

Snapshot of Global Solid Waste Management Practice

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Abstract: The need to manage solid waste is felt all over the world as unmanaged wastes pose substantial risks to human health and the environment. This paper presents an overview of solid waste generation rates, characteristics, and management practices across the globe. It was observed that there is unevenness in the generation rate and composition of solid wastes across the globe. High-income countries tend to generate more solid wastes per capita than low-income countries and their wastes contain more paper, metals, plastics and less organic materials. Solid waste management techniques are equally diverse across the globe, basically depending on the local condition, technology and fund availability, national or municipal policies, and solid waste management goals. However, most developed countries provide high levels of solid waste management service while developing countries require technical and financial assistance to upgrade existing management practices. As global population and economy are growing, it is suggested that international and national effort should be geared towards full implementation of the Integrated Solid Waste Management (ISWM) strategy.

Keywords: Solid waste, generation, composition, management, the world

Introduction

Human activities require materials to be drawn directly and indirectly from the environment, some of which are ultimately returned to the environment as waste products. Solid waste is generally regarded as an unwanted solid material, which is useless or worthless and of no value to the owner. The need to manage solid wastes is felt all over the world as improperly managed wastes constitute a source of pollution and pose significant risks and adverse impacts to human health and the environment (Medina, 2005; Kassim and Ali, 2006; McLeod et al., 2006; Sharholy et al., 2008; UN-HABITAT, 2010b). Failure to implement a systematic and comprehensive solid waste management system also increases the spread of diseases, exacerbates visual deterioration and increases carcinogenic air emissions (McBean et al., 2005). More so, serious financial and socio-economic losses may occur as a result of

inappropriate waste management strategy (Ağdağ, 2009).

The management of increasing quantities of solid waste as a result of population growth and rapid urbanization is a global issue (Tinmaz and Demir, 2006). The international community has been deeply concerned about the growing need to protect public health and environment from the menace of solid waste and other crucial matters that affect drinking water and sanitation. Several international treaties (agreements, protocols, conventions) have served as a source of environmental obligations and have assisted in developing techniques and technologies for solid waste management. An example is the multilateral environmental agreement known as "The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal" which was made under the auspices of the United Nations Environmental Program. The treaty compels the reduction of hazardous waste production

and limits its movement between countries. Also of utmost significance is the global plan of action known as "Agenda 21" which was adopted at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992. Chapter 20, 21, and 22 of the global plan was dedicated to solid waste management while other Chapters embrace supplementary areas of sustainable development.

Chapter 20 was titled "Managing Hazardous Wastes" and it encourages minimization, treatment and safe disposal of hazardous wastes either at the national or regional level. Chapter 21 (Managing Solid Wastes and Sewage) called for waste minimization and increased reuse/recycling of wastes by strategies such as energy recovery, compost production, and the use of wastewater for irrigation. It appealed to governments to establish guidelines for the safe reuse/recycling of wastes and encourage a market for reused/recycled products. Chapter 22 (Managing Radioactive Wastes) called on countries to partner with international organizations in efforts to minimize, store, process, condition, transport and dispose radioactive wastes. Other areas addressed by Chapter 22 are technical assistance to developing countries, environmental impact assessment, and implementation of the code of practice on the transboundary movement of radioactive wastes.

Treaties from such conferences are mainly political and diplomatic approaches which served as models for participating

countries to draft legislations and regulations for effective and efficient waste management. Therefore each country has to take into consideration its legal, economic or socio-political framework in order to accommodate the models and set national or municipal targets. Hence solid waste management practice is expected to vary widely in sophistication within the globe. Several independent papers which discuss solid waste management strategies adopted by various stakeholders are present in literature. This paper presents an overview of the output and characteristics of the solid waste and draws together some published reports on the management of solid waste across the globe.

Global Output and Characteristics of Solid Waste

The output and characteristics of solid wastes can be regarded as a quantitative indicator of the use of resources, and the aftermath of production and consumption processes. Economic prosperity and population growth are major inputs that account for the output of wastes (Doğan, and Süleyman, 2003; Sarkar, 2003; Zia and Devadas, 2008; Ağdağ, 2009; Mihelcic and Zimmerman, 2010; Guerrero et al., 2013). The World Bank classified the economy of countries as low income, lower middle income, upper middle income and higher income. This classification of economies as of July 2013 according to Gross National Income (GNI) per capita is illustrated in Figure 1.

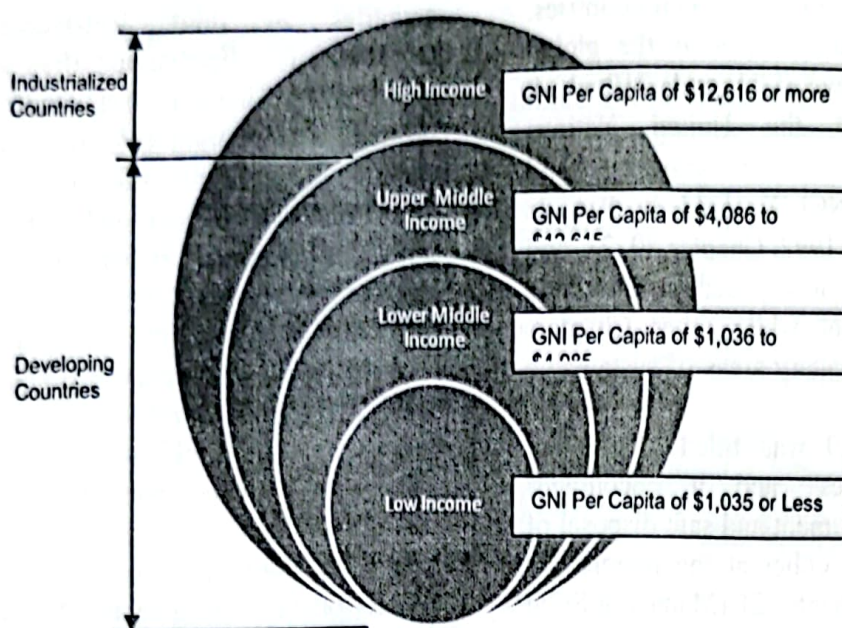


Figure 1: Group of economies and their GNI
 Source: Adapted from <http://data.worldbank.org>

From this classification, 36 countries are regarded as low-income countries, 48 are lower-middle income countries, 55 are upper middle-income countries, and 75 are high-income countries (<http://data.worldbank.org>). Countries with low and middle-income economies are referred to as developing countries while countries with high income economies are termed industrialized countries. This criterion (economic status) forms a key indicator of a country's development and may reflect similar solid waste generation rate, composition, and management technique of a group of countries in the same class.

The per capital solid waste generation rates for low-income, middle-income and high-income countries are shown in Table 1. The per capital generation rates of solid waste are highest for industrialized countries, followed by middle-income countries while

low-income countries have low per capita generation rate. Specifically, the rate of generation of residential waste in industrialized countries is about one and half times more than middle-income countries and double the amount generated by low-income countries.

Table 1: Global outlook of solid wastes generation rate, composition, and characteristics

Parameter	Low income Country		Middle income Country		High-income country	
*Average waste generation rate (kg/capita/day)	0.60		0.99		2.1	
**Mixed urban waste large city (kg/capita/day)	0.50 - 0.75		0.55 - 1.10		0.75 - 2.2	
**Mixed urban waste medium city (kg/capita/day)	0.35 - 0.65		0.45 - 0.75		0.65 - 1.50	
**Residential waste only (kg/capita/day)	0.25 - 0.45		0.35 - 0.65		0.55 - 1.00	
Composition (%)	*	**	*	**	*	**
Organic	64	40-85	56.5	20-65	28	7-55
Paper	5	1-10	11.5	15-40	31	15-50
Plastics	8	1-11	11.5	2-13	11	2-20
Glass	3	1-10	4	1-10	7	4-10
Metal	3	1-5	2.5	1-5	6	3-13
Others	17	16-53	14	16-45	17	7-32
**Density (Wet density per kg/m ³)	250-500		170-330		120-200	
**Moisture (percentage)	40-80		40-60		20-35	
**Calorific heating value (KCAL/Kg)	800 - 1100		1000 - 1500		1500 - 2700	

*Source: World Bank (2012) **Source: Cointreau (2006)

As equally observed from Table 1, a typical solid waste from a low and middle-income country (developing country) contains more organic materials and less paper, hence the solid waste is normally high in moisture content and low in calorific heating value. On the other hand, solid wastes from industrialized countries contain more paper, metals and plastics, and less organic materials. Therefore the solid waste has a high calorific value and low density. Population has a significant input in the amount of solid waste generated from a locality because population is positively correlated with solid waste generation. The population of the world was 5.28 billion in 1990, 6.39 billion in 2004 and it is expected to reach 7.22 billion in 2015 (WHO and UNICEF, 2006). Based on this projection, the global output of wastes is expected to increase. In totality, the yearly production of solid waste in the

world is about 1.6 billion metric tons (Ali and Ahmed, 2006).

Economic level and population tend to prevail over other factors even within a locality as testified by Hoornweg and Thomas (1999), Palczynski (2002), Rhea (2003) and Ağdağ (2009). For instance, in urban areas of a country where the standard of living is usually higher than the rural areas, the output of wastes is considerably higher. On country basis, the United States of America is the highest generator of solid waste because it consumes over 20% of the materials produced globally and invariably has the highest per capita waste generation in the world (Kaufman and Themelis, 2004). In contrast, another report (www.siteresources.worldbank.org) rated China as the highest generator of wastes and China is believed to have surpassed the United States of America in the output of wastes in 2004. Perhaps the outstanding feature of each of these

two countries (economy and population) tends to account for their ranking. China's population in 2004 was 1.30 billion (www.chinability.com) typifying the most populous country in the world and China is regarded as the sixth largest economy in the world with a GDP of \$2 trillion (www.chinadaily.com). The United States of America is the largest and most technologically powerful economy in the world with a GDP of \$10.98 trillion (www.immigration_usa.com) and has a population of 293,027,571 (about 5% of the world's population) in 2004 (www.census.gov).

Solid Waste Management Strategies

The essence of a typical solid waste management system is to effectively and efficiently handle solid wastes from the point of generation to the treatment or disposal point. However, the management of municipal solid waste takes different forms across the continent based on demographics, available economic resources, and technology. Planning, design, and implementation of solid waste management schemes also vary from country to country and from city to city though the overall goal is to reduce, store, collect, and process or dispose of solid wastes safely (Aremu and Sule, 2010). The following section describes the functional elements involved in the management of solid wastes across the globe.

Solid waste storage systems

Once a material has been identified as a waste, it has to be temporarily stored. Storage of municipal solid wastes prior to collection could be

in household bins, disposable paper or polyethylene bags, trash bags, refuse chutes, waste baskets, wheeled bins, masonry depots, concrete pipe containers, tractor trailer containers or municipal storage bins. In some developing countries, solid wastes are often stored on open grounds awaiting collection. On the other hand, it is common to find plastic and galvanized steel bins with lids in middle-income and high-income areas (UN-HABITAT, 2010a). The types and capacities of the containers used for storage of solid wastes depend on the characteristics and types of solid wastes to be collected, the type of collection system in use, the collection frequency and the space available for the placement of containers (Tchobanoglous, 1993).

There are several regulations for the design and placement of containers used for solid waste collection. These regulations usually specify the makeup material, length, height, diameter or width, thickness, weight and other associated container accessories. Abduli (1995) presented seven designs of local bins used for storage of solid wastes in residential areas of Tehran, Iran. It was observed that there was no standard container for storage of solid wastes in Tehran and containers are built according to the desire of the home owners. Tinmaz and Demir (2006) proposed the use of different containers for the storage of solid wastes in Corlu town of Turkey in order to separate solid wastes at source. A separate container was recommended for storage of paper and cardboard, recyclable materials, organic materials, hazardous wastes, and ash. The authors criticize the use of disposable plastic bags as they are disposed along with the wastes thereby

increasing the quantity of plastics in the wastes.

The makeup material and dimensions of solid waste containers vary considerably across the globe. Conventional makeup materials are galvanized metal, plastic, paper, aluminum or fiber. Black bags, 0.4m³ containers, one compartment containers and three compartment containers (for separation of paper, plastics and glass) are used for interim storage of wastes in Denizli, Turkey (Ağdağ, 2009). 1m³ street containers and 70 liter capacity dustbins are commonly used for the storage of solid wastes in Tubas, Palestine (El-Hamouz, 2008). Solid waste generators in Monrovia, Liberia, are expected to provide their own primary storage facilities (plastic bags or containers) while the City Corporation provides 10m³ communal containers at designated locations for communal storage of wastes (Mensah, 2006). Three types of solid waste bins of capacity 7m³, 0.75 m³, 0.5m³ were proposed to be placed at different parts of Asansol municipality, India (Ghose et al., 2006) based on population density, the width of the roads, availability of space, and minimum travel distance.

Solid waste collection systems

The worldwide systems adopted for the collection of solid wastes are the individual system, franchise system, municipal system, and the contract system. The individual system is the technique by which the house holder, company, or institution is responsible for getting the wastes from the point of storage to a nearby disposal point. A licensed collector is responsible for the collection of solid wastes from the vicinity of the generator to the disposal

site in the case of the franchise system. The mode of operation of a franchise may be by direct collection of user charges *as pay as you throw basis* or over a period of time. In the municipal system, a municipality provides and maintains its own equipment and employees. The responsibility for collection of solid wastes may be under the authority of a municipal agency, department or ministry. Historically, it is the responsibility of the municipal government to manage solid wastes and this method is still practiced by some developing countries. In the contract system, individuals, communal groups, and businesses contract solid waste collection to a solid waste collector who operates under an agreement. The contractual agreement varies, nonetheless, the agreement between the municipal authority and a private enterprise under a public – private partnership is prominent worldwide.

Under a public-private partnership (PPP), the city authority maintains oversight functions to ensure satisfactory solid waste collection while the private sector is the service provider. The PPP arrangement takes different forms in different municipalities of various countries as testified in literature; Developing countries (Cointreau-Levine, 1994), Egypt (www.ecaa.gov), Bangladesh (Ali and Ahmed, 2006), and Tanzania (Kassim and Ali, 2006). The PPP is gaining enormous acceptance by a number of municipalities across the globe as an alternative to reform the weak performance of the public sector, reduce cost, improve efficiency and ensure environmental protection (El-Fadel, 2003).

In most high-income countries, virtually all municipal solid wastes are

collected. It was reported that no region is unserved in Southwest Georgia, USA (www.swgrdc.org) while 85% of municipal solid waste is collected and treated in an organized manner in Hungary (www.un.org). Developing countries experience low levels of collection service. Typically in middle-income countries 50% to 80% of municipal solid wastes are collected while 30% to 60% of municipal solid wastes are collected in low income countries (Cointreau, 2005). It was reported that 68% of municipal solid waste is collected on average in Cairo, Egypt (www.ecaa.gov). Collection efficiencies in Egypt range from 0% in low-income rural areas to 90% in high-income areas of large cities. In South Africa, before the end of the apartheid regime, the whites-only suburbs operate regular door-to-door refuse collection while in most black townships and rural areas, residents are forced to dump their solid wastes in open spaces or in unsealed communal skips (Qotole et al., 2001).

Three means of moving solid waste from the storage point are observed across the globe (Ogawa, 1989). These means are classified according to the source of moving force as:

- (i) Human-powered equipment: Trolleys, pushcarts, pedal tricycles and wheelbarrows.
- (ii) Animal-powered: Carts, and wagons drawn by animals such as donkeys and cows.
- (iii) Engine-powered: Wagon drawn by a motorcycle, skip trucks, mechanized collection vehicles, roll on- roll off

trucks, compaction trucks, light and heavy duty tractor trailers, container trains and conveyors.

Human-powered equipment is common in remote areas of developing societies and this is in conjunction with animal powered techniques. However, this technique is used for diverse purposes in some areas. Push carts are used for areas that are inaccessible to collection vehicles, pedal tricycles are used for short distance travel to disposal sites wheelbarrows are used for hauling street sweepings and other solid wastes to a collection point. The animal-powered method is common in developing societies with narrow streets and hilly terrains. The human and animal powered methods are suitable for pre-collection of solid wastes in inaccessible areas prior to collection by municipal authorities as practiced in Nigeria, Cameroun, Egypt, South Africa and Liberia. Engine-powered methods use petrol or diesel engine or electricity as a driving force for hauling of wastes. Some trucks (compaction trucks) have a hydraulic compressor for reducing the volume of wastes. The compaction vehicles are more relevant in industrialized countries than in developing countries because their solid wastes have low density and moisture content. Trains and conveyors are visible collection devices in highly developed industrial and commercial areas. Table 2 shows a gradual trend in the level of sophistication of solid waste collection options. The more the level of sophistication of the collection option, the more the volume of solid wastes collected.

Table 2: Characteristics of solid waste transportation options

Parameter	Manual Handcart	Pedal Tricycle	Animal Cart	Tractor Trailers	Flat Bed Trucks	Compactors or Trucks
Distance Travelled	< 2 km	< 10 km	< 10 km	< 15 km	Unlimited	Unlimited
Speed	Very slow	Slow	Slow	Relatively slow	Fast	Fast
Applicable Width of street	Narrow	Narrow	Moderate	Moderate	Wide	Wide
Volume per Vehicle	0.5-1 m ³	2-3m ³	4 m ³	4 m ³	8 m ³	12 m ³
Labour Requirement	1 collector	1 Driver	1 Driver 2 Loaders	1 Driver 2 Loaders	1 Driver 3 Loaders	1 Driver 3 Loaders
Purchase Cost	Very low	Low	Low	Relatively Low	Moderately high	Very High
Maintenance Requirement	Very low	Low	Low	Low	Moderately high	Very High

Source: Ogawa (1989)

However, some areas within a city are served with multiple collections means to suit specific conditions such as city center, market places, high and middle-income residential areas, low income-low density and low income high density residential areas, accessibility and availability of space (Mensah, 2006).

Global status of material/energy recovery and solid waste disposal

Material/energy recovery is the act of extracting secondary materials or energy out of solid waste. Solid waste residues after material or energy recovery are finally disposed by placing them systematically on the earth's surface or in oceans. Material recovery from solid wastes could be in form of solid waste reuse and it takes place mainly at the household level or community level. Solid wastes such as clothes, plastics, bottles, paper, cans, and

cardboard are reused directly, picked up by scavengers or sold. Household and commercial organic wastes are sometimes fed to domestic animals. Empty glass bottles for beverages and beer are swapped for filled bottles at the beverage or beer industry. The waste exchange is another reuse strategy whereby solid waste is diverted from disposal for a beneficial purpose. More than 50 waste exchanges as free service to industries exist in New York, Chicago and Toronto (Hoomweg and Thomas, 1999). Two benefits are accruable from such exchanges: 1) The waste generator saves disposal costs and 2) The waste consumer gets free raw materials.

Recycling is the process by which recyclables are processed and turned into useful products. In low income, middle income and high-income countries, recyclable materials comprise about 15%, 30% and 60% of the total solid waste stream respectively (Cointreau-Levine, 1994). Most

recycling activities in developing countries are performed by scavengers at the point of collection or at the disposal site. Recycling activities in industrialized countries have become popular and some nations promote recycling through financial incentives and provision of market for these recyclables. Recyclable solid wastes include textile, construction wastes, paper, plastic, ferrous and nonferrous metals, and glass. The plastic recycling industries shred plastics into pellets to manufacture other plastics and allied products. Some recycling factories process waste paper and cardboard to

tissue paper, newsprint or bulk packaging materials. Waste glass is processed by glass or terrazzo companies, non-ferrous metals are processed by aluminum smelters and tin is recovered from aerosol cans (Palczyski, 2002).

Recycling of wastes furnishes economic returns. The economic returns from some recycled goods in Argentina are summarized in Figure 2. Plastic wrap (chlorinated plastics with stretch ability) provides the highest economic return followed in decreasing returns by cardboard and paper, other plastics, and plastic soft drink bottles.

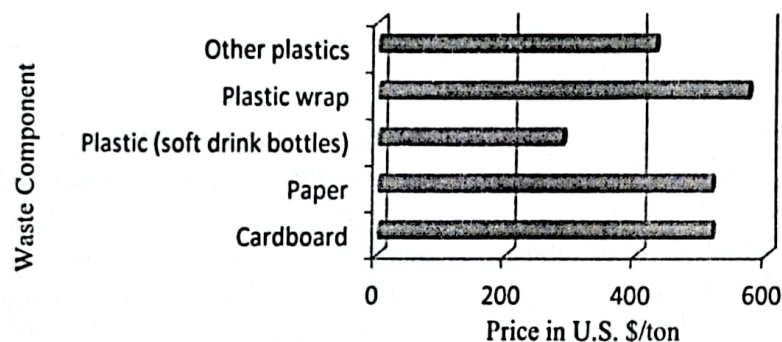


Figure 2: Economic value of some recycled goods in Argentina

Source: Adapted from McBean et al. (2005)

A comparable study in Turkey by Tinmaz and Demir (2006) indicated that the market price of recycled metal outstrips the revenue from other recyclables such as paper, cardboard, plastics, glass, and compost (Figure 3). Aluminium is also a major recyclable resource in which global aluminium

recycling rates are about 90% for transport and construction appliances and 60% for beverage cans (UNEP, 2011). In total, all forms of recovered solid wastes are approximately one billion tons and recycling alone represents 700 million tons (Chalmin and Gaillochet, 2009).

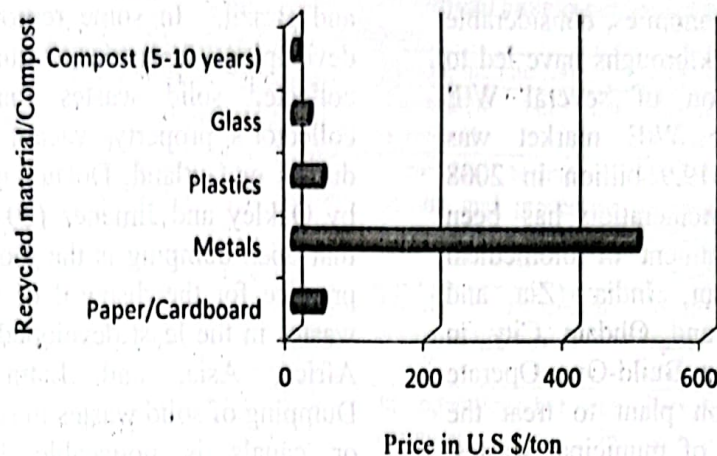


Figure 3: Market price of some recyclable materials and compost in Turkey
 Source: Adapted from Tinmaz and Demir (2006)

Composting is a controlled natural process of decomposition of the organic waste material. Composting facilities are designed to process a variety of organic wastes such as food wastes, yard wastes, and agricultural wastes. Backyard composting is prominent in Australia, Japan, and New Zealand. Centralized composting facilities are common features of Northern European waste management programs while both backyard and centralized composting are common in North America but find limited application in Africa (UNEP-IETC and CalRecovery, Inc., 2005). Modern composting plants are installed with anaerobic digesters to yield biogas which can be captured for power or steam generation. Composting has been a long traditional practice in India, and the national waste legislation in India clearly stipulates composting as an option for organic waste treatment (Zurbrugg et al., 2004). This legislation encouraged setting up of small and middle scale compost entrepreneurs and compost production now makes up 10-

15% of recovered materials. The optimal solution of the model presented by Rathi (2007) also indicated that community compost plants are the best option for solid waste management in Mumbai, India by taking various economic and environmental costs into consideration. Also, informal waste scavengers in Egypt (Zabbaleen) have established their economic survival through composting of solid wastes.

In the incineration process, solid waste is burned at high temperature. Solid waste from low-income countries is less suitable for incineration than solid wastes from high-income countries because these wastes have a high percentage of moisture and non-burnable inert materials such as ash and sand. Incineration or waste-to-energy (WtE) operates well in industrialized countries by recovering energy in the form of steam for heating or cooling processes and electricity generation. Incineration and WtE may not play a significant role in municipal waste management in Africa because of its high cost, the high organic content of its waste and limited

infrastructure (Palczynski, 2002). In more advanced economies, considerable technological breakthroughs have led to the implementation of several WtE projects and the WtE market was estimated at US\$19.9 billion in 2008 (UNEP, 2011). Incineration has been used for the treatment of biomedical wastes in Kanpur, India (Zia and Devadas, 2008) and Ohdate City in Japan developed a Build-Own-Operate (BOO) incineration plant to treat the projected volume of municipal wastes, sewage sludge and industrial wastes (Kleiss and Imura, 2006).

Disposal by landfilling is the last resort when other options for solid waste management such as waste reduction, re-use, recycling, composting and incineration have been exhausted. A comparative study of disposal options across the world shows that landfilling is the commonest method of solid waste disposal. Landfilling has been found to be the cheapest when compared with incineration, composting or recycling. For example, when compared to per ton incineration costs, landfilling is \$70 per ton cheaper in Germany and \$20 per ton cheaper in the United States (www.inece.org). Landfilling is also not capital intensive and does not require skilled labour. In low-income countries, solid wastes are brought from the city and dumped at designated centres or unofficial centers in the outskirts of the town. When the dumpsites are full they are closed. These practices of uncontrolled landfilling cuts across the globe and are common sights in Ethiopia, Nigeria, Liberia, Congo,

Ghana, Bosnia and Herzegovina, India and Brazil. In some remote parts of developing countries, dumping of collected solid wastes may be the collector's property, vacant lots, open dumps or Outland. Documented studies by Oakley and Jimenez (2012) suggest that open dumping is the most common practice for the disposal of urban solid wastes in the least developed regions of Africa, Asia, and Latin America. Dumping of solid wastes in seas, oceans, or canals is noticeable features in Indonesia (McBean et al., 2005). It was observed by Cointreau (2006), that in middle-income countries, about 10% of collected solid wastes are deposited in uncontrolled landfills, and less than 5% are deposited in sanitary landfills while in low-income countries, almost all the collected solid wastes are deposited in open dumps.

In the context of solid waste management, the strategy presented by the Integrated Solid Waste Management (ISWM) is to reduce the quantity of solid wastes produced and to recover materials from waste as much as possible. Many countries have adopted this strategy especially the high-income countries. Table 3 presents the level of participation of different economies in the options presented in the solid waste management hierarchy. It shows that municipalities in developing countries across the globe rely heavily on disposal of solid wastes by landfilling while developed countries are shifting towards decreasing the volume of solid waste produced and optimization of material recovery from solid wastes.

Table 3: Comparison of material recovery and disposal options performed by different economies

Activity	Low-income country	Middle-income country	High-income country
Source Reduction/Reuse	No organized programs, but reuse is common	Advocated but not organized	Organized source reduction and reuse programs
Recycling	Recycling mostly performed by scavengers	Some high technology sorting and processing facilities	Dedicated collection services and high technology sorting and processing facilities
Composting	Rarely undertaken through high compostable materials	Mostly small-scale composting projects	Mostly backyard and large-scale facilities. Low compostable materials
Incineration	Uncommon, expensive and limited	In operation but not common as in industrialized countries	Prevalent in areas with high land costs and most have some type of energy recovery system
Landfilling	Low-technology sites, usually open dumping	Enclosed landfills with some environmental controls	Well developed sanitary landfills and some have recovery systems

Source: Adapted from www.inece.org

In 2002, 100% of the municipal solid waste generated in Portugal was disposed off appropriately by a network of 3 incineration plants, 7 organic recycling plants, 37 landfills, 77 transfer stations, 18 sorting units, 133 drop-off centers and 13,500 drop-off-points (Passaro, 2003). A study by Tinmaz and Demir (2006) to improve the solid waste management system in Corlu town, northwest of Turkey, recommended maximizing recycling and minimizing landfilling of municipal solid wastes. The recommended system is a stage-wise process of separation at source, collection, sorting, recycling, composting and sanitary landfilling as the final option. The system was found to reduce the required landfill volume by 27% and it is expected to generate 80 million US dollars after 30 years of operation.

Open burning is the most common in African countries, though sanitary land filling, composting and incineration is gaining ground. Composting is the most viable option because a greater percentage of solid

wastes from African countries contain organic matter and some small scale composting facilities have been sponsored by international NGOs in Benin, Cameroon, Egypt, Kenya, Nigeria, South Africa, and Zambia (UNEP, 1996). The cost of construction and operation of incineration facilities is high and have failed when implemented in Tanzania and Nigeria while there has been resistance to building incinerators by environmentalists in South Africa. The high organic content of solid wastes from African countries coupled with the negative environmental, social and health consequences of discharges from incineration plants makes it a less viable option.

An evaluation of the cost of solid waste management options indicates that incineration is 5-10 times more costly while composting is 2-3 times more costly than sanitary landfill for developing countries (Cointreau, 2006). A similar study by Timaz and Demir, (2006), calculated the capital and operating costs for recycling, composting and sanitary landfilling for

the year 2006 as \$374,622, \$437,799, and \$102,948 respectively while their income was estimated as \$1,729,562, \$102,233, and \$1,831,795 respectively.

Table 4 shows the costs associated with some solid waste management practices in developing and developed countries. The costs are higher in developed countries perhaps because of the high generation rates and the use of sophisticated equipment for

solid waste management. Nonetheless, the cost as a percentage of the income of developed countries is low compared to developing countries. The low management costs of the middle income and low-income countries may be attributable to economies of scale, poor funding, low service coverage and the use of crude or outdated methods for the management of these wastes.

Table 4: Global Summary of solid waste management practices and costs

Activity	Low-income country	Middle-income country	High-income country
Average waste generation (metric ton/capita/year)	0.20	0.30	0.60
Average income from GNP (\$/capita/year)	370	2,400	22,000
Collection cost (\$/ metric ton)	10-30	30-70	70-120
Transfer cost (\$/ metric ton)	3 - 8	5 - 15	15 - 20
Sanitary landfill cost (\$/ metric ton)	3 - 10	8 - 15	15 - 50
Total cost without transfer (\$/ metric ton)	13 - 40	38 - 85	90 - 170
Total cost with transfer (\$/ metric ton)	16- 48	43- 100	105-190
Cost as percentage of income	0.7 - 2.6%	0.5 - 1.3%	0.2 - 0.5%

Source: Cointreau (2006)

Conclusion

From the foregoing information from various sources, there is an apparent unevenness in the generation rates and composition of solid wastes across the globe. Countries with higher income tend to generate more solid wastes per capita than lower income countries due to higher commercial and industrial activities. Their solid wastes have higher proportions of recyclables and inorganics, therefore these wastes have higher calorific values than solid wastes from developing countries. The present situation of global solid waste

output is likely to increase because global population and economy are expected to increase. Also, there is an envisaged pronouncement in the diversity of solid wastes as a result of increasing use of natural resources, advancement in science and technology, and change in consumption pattern.

Solid waste management techniques such as storage, collection, material recovery and disposal options are equally diverse across the globe. Management practices essentially depend on the local condition, technology and fund availability, national or municipal policies and solid

waste management goals. However, most developed countries provide high levels of solid waste management service than developing countries. In developed countries, virtually all municipal solid wastes are collected while developing countries experience low levels of collection service. Also, municipalities in developing countries rely heavily on disposal of solid wastes by landfilling while developed countries are shifting towards solid waste reduction and enhancement of material recovery from solid wastes. As global population and economy are growing, developing countries need technical and financial support. International and national effort should be geared towards global implementation of the Integrated Solid Waste Management strategy which is based on the principles of sustainability.

References

- Abduli, M.A. (1995), "Solid Waste Management in Tehran". *Waste Management and Research*, 13, 519-531.
- Ağdağ, O.N. (2009), "Comparison of Old and New Municipal Solid Waste Management Systems in Denizli, Turkey". *Waste Management*, 29 (1), 456-464.
- Ali, S.M. and Ahmed, S.A. (2006), "People as Partners: Facilitating People's Participation in Public-Private Partnership for Solid Waste Management". *Habitat International*, Vol. 30, No. 4, 781-796.
- Aremu, A.S. and Sule, B.F. (2010), "Policies, Practices, and Challenges of Municipal Solid Waste Management in Nigeria". *Environmental Issues*, 3(1), 1-10.
- Chalmin, P. and Gaillochet, C. (2009) "From Waste to Resource. An Abstract of World Waste Survey 2009". http://www.uncrd.or.jp/env/spc/docs/plenary3/PS3-F-Veolia_Hierso-Print%20abstract.pdf. Accessed on the 7th of May, 2014.
- Cointreau, S. (2005), "Waste Collection Systems in Developing Countries". www.worldbank.org/urban/urbanforum2005/ulwpresentations/sw/cointreau2.pdf. Accessed on the 4th of April, 2008.
- Cointreau, S. (2006), "Occupational and Environmental Health Issues of Solid Waste Management Special Emphasis on Middle- and Lower-Income Countries". Urban Sector Board, the World Bank, Washington, DC, U.S.A.
- Cointreau-Levine, S. (1994), "Private Sector Participation in Municipal Solid Waste Services in Developing Countries". The World Bank, Washington, DC, U.S.A.
- Doğan, K. and Süleyman, S. (2003), "Report: Cost and Financing of Municipal Solid Waste Collection Services in Istanbul". *Waste Management and Research*, 21, 480-485.
- El-Fadel, M., Massoud, M.A., and Abdel Malak, A. (2003), "Assessment of Public vs Private Municipal Solid Waste Management: A Case Study". *Journal of Environmental Management*, 69, 15-24.
- El-Hamouz, A.M. (2008), "Logistical Management and Private Sector Involvement in Reducing the Cost of Municipal Solid Waste Collection Service in the Tubas

- Area of the West Bank". *Waste Management*, 28 (2), 260-271.
- Ghose, M.K. Dikshit, A.K. and Sharma, S.K. (2006), "A GIS-Based Transportation Model for Solid Waste Disposal- A Case Study of Asansol Municipality". *Journal of Waste Management*, 26, 1287-1293.
- Guerrero, L.A., Maas, G. and Hogland, W.(2013), "Solid Waste Management Challenges for Cities in Developing Countries". *Waste Management*, 33, 220-232.
- Hoornweg, D. and Thomas, L. (1999), "What a Waste: Solid Waste Management in Asia". The International Bank for Reconstruction and Development and the World Bank, Washington, D.C., USA.
<<http://www.worldbank.org/html/fpd/urban/publicat/Whatawaste.pdf>> Accessed on the 12th of December, 2007.
<http://data.worldbank.org/about/country-classifications/country-and-lending-groups>. "Country and Lending Groups Data". Accessed on the 5th of May, 2014.
- Kassim, M.S. and Ali, M. (2006), "Solid Waste Collection by Private Sector: Households' Perspective-Findings from a Study in Dar es Salaam City, Tanzania". *Habitat International*, 30, 769-780.
- Kaufman, S.M. and Themelis, N. J. (2004), "Waste Management in a Land of Plenty- Solid Waste Generation and Management in the United States". Accessed from www.iswa.org on the 13th of July, 2008.
- Kleiss, T. and Imura, H. (2006), "The Japanese Private Finance Initiative and its Application in the Municipal Solid Waste Management Sector". *International Journal of Project Management*, 24, 614-621.
- McBean, E.A., Del Rosso, E., and Rovers, F.A. (2005), "Improvements in Financing for Sustainability in Solid Waste Management". *Journal of Resources, Conservation, and Recycling*, 43, 391-401.
- McLeod, D., Meyers, G.D., and Anbarci, M.A. (2006) "An International Waste Convention: Measures for Achieving Sustainable Development". *Waste Management & Research*, 24, 505-513.
- Medina, M. (2005), "Serving the Unserved: Informal Refuse Collection in Mexico". *Waste Management and Research*, 23, 390-397.
- Mensah, A. (2006), "People and Their Waste in an Emergency Context: The Case of Monrovia, Liberia". *Habitat International*, 30, 754-768.
- Mihelcic, J.R. and Zimmerman, J.B. (2010), "Environmental Engineering: Fundamentals, Sustainability, Design". John Wiley and Sons, Inc. U.S.A.
- Ogawa, H. (1989), "Selection of Appropriate Technology for Solid Waste Management in Asian Metropolises". *Regional Development Dialogue*, Vol. 10, No. 3, in (www.inece.org, 1995). Residential and Industrial (Solid) Waste Disposal Support Package.
- Oakley, S.M., and Jimenez, R. (2012) Sustainable sanitary landfills for neglected small cities in developing countries: The semi-

- mechanized trench method from Villanueva, Honduras. *Waste Management*, Vol. 32, No.12, 2535-2551.
- Passaro, D.A. (2003), "Report: Waste Management in Portugal between 1996 and 2002". *Waste Management*, 23, 97-99.
- Qotole, M., Xali, M., and Barchiesi, F. (2001), "The Commercialization of Waste Management in South Africa". Occasional Paper Series No. 3. Municipal Services Project, South Africa.
- Rathi, S. (2007), "Optimization Model for Integrated Municipal Solid Waste Management in Mumbai, India". *Journal of Environment and Development Economics*, Vol.12, 105-121.
- Rhea, A.N. (2003), "A Systems Approach on Solid Waste Management in Metro Manila, Philippines". International Master's Programme in Environmental Science Thesis, Lund University, Sweden. www.lumes.lu.se/database/alumni/02.03/theses/navarro_rhea-abigail.pdf Accessed on the 9th of August, 2007.
- Sarkar, P. (2003), "Solid Waste Management in Delhi- a Social Vulnerability Study". Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December 2003, Department of Geography, University of Madras and Faculty of Environmental Studies, York University, 451-464.
- Sharholly, M., Ahmad, K., Mahmood, G., and Trivedi, R.C. (2008), "Municipal Solid Waste Management in Indian Cities – A Review". *Waste Management*, 28, 459-467.
- Tchobanoglous, G., Thiesen, H., and Eliassen R. (1993), "Solid Wastes: Engineering Principles and Management Issues". McGraw-Hill, Inc., New York, U.S.A.
- Tinmaz, E. and Demir, I. (2006), "Research on Solid Waste Management System: To Improve Existing Situation in Corlu Town of Turkey". *Journal of Waste Management*, Vol. 26, 307-314.
- UN-HABITAT (2010a), *Collection of municipal solid waste in developing countries*. United Nations Human Settlements Programme, Nairobi, Kenya.
- UN-HABITAT (2010b), "Solid waste management in the world's cities: Water and sanitation in the world's cities 2010". Earth scan Ltd, U.K on behalf of United Nations Human Settlements Programme, London/Washington DC.
- UNEP (1996), "International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management". IETC Technical Publication Series 6. United Nations Environmental Programme.
- UNEP (2011) "Waste - Investing in Energy and Resource Efficiency: Towards a GreenEconomy". www.unep.org/greeneconomy/Portals/88/documents/ger/GER_8_Waste.pdf Accessed on the 5th of May, 2014.
- UNEP-IETC and CalRecovery, Inc. (2005), "Solid Waste Management, Volume II:

- Regional Overviews and Information Sources". United Nations Environmental Programme, Division of Technology, Industry and Economics, International Environmental Technology Centre, Japan.
- WHO and UNICEF (2006), "Meeting the MDG Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade". WHO Press, Geneva, Switzerland.
- World Bank (2012) What a waste. A global review of solid waste management. Urban Development Series Knowledge Papers, March 2012, No.15. Urban Development & Local Government Unit, World Bank, Washington DC, USA.
- www.census.gov/cgi-bin/ipc/idbagg. "United States Census Bureau, International Data Base". Accessed on the 13th of July, 2008.
- www.chinability.com/population/hm "China Statistical Year Book". National Bureau of Statistics. Accessed on the 13th of July, 2008.
- www.chinadaily.com.cn/english/200-12/20/content_504977.htm. Accessed on the 3th of August, 2008.
- www.eea.gov.seam/Manuals/DakahSolidWaste/content.html "Solid Waste Management in Egypt". Solid Waste Management Strategy for Dakahleya Governorate. Accessed on the 16th February 2007.
- www.inece.org. "Residential and Industrial (Solid) Waste Disposal Support Package, February 1995". International Network for Environmental Compliance and Enforcement (INECE). Accessed on the 20th of January, 2007.
- www.siteresources.worldbank.org/INTEAPREGTOPURBDEV/Resources/China-Waste-Management1.pdf. "Waste Management in China: Issues and Recommendations". Urban Development Working Papers. Working Paper No. 9. East Asia Infrastructure Department, World Bank. Accessed on the 13th of August, 2008.
- www.swgrdc.org/agenda/website%2pdfSolid%Waste.pdf. "6.9 Solid Waste Management". Accessed on the 13th of August, 2008.
- www.un.org/esa/agenda21/natinfo/country/Hungarysanitation04f.pdf. "Sanitation Country Profile Hungary". Accessed on the 13th of August, 2008.
- Zia, H. and Devadas, V. (2008), "Urban Solid Waste Management in Kanpur: Opportunities and Perspectives". Habitat International, 32 (1), 58-73.
- Zurbrugg, C., Drescher, S., Patel, A. and Sharatchandra, H.C. (2004), "Decentralized Composting of Urban Waste: An Overview of Community and Private Initiatives in Indian Cities". Waste Management, 24, 655-662.