8.0	10	3.0	1.0	19.0	Huang et al. (2006)
Vietnam	NA	49.4	14.7	15.1	9.7	3.4	7.7	Shekdar (2009)
Indonesia	NA	74.0	10	8.0	2.0	2.0	4.0	Shekdar (2009)
Malaysia	2005	44.8	16.0	15.0	3.0	3.3	17.9	Periathamby et al. (2009)
Philippines	NA	41.6	19.5	13.8	2.5	4.8	17.8	Shekdar (2009)

Table 5 Physical composition of MSW in Indian cities

City	Organic (%)	Recyclables (%)	Others (%)	Moisture content (%)	C/N ratio	HCV (kcal/kg)
Ahmadabad	41	12	47	32	30	1,180
Bengaluru	52	22	26	55	35	2,386
Bhopal	52	22	26	43	22	1,421
Bhubaneswar	50	13	37	59	21	742
Chandigarh	57	11	32	64	21	1,408
Chennai	41	16	43	47	29	2,594
Delhi	54	16	30	49	35	1,802
Guwhati	54	23	23	61	18	1,519
Indore	49	13	38	31	29	1,437
Kanpur	48	12	40	46	28	1,571
Kolkata	51	11	38	46	32	1,201
Lucknow	47	16	37	60	21	1,557
Mumbai	62	17	21	54	39	1,786
Nagpur	47	16	37	41	26	2,632
Puducherry	50	24	26	54	37	1,846

Source: Status report on municipal solid waste management, CPCB 2004–2005

leukocyte and platelets as well as airway inflammation (Ray et al. 2009).

5.2 Environmental impacts

Each and every kind of waste generated needs to be managed in an appropriate manner. In India, the landfill site selection is done on the basis of convenience without prior consideration of environmental impact. The mismanaged and unscientific disposal of waste deteriorates the nearby environment causing severe implications on air, soil and water pollution.

5.2.1 Soil

Soil is "a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms" (Brady 1974). Additionally, it also acts as a protecting filtering layer laid over the ground water that mitigates the impact of several harmful pollutants (Venkatesan and Swaminathan 2009). The urbanization and industrialization have increased the burden of MSW on land which is adversely affecting soil properties (both biotic and abiotic) and its yield. This situation is very common in cities of developing countries. Rawat et al. (2009), has reported increased concentration of heavy metals (Mn, Zn, Cu, Cd, Ni, Pb and Cr) in soil and road dust samples from Kanpur city, this might be due to the deposition of dust from industries.

5.2.2 Water

Water is the basic element of life, livelihood, food security and sustainable development. On one side the world is facing fresh water scarcity, on the other hand whatever the remaining ground water resources are available, is facing critical stress in quality due to improper urbanization and industrialization. Besides this, inadequate maintenance of distribution system also pollutes drinking water. Nagarajan et al. (2012) has compared different physic-chemical parameters of ground water quality in Erode city, Tamil Nadu, India with Bureau of Indian Standards (BIS) and World Health Organization standards (WHO), and had observed increased concentration of constituents like total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), sodium (Na^{+}), magnesium (Mg^{2+}), chloride (Cl^{-}), fluoride (F^{-}) and nitrate (NO_3^{-}) above the upper permissible limit for drinking purpose making the water not potable. Moreover, the leachate, a byproduct of organic waste decomposition percolates through the soil and finally pollutes underlying and adjacent aquifers at landfill sites (Mor et al. 2006a, b). This leachate alters the quality of ground water like electrical conductivity (EC), total dissolved solid (TDS), chloride (Cl^-), and sulphate (SO_4^{-2}) etc (Nagarajan et al. 2012). There is therefore a need to consider both the resource availability and threat of underground water contamination prior to designing of a landfill site. Similarly Vasanthi et al. (2008) investigated ground water quality from different wells surrounding Perungudi dumping yard, Chennai found increased concentration of contaminants like TDS, EC, TH, Cl^-, chemical oxygen demand (COD), NO_3^- and SO_4^{2-}. Mor et al. (2006a, b) reported moderately high concentration of Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, phenol, Fe, Zn and COD in ground water samples collected from Gazipur landfill-site and its adjacent areas in Delhi suggested ground water contamination through leachate percolation.

5.2.3 Air

In developing countries MSW is mainly characterized by high density that emulates high degree of biodegradable organic matter and moisture content, which when undergoes anaerobic decomposition in landfills, leading to production of landfill gas. The landfill gas mainly consists of about CH_4 and CO_2 together with small amount of volatile organic compounds and other trace gases (Hegde et al. 2003). Being GHGs both CH_4 and CO_2 have global warming potential, which is 25 times higher in CH_4 than global warming potential of CO_2 with atmospheric residence time of 12 ± 3 years (IPCC 2007). Jha et al. (2008) measured GHG emission from two landfill sites in Chennai, reported that emission flux ranged from 1.0 to 23.5 mg CH_4 m^{-2}/h, 6 to 460 μg N_2O m^{-2}/h and 39 to 906 mg CO_2 m^{-2}/h at Kodungaiyur and 0.9 to 433 mg CH4 m^{-2}/h, 2.7 to 1,200 μg N_2O m^{-2}/h and 12.3 to 964.4 mg CO_2 m^{-2}/h at Perungudi.

Similarly Kumar et al. (2004) assessed methane emission inventory from Okhala dumping site, Delhi reported the total gas generated in the time span of 8 years from 1994 to 2001 is 102.006 Gigagram (Gg), for which total waste (excluding inert) deposited in the landfill up till 2001 is taken (i.e. 3,311.867 Gg). About 604.5 Gg of CH_4 emissions have been reported from Indian landfills in 2007 (INCCA 2010). However, there is great uncertainty about quantity of landfill gas emission due to lack of available data.

6 Existing waste management practices

6.1 Waste to energy

6.1.1 Incineration

Incineration is a thermal waste management process. In incineration combustion of raw or unprocessed waste takes place under controlled condition at 850 °C in the presence of air (DEFRA 2007). It takes place in an enclosed structure. The byproducts are carbon dioxide, sulphur dioxide, carbon monoxide, particulate matter, dioxins, furans, water vapor, ash, heat and non-combustible material. The ash produced is termed as incinerator bottom ash (IBA) which contains residual carbon in little amount. Incineration provides maximum volume reduction of waste but employ second last priority in an ISWM approach due to environmental concerns. It is highly an exothermic process, generating heat which could be utilized in the production of steam and electricity. For high level of efficiency, solid waste should have low moisture content (<50 %) and high heating value (>5 MJ/kg) (Vergara and Tchobanoglous 2012). It is more popular in developed countries as compared to developing countries (DC) because DCs generate large amount of organic waste with high moisture content and low CV. In India, the first incineration plant was installed in Timarpur, Delhi in 1987, but was shut down just few months after installation. Because in India, waste generated is not suitable for incineration due to high moisture content (around 50 %) and low CV (3,350–4,200 kJ/kg) (Sharholy 2005; Sharholy et al. 2008). However, in many cities small incinerator plants are running for burning biomedical waste. The installed capacity of incineration plant in India is about 83 MW (Jain and Sharma 2011). In India, due to high organic matter (40–60 %), high moisture content (40–60 %) and low CV (800–1,100 kcal/kg) in MSW, incineration is not successful technique. Another plant was constructed at BARC (near Mumbai) for burning only institutional waste (Lal 1996; Sharholy 2005).

However, the potential inimical effect of waste incinerators on human health is always being a matter of concern. Elliott et al. (1996) reported that the people residing in the close vicinity of municipal incinerators are more prone towards liver cancer in Great Britain. Figure 4 shows existing MSWM system in India.

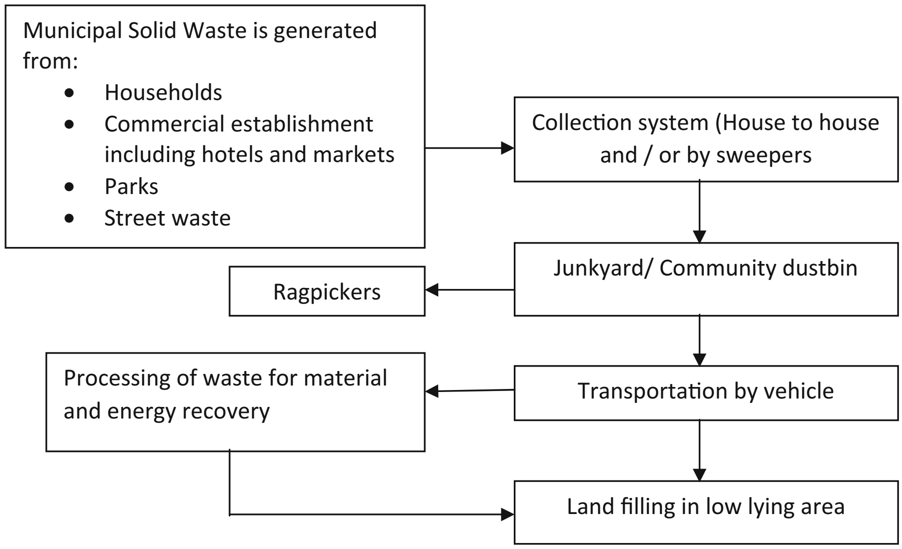

Fig. 4 The flow chart of existing municipal solid waste management system in India (Singh et al. 2011a)

6.1.2 Pyrolysis and gasification

This option converts waste to energy by combusting solid waste in oxygen deficient condition. Both pyrolysis and gasification are endothermic process. Pyrolysis is thermal degradation of organic matter under pressure and temperature ranges between 400 and 1,000 °C in absence of oxygen. Gasification is the partial combustion of organic matter at temperature ranges between 1,000 and 1,400 °C in less amount of oxygen or air (NSCA 2002). In both the processes the end products are gas (termed as syngas), liquid (containing acetic acid, acetone and methanol) and char (containing carbon with inert material). Syngas is the end product of both the processes, mainly composed of carbon monoxide, methane and hydrogen, with lesser amount of carbon dioxide, nitrogen and hydrocarbons (Bridgwater 1994). Syngas can be burned as a fuel after cleaning and used in internal combustion engine generator sets or turbine to produce electricity (MoEF 2010) and char can be used as fuel or soil conditioner as used by Amazonian indigenous people. There are two different designs of gasifiers exist in India. The first one (NERIFIER gasification unit) is installed at Nohar, Hanungarh, Rajasthan by Narvreet Energy Research and Information (NERI) which is mainly used for combustion of agro-wastes. It has waste processing rate of about 50–150 kg/h with efficiency of 70–80 %. The fuel gas generated is utilized for power generation and around 25 % of the fuel gas produced may be recycled back into the system in order to support the gasification process. The second unit is installed in The Energy Research Institute (TERI) (CPCB 2004; Sharholy et al. 2008). Recently, the plasma arc gasification plant was established in Pune in 2010, which process about 70 tons of waste. The Plant was designed to produce 2.4 MW, but instead produced 1.7 MW. Despite this shortfall in the performance it is a very promising technology for energy generation from waste. The main limitation for success of gasification plant in India is high moisture content and low CV of Indian waste.

6.2 Composting

Composting is referred as the process of aerobic biological decomposition of organic material under controlled conditions like temperature, humidity and pH. The indigenous microorganisms (thermophile and mesophile) mold organic material to a stabilized product i.e. compost (Hashemimajd et al. 2004). The compost thus produced acts as soil conditioner and can be used in agricultural and horticultural or landscaping applications (Singh et al. 2011a; Neher et al. 2013). The quality of compost from MSW depends on many factors like source and nature of waste, the composting design, maturation length and composting procedures which have been followed during composting (Hargreaves et al. 2008).

Hashemimajd et al. (2004) described composting as "batch" process due to successive involvement of microorganism during decomposition process. It involves thermophilic phase earlier in which sanitization is achieved due to rise in temperature (45–65 °C) (Dominguez et al. 1997). In mesophilic phase, also considered as maturation phase the remaining organic compounds slowly degrade. In developing countries, over 60 % of MSW is organic in nature, has high moisture content and compost is traditionally used in improving soil quality but the present mindset has changed due to contamination of MSW with hazardous wastes (pesticides, paints, batteries, fluorescent light etc.) that impose negative effect (Jain and Sharma 2011). Overall it is a good option which helps in recycling of plant nutrients like C, N, P, K back to the soil, if proper segregation practices are enforced. Besides this it reduces the amount of waste finally reaching to the landfill site thus extending their life span (Singh et al. 2011a) and ultimately helps in decreasing the demand of land for land filling and fuel consumption required for transportation of waste to landfill site. Thus composting could be considered as an eco-friendly and sustainable approach.

Composting of MSW is one of the most promising and cost effective option for MSWM. It was encouraged earlier 1960s by the Government of India (GOI) which was blocked in 4th 5 year plan (1969–1974). In 1974, GOI launched a modified scheme to revive MSW composting once again, particularly in cities with a population greater than 0.3 million. In India, composting of MSW is taking place in large scale as well as at decentralized level. The first large scale composting plant was established in Mumbai which process 500 tonnes/day of MSW by Excel Industries Ltd. Another plant has been operated in Vijaywada which handle 150 tonnes/day. About 9 % of MSW is treated by composting (Kansal 2002; Sharholy 2006; Sharholy et al. 2008). About 700 tonnes/day of MSW is composted by Kolkata Municipal Corporation (KMC) in collaboration with M/S Eastern Organic Fertilizers (India) Private Limited. The selling price of end MSW compost is 3.50 INR (Chattopadhyay 2003, 2009).

6.3 Vermicomposting

Vermicomposting is an eco-friendly, eco-biotechnological and bio-oxidative process which stabilizes organic solid waste into valuable bio-product, i.e. vermicompost. It involves inter-mutual action of earthworms and microorganisms. In addition to the feedstock, the microbial biomass present in the earthworm's gut is also responsible for the biochemical decomposition of organic matter. Earthworms act as important mediators which increase accessible surface area to microorganisms, thereby improving enzymatic actions and responsible for alteration of physical status of organic waste directly and chemical status indirectly (Malley et al. 2006; Fornes et al. 2012). Besides this the faecal matter produced by earthworms provides suitable organic substrate to colonize surrounding microbes supporting microbial growth and action (Williams et al. 2006). It has been reported that pre-composting is requisite in order to prevent earthworm mortality in vermicomposting (Kaushik and Garg 2003). The mineralization and maturation of vermicompost is denoted by substantial decrease in C/N ratio, volatile solids (VS), aliphatic, lignocellulosic, protein and carbohydrate contents whereas increase in humic acid, aromaticity and acid phosphatase activity (Sen and Chandra 2007; Lv et al. 2013). Thus the vermicast produced is rich in C, N, P, K, content, enzymatic activity and also inhibit plant pathogens (Pramanik et al. 2007; Yasir et al. 2009; Bhattacharya et al. 2012). Humic acids contain carboxyl and phenolate functional groups, which have an excellent chelating property and form complex with heavy metals particularly Cu and Zn (Hsu and Lo 2000; Kang et al. 2011). Previous study by Suthar (2008) reported that earthworm's excretory products, mucus, body fluids; enzymes play a considerable part in improving nitrogen level of vermicompost. Many workers have emphasized on earthworm's ability to accumulate heavy metals and demonstrated that earthworms accumulate a significant amount of heavy metals like copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in the tissue (Suthar 2008; Suthar and Singh 2009; Yadav and Garg 2009; Hait and Tare 2012). The absorption of heavy metals takes place by epithelial layer of gut from contaminated organic waste; hence bioavailability of heavy metals turns to decrease during vermicomposting (Dominguez and Edwards 2004). Some epigeic earthworms *Eisenia foetida*, *Eudrilus eugeniae*, *Perionyx excavates* and *Perionyx sansibaricus* are generally used for vermicomposting (Oyedele et al. 2005; Suthar 2007, 2009, 2010a, b). Out of which *Eudrilus eugeniae* and

Perionyx excavates are the most efficient earthworm species for vermistabilization of organic stuff in tropical and subtropical condition (Ismail 1993; Kale 1998). Both the composting and vermicomposting are effective in improving soil quality but vermicomposting being the most excellent process to produce superior and larger diversity of bacteria and other purposeful organisms (Ismail 1993; Vivas et al. 2009). Vermicomposting has been used in Hyderabad, Bangalore, Mumbai and Faridabad (Jha et al. 2003; Ghosh 2004).

As earthworms are considered as the biological indicators of soil health (Ismail 1997) thus they have a major role in solid waste management plus soil management. They decrease the stabilization time of household waste and sewage sludge by vermicomposting and turned them into valuable end product i.e. vermicompost that can be further utilized in agricultural and horticultural practices (Kale et al. 1982; Ismail 1993; Edwards and Bohlen 1996; Ismail 2005; Ansari and Ismail 2008), thus improving the productivity and fertility of soil (Edwards et al. 1995).

6.4 Landfilling

Landfill is a vacated land area onto or into which waste is disposed. It is an integral part of any planned MSW management system. They are the final depot of any city's MSW after pertinence of all available management options. Open dumping is the most common, lucid and economical practice implemented in most of the developing countries. In Asia 51 % open dumping takes place among all available management practices (World Bank 2012). Although, in recent years open dumping has dropped its status due to environmental concerns and availability of other engineered techniques like sanitary landfills, pyrolysis, incinerators, etc these are less frequent in developing countries due to economic and technical barriers as well as nature of MSW. In Indian cities an uncontrolled open dumping is a common practice which adversely affects environment and pollute ground water, soil and air (Kansal et al. 1998).The landfill gas produced contains CO_2 (34–60 %) and methane (30–60 %) which being GHGs play an important role in global warming thus deteriorating our environment (CPHEEO, MoUD, GoI, Manual on MSWM 2000). Besides this it creates unhygienic condition in surrounding environment negatively affecting human health. Therefore a well-planned, administered and managed MSWM system is required for safe and efficient working of landfills. It can be subdivided into three main categories, which are discussed below.

6.4.1 Open dumps or open landfills

This is the most common unscientific, non-engineered MSWM approach in developing countries. In open dumping, wastes are casually disposed off in low lying areas in an unacceptable manner without any discrimination resulting in environmental, health and aesthetic hazards. In Indian cities more than 90 % of MSW is directly disposed off on open lands without any pretreatment (Sharholy et al. 2008; Narayana 2009). Uncontrolled and poorly administered dumping results in heaps of wastes onto the dumping sites, which is susceptive to open burning, thus emitting toxic gases directly affecting the environment and life. Landfills provide a suitable breeding ground for many disease causing vectors, rodents, fleas and mosquitoes (Anon 2001; Suchitra 2007). Besides this it also has the ability for producing leachate which contaminates ground water thus creating an unhygienic condition and is vulnerable to health (Mor et al. 2006a, b). Joseph et al. (2003) described that about 70–90 % of landfills operating in India are open dumps.

6.4.2 Semi-controlled or operated landfills

It is almost similar to that of open landfills which are inefficacious and non-devised to combat against the leachate discharge and uncontrolled landfill gas emissions. But in operated landfills regularly a topsoil covering is provided in order to prevent direct exposure of harmful waste to the surrounding environment.

6.4.3 Sanitary landfills

These are scientifically engineered landfill sites. Sanitary landfills have the facility for management of obnoxious landfill gases and leachate produced from degenerating organic wastes thus lessening their effect on air and ground water pollution respectively. Landfills attains the lowest priority in ISWM system but is indispensable because residual wastes coming from different waste management practices ultimately find their way on landfill sites. This is most frequent in

Table 6 Typical major components of landfill gas (CPHEEO, MoUD, GoI, Manual on MSWM 2000)

Major components	Range (%)
Methane	30–60
Carbon dioxide	34–60
Nitrogen	1.0–21
Oxygen	0.1–2.0
Hydrogen sulfide	0.0–1.0
Carbon monoxide	0.0–0.2
Hydrogen	0.0–0.2
Ammonia	0.1–1.0

developed countries. There is a need of basic information about geographical location, temperature, rainfall, soil/terrain characteristics, ground water table, population, socio-economic status and transportation facility before designing of sanitary landfills (Table 6).

Presently GIS has turned up as an important tool in managing MSW. Models based on GIS help in mapping the impacts spatially and display them pictorially for a particular project (MoEF 2010). It also helps in choosing suitable landfill site, in determining the minimum cost/distance efficient collection paths for waste transportation to landfill site (Ghose et al. 2006), in determining spatial variation of the total dissolved solid in ground water (Nagarajan et al. 2012), for setting and placement of facilities etc. (Church 2002; Zia and Devadas 2008). Malczewski (2004) said that GIS based information could help policy-makers in correlating information from different sources, in visualizing and analyzing trends in order to make strategy for long term planning goals.

6.5 Land application of waste

At certain places agricultural land is directly subjected to organic waste like solid waste as well as sewage sludge without any pretreatment. Sewage sludge improves soil nutrient profile of agricultural and horticultural land and improves plant growth (Singh and Agrawal 2007, 2008, 2009, 2010a, b). The organic fraction of MSW usually is rich in organic matter, nitrogen, phosphorus, potassium, micronutrients as well as macronutrients and this may help in restoring soil fertility (Sigua 2005; González et al. 2008). The MSW is usually contaminated with other hazardous and biomedical wastes. So, if applied on fields for a long duration, may lead to accumulation of heavy metals in soil (Lopez-Mosquera et al. 2000), which may enter the food chain at elevated levels (Page et al. 1987). This may impose negative effect on soil fertility, on plants as well as on human beings (Wang et al. 2003).

7 Waste as a resource: opportunities

Municipal solid waste, an important by-product of urban lifestyle needs to be seen and treated as an opportunity in order that total gain in terms of environment and monetary could be obtained (Kathiravale and Muhd Yunus 2008).

7.1 Source of energy

Growth of any country largely depends on energy. Meeting the increasing demand of energy is one of the biggest challenges for developing countries. The extensive and non-sustainable use of conventional energy sources are non eco-friendly, so renewable energy sources are getting more importance. In recent years, the hidden potential of energy generation from MSW is getting worldwide attention of researchers. Energy production from MSW not only helps in meeting the increasing energy demand but also reduces the huge amount of waste finally reaching the landfill sites. Moreover, it also improves the quality of waste finally disposed off, thus helpful in meeting pollution control standards. The conversion of MSW to ethanol is getting technical acceptance from scientists due to high percentage of lignocelluloses in waste produced by the society (Kalogo et al. 2006; Vergara and Tchobanoglous 2012). Besides this there are many companies trying to recover the industrial chemical polylactic acid, and 'drop-in' fuels such as butanol, which are close substitutes for petroleum, diesel or jet fuel from waste (Schubert 2011). However this technique is yet to be utilized due to lack of proper segregation of waste and high cost to set up these plants in developing countries (Sabbas et al. 2003).

As per Ministry of New and Renewable Energy (MNRE 2011) estimation, In India the existing potential of energy generation is about 1,460 MW from MSW and about 226 MW from sewage. However, only

Table 7 Energy potential from waste in mega cities of India (Annepu 2012)

City	MSW generated (TDP)	Calorific value (MJ/kg)	Power production potential (MW)	Coal substitution (TPY)
Greater Kolkata	11,520	5.0	129.9	1,445,194
Greater Mumbai	11,124	7.5	186.6	2,075,263
Delhi	11,040	7.5	186.8	2,078,043
Chennai	6,118	10.9	149.0	1,657,716

24 MW of this have been capitalized as per MNRE report. This large amount of energy generated from waste can substitute million tons of coal every year, which accounts for 86.16 % of total installed thermal power generation in India (Ministry of Power, GoI 2013). Thus reducing the burgeoning pressure on non-renewable resources mainly coal (Table 7).

7.2 Source of recycling

Recycling is an important component of sustainable solid waste management system which is based on doctrine of waste minimization and comes after reuse of products in integrated waste management hierarchy. Recycling is the reprocessing of scrapped materials into useful products thus giving value to the refused materials or MSW which would otherwise end up in dumpsites. Furthermore, it is helpful in providing raw or crude materials for goods manufacturing industries which will deduct the urge of other natural resources, ultimately reducing emissions and input of energy required in extraction and processing of raw materials. In developing countries, a large number of people depend on informal recycling for their livelihoods. In India recycling is mainly performed by rag pickers. According to Agarwal et al. (2005), rag pickers search for recyclables in the discarded wastes which play an important role in maintaining the economy flow of MSW system. In India, this informal sector consists of wastes recyclers and a hierarchy of recyclable dealers (Fig. 5).

7.3 Land restoration/soil health/plant nutrient

The organic fraction of MSW can be used as soil amendment which will help in restoring the fertility of degraded land. Thus this can solve two fold problems viz. waste disposal and soil fertility management. Taylor et al. (2012) reported that vermicompost as soil amendment showed greater effect on plant production than the non vermicomposted organic waste. The composted/vermicomposted organic wastes have improved nutrient profile (NPK), aeration, porosity, structure, moisture and nutrient holding capacity (Hashemimajd et al. 2004). Besides this being rich in humic acid, compost/vermicompost assists lateral growth of roots by activating proton pumps (H^+-ATPase activity) in plasma membrane of root cells (Aguiar et al. 2012) thus promoting the yield of both horticultural plants and agronomic crops (Chaoui et al. 2003).

7.4 Source of employment generation

Unemployment is a serious problem faced by the government of developing countries like India due to burgeoning population. In India, a number of people depend on recycling and sanitary support services for their livelihood (like rag pickers, scrap dealers, sweepers etc). Although, informal recyclers face adverse working condition but it is more important to understand that it (trash) allows those to survive and be employed (Medina 2000).

Recycling of MSW is now have got the recognition as the “most environmentally sound” strategy for dealing with waste which follow only the preventive strategy of source reduction and reuse (EPA 2004). Recycling is taking place to a very large extent in India. Datta (1997) investigated that over 85,000 people were involved in such activities in Delhi, the capital of India. Similarly Agarwal et al. (2005) on basis of extensive study of this waste trade with special emphasis on recyclers, extensive interviews, surveys and models reported that nearly 89,600 recyclists, who belong to the poorest income group of society largely depend on recycling sector for their livelihood in

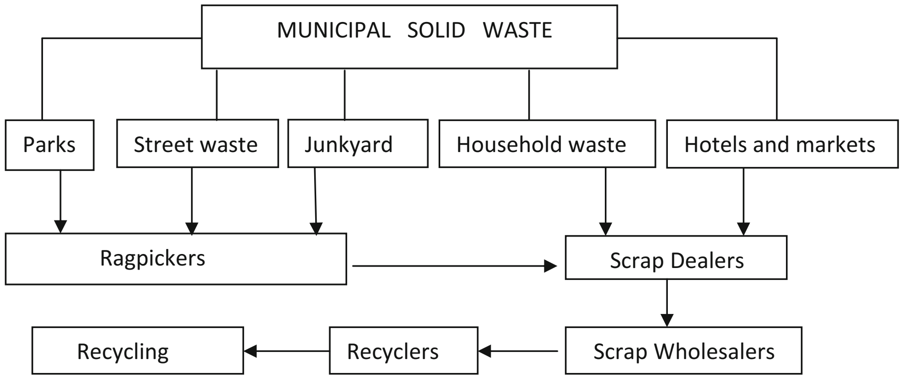

Fig. 5 Existing municipal solid waste reycling system in India (Mehta 2013)

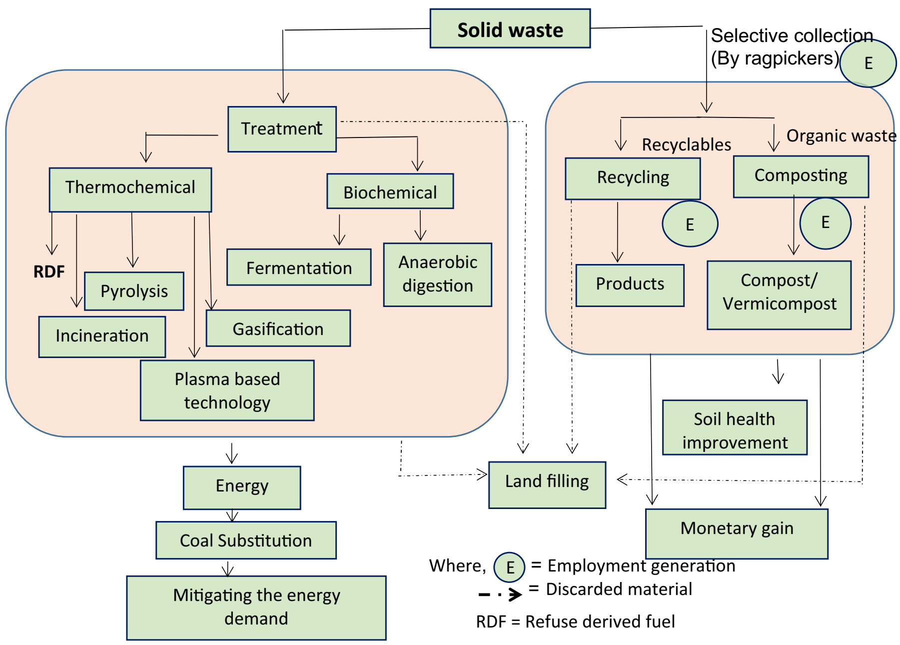

Fig. 6 Opportunity generated from waste

Delhi. Apart from that around 150,000 ragpickers are involved in Municipal Corporation of Delhi (Chaturvedi 1998). It has been estimated that more than 20,000 women work as paper pickers in Ahmadabad city (Salahuddin and Shamim 1992).

Thus waste management sector provides a good job opportunity for those who desire and facilitate them in improving their life styles. Besides this it also brings opportunity for business with a good potential of employment generation. Figure 6 shows different opportunities generated from MSW.

8 Planning for solid waste management

Planning is the first step in designing or improving a solid waste management system. A proper planning is essential for success of a solid waste management system and might be vary from city to country level. Therefore, a balanced coordination among different factors (social, institutional, environmental, financial and technical) is needed to get an optimal waste management plan (United States Environmental Protection Agency 2002). These are the following points that should take into consideration prior to designing of SWM plan for a city:

(a) Population, socio-economic status and climatic condition of city (Imam et al. 2008; Hoornweg and Bhada-Tada 2012);
(b) Data on solid waste generation, including present as well as projections over the lifetime of proposed plan (Phuntsho et al. 2009; Hoornweg and Bhada-Tada 2012);
(c) Data on composition of MSW as well as its characteristics like moisture content and density (Idris et al. 2004);
(d) Identification of proposed options and their evaluation for the best;
(e) An assessment of both investment as well as recurrent costs associated with the proposed facilities and services over lifetime of the plan (Hoornweg and Bhada-Tada 2012);
(f) Cooperation between various levels of government, as well as between neighboring regions and states or provinces (Thomas et al. 1990);
(g) Social acceptability;
(h) An assessment of environment and health impact;
(i) Inclusion of mathematical programming model for MSWM (Chang and Chang 1998; Fiorucci et al. 2003; Srivastava and Nema 2011);
(j) Inclusion of GIS based information in optimizing route of MSW collection, in selecting landfill site as well as in deciding the MSW plan (Malczewski 2004)

SWM plans are adversely affected by lack of resources to finance these services. In developing countries, major portion of budget for MSWM meets only collection and transportation cost leaving very less for the rest services. Thus, providing good SWM services together with financial sustainability of the system continues to be a difficult task in cities of developing countries (Lohri et al. 2014). Lohri et al. (2014) proposed four options on how financial sustainability of SWM system in Bahir Dar, Ethiopia could be achieved: (1) improved fee collection efficiency by linking the fees of solid waste collection to water supply; (2) increasing the value chain by sales of organic waste recycling products; (3) diversifying revenue streams and financing mechanisms (polluter-pays-, cross-subsidy- and business-principles); and (4) cost reduction and improved cost-effectiveness. Yadav et al. (2010) reported that how Mysore city corporation (MCC) is facing financial crisis for managing MSW based on empirical studies and authentic data collected from MCC. He found that the total capital receipt (Grants share of state government and financial institutions) in financial year 2005 was Rs. 320.1 million, however, capital expenditure was Rs. 365.7 million in the same financial year by MCC.

To improve financial situation of MCC (applicable on most of the local governing bodies in Indian cities) he proposed following recommendations to be implemented:

(a) Improvement in property tax collection efficiencies (Madon et al. 2004);
(b) Implementation of 'polluter pays' principle (Karagiannidis et al. 2008);
(c) Implementation of 'pay-as-you-throw' scheme (Karagiannidis et al. 2008);
(d) Relatively better tax collection, property tax reform and utilisation of assets/land in an appropriate manner in order to generate revenue, impact fee in new development, parking revenues, etc. (Yadav et al. 2010).

Rathi (2006) reported how participation of community based organization (CBO) and public private partnership (PPP) help in meeting the expenses on management of MSW by Municipal Corporation of Greater Mumbai (MCGM). It was found that the cost required for managing per ton of waste is Rs. 1,518 (US$35) with CBO participation; and Rs. 1,797 (US$41) with PPP participation and Rs. 1,908 (US$44) when it was managed by MCGM only.

9 Challenges/issues related to MSWM

This section addresses some of the problems related to MSWM.

9.1 Source segregation

Source segregation is the biggest challenge for sustainable waste management system in developing countries where waste disposal takes place unscientifically without proper planning. Inhabitants of Indian cities rarely segregate waste and sorting is mainly performed by waste collectors and ragpickers (informal sector). As a consequence the segregation efficiency is very poor in developing countries because waste collector and rag pickers segregate only those things which have high economic value in recycling industry leaving the remains. The mixed waste produced in Indian cities is not suitable for incineration as well as MSW usually contaminated with biomedical rendering unsuitable for composting in India.

9.2 Technical issues

Many technical factors like limitations of technical expertise (Hazra and Goel 2009) and planning potential among the personnel within municipal councils and government authorities may adversely affect solid waste management system. Though, it is present in some mega and metro cities it is not capitalized in an efficient manner for decision making. The technology which is often selected without due consideration to its appropriateness for socioeconomic status, climatic condition, nature of waste etc. leads to failure of solid waste management (SWM) plan for a city. Thus, waste characteristics and working condition at the local level should keep in consideration before selection of the waste management technology (Shekdar 2009). The physical characteristics of waste like waste composition, moisture content and density significantly influence the feasibility of certain treatment options e.g. the waste with high moisture content, high density and low CV is not suitable for incineration. The financial constraint adversely affect designing and development of sanitary landfills, waste to energy conversion technologies etc. Besides this ambiguity in reported data, lack of universal standard for the definition, measurement, categorization and data generation, and inadequate research and development adversely affect solid waste management systems (Guerrero et al. 2013; Vergara and Tchobanoglous 2012).

9.3 Financial issues

Availability of funds is essential for successful implementation of solid waste management system. But in developing countries the urban local bodies (ULBs) or municipality is unable to generate adequate funds from their own sources in the form of municipal tax. Besides this, unwillingness of the inhabitants (Sujauddin et al. 2008) to pay for the services provided and a lean profit make it less attractive to private companies for investment in this sector. The local authorities often struggle to provide adequate services to the society together with financial sustainability. Therefore, it is essential to promote the participation of private sector (PPP) that would help to overcome constraints imposed by lack of funds and professional experiences (Joseph and Nagendran 2007). Lohri et al. (2014) reported that an alliance between the Municipal Corporation and PPP in Bahir Dar, Ethiopia is providing financial sustainability to the MSW system.

9.4 Social issues

The haphazardly growing, low-income residential areas are challenge for MSWM. This is characterized by inadequate infrastructure services such as roads, drains and sanitary facility. Existing drains often clogged with waste materials and poly bags, providing a suitable place to flourish for disease causing vector and other harmful pathogens.

In developing countries a number of people (informal sector) depend on waste management sector for their livelihood as discussed earlier. They are socially marginalized and belong to low income group of society and work under harsh conditions which are extremely hazardous to health. Hence, it is essential to improve their working condition, earning and social status. There is a need of an innovational approach to integrate this informal or unorganized sector as a part of ISWM plan in order to support them. Besides this lack of awareness programs for giving ISWM related information to public, low social status and salary of waste workers as well as lack of interest amongst the public and stakeholders are the major social issues.

9.5 Education/awareness programs

Lack of educational programs related to solid waste management at secondary and higher levels of education has resulted in improper management; consequently the people working in this field do not have the expertise or an exposure, so there is a need of professionals to fill this existing gap.

9.6 Legislative issues

In developing countries due to inappropriate coordination between regulatory authorities addressing environment and industries, the waste management process gets affected. The problem arises due to the legal constraints affecting waste management including inadequate enabling laws, regulations, standards, policies and inadequate enforcement of the existing laws, political interference and weak penalty (Dubey 2013).

10 Conclusions

Disposal of MSW is one of the biggest challenges for all countries. Rapid urbanization and industrialization is continuously going on in developing countries like India and China to attain developed status. This would result in more haphazard urban growth and solid waste generation globally. Therefore demand for healthier and proper disposal of solid waste is justifiable and situation will be more difficult for developing countries to combat with this enormous amount of MSW in near future. Open dumping is very common practice in developing country posing risk to human health and nearby environment. MSW from developing country has high moisture content and density therefore is not suitable for energy conversion. Land application of waste could be a good option as it is rich in organic carbon and has high nutritive value. However, due to presence of heavy metals and other toxic compounds its long term application is not suggested. Composting/vermicomposting of MSW could be good option for MSW in developing countries due high nutritive value and is pathogen free. This waste poses several negative effects on health, environment and aesthetic values if not managed properly. But it also provides us opportunity because it has potential of energy and employment generation. Besides this it could be treated as raw materials for goods manufacturing industries and for composting/vermicomposting. Thus, if MSW is managed in an appropriate manner then it not only mitigates the negative effects but it could help in meeting the demand of energy and employment. It is advisable that wastes generating from one industry as byproduct should be investigated in such a way that it could be utilized as raw material for other good manufacturing industry. A proper planning is needed for MSWM. Prior to designing a SWM plan, the population, climatic condition, socio-economic condition, solid waste nature, financial support, environmental pollution, health impact etc. should take into consideration. Besides this systematic planning and implementation, designing ISWM system, source segregation, 4Rs (Reduce, reuse, recycling and recovery) strategy for waste minimization, GIS application for MSW management, decentralized composting at micro level, compliance of MSW rules, user-charge system based on income, prohibition of open burning, separate treatment for biomedical waste, awareness programs, involvement of formal/informal stakeholders and promotion of R&D should be taken place for safe, hygienic and proper management of MSW. Thus if MSW is managed in an appropriate manner then it not only mitigates the negative effects but it could help in meeting the demand of ecology and economy.

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