

Chapter 2

Waste Characteristics and Practices

This chapter presents an overview of the trend of the waste generation rate in different countries. The sources and characteristics of waste are presented to provide a snapshot of the waste situation in different regions. The makeup of waste affects how it should be managed. The common practice of waste management is explained and its performance is compared between low-income and high-income countries. Formal and informal waste recycling play increasingly important roles in the resource recovery system. Recycling practices are discussed. The local community is key to managing waste at source (waste reduction and separation). Therefore, community-based waste management is also highlighted in the chapter.

2.1 Waste Generation Rate

Globally, the composition of municipal solid waste (MSW) can be classified according to each country's income level. Hoornweg and Bhada-Tata (2012) provided a review of the global MSW situation and reported that the annual global MSW generation amount was at 1.3 billion tons and the global MSW generation rate at 1.2 kg/capita/day. By 2025, this will likely increase to about 1.42 kg/capita/day (~2.2 billion tonnes of MSW per year). The report estimates that actual per capita rates, however, are highly variable, as there are considerable differences in waste generation rates across countries, between cities, and even within cities.

MSW generation rates are influenced by economic development, the degree of industrialization, public habits, and local climate. Generally, the higher the economic development and rate of urbanization, the greater the amount of solid waste produced. Income level and urbanization are highly correlated and as disposable incomes and living standards increase, consumption of goods and services correspondingly increases, as does the amount of waste generated. Urban residents produce about twice as much waste as their rural counterparts. What a Waste (2012).

The higher the income level and rate of urbanization, the greater the amount of solid waste produced. High-income countries produce MSW at the highest rate of 2.13 kg/capita/day while lower income countries produce MSW at lower rates. When lower and lower middle-income strata are combined, the average of combined urban waste generation is 0.84 kg/capita/day. Generation rates in upper middle-income and high-income countries are increased (largely from urban residents). The rate of MSW generation is likely to escalate in the same direction once countries engage in higher economic activity.

Considering the MSW composition from countries with different income levels, the percentage of organic waste in MSW and income levels are often inversely correlated while other MSW constituents tend to correlate directly with income levels. Hoornweg and Bhada-Tata (2012) revealed that low to upper middle-income strata often process the highest percentage of organic waste (64, 59, and 54%, respectively) while the high-income strata has paper waste (31%) as the highest proportion in MSW composition with organic waste ranked as second (28%). The percentage of plastic, glass, and metal waste does not wildly differ among income strata. In all income strata, organic, paper, and plastic waste tend to be the highest constituents in MSW.

Hoornweg and Bhada-Tata (2012) forecast and reported the amount of MSW in different regions (see Table 2.1). They indicated the current waste generation per capita by region, the lower and upper boundary for each region, as well as average kilogram per capita per day of waste generated within each region (see Table 2.1). It was observed that countries in the OECD have the highest waste generation rate of around 2.2 kg/capita/day while countries in Africa have the lowest waste generation rate of around 0.65 kg/capita/day. This matches expectations in that waste generation increases with economic growth. Africa has relatively smaller economic activity compared with other regions. When categorizing the waste generation rate based on the incomes of countries, it is found that the larger the national income, the bigger the MSW generated (see Table 2.2). The low-income country group has an average waste generation rate of around 0.6 kg/capita/day while the high-income country group has a rate of around 2.13 kg/capita/day.

Table 2.1 Waste generation rate per capita in different regions

Region	Waste generation per capita (kg/capita/day)		
	Lower boundary	Upper boundary	Average
Africa	0.09	3	0.65
East Asia and Pacific	0.44	4.3	0.95
Europe and Central Asia	0.29	2.1	1.1
Latin America and the Caribbean	0.11	142	1.1
Middle East and North Africa	0.16	5.7	1.1
OECD	1.1	3.7	2.2
South Asia	0.12	5.1	0.45

Source Adapted from *What a Waste* (2012)

Table 2.2 Different income strata at the global scale and MSW data

Region	Total urban population (millions)	Urban waste generation	
		Per capita (kg/capita/day)	Total (tons/day)
Lower income	343	0.6	204,802
Lower middle income	1293	0.78	1,012,321
Upper middle income	572	1.16	665,586
High income	774	2.13	1,649,547
Total	2982	1.19	3,532,256
Level of income	Waste generation per capita (kg/capita/day)		
	Lower boundary	Upper boundary	Average
High	0.7	14	2.1
Upper middle	0.11	5.5	1.2
Lower middle	0.16	5.3	0.79
Lower	0.09	4.3	0.6

Source Adapted from *What a Waste* (2012)

2.2 Waste Composition

Production and consumption have a direct correlation with the sources and types of waste generated. The main sources of waste typically come from residential, industrial, commercial, and institutional sources. However, there are some specific types of sources including construction and demolition, municipal services, agricultural, and medical that need special treatment. The typical source likely generates certain types of solid waste (see Table 2.3). These sources (especially medical) produce a specific type of waste that requires a specific procedure for handling and treatment. The major purpose and advantage of classifying waste types is to facilitate appropriate waste management and better utilize recovery from the waste cycle. The makeup of waste impacts how waste is collected and disposed as well as the potential to recover it (Table 2.4).

A number of studies indicated that waste composition is influenced by socioeconomic factors such as level of economic development, culture, demographic, geographic location, environmental condition such as climate, and energy sources. MSW in high-income countries has paper, plastics, and other inorganic materials sharing the highest proportion. Whereas low-income countries have the highest proportion of organic waste.

Generally, low and middle-income countries have a high percentage of organic matter in the urban waste stream, ranging from 40 to 85% of the total. The paper, plastic, glass, and metal fractions increase in the waste stream of middle and

Table 2.3 Sources and types of waste

Source	Typical waste generators	Types of solid waste
Residential	Single and multifamily dwellings	Food waste, paper, cardboard, plastics, textiles, leather, yard waste, wood, glass, metals, ash, special waste (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), household hazardous waste (e.g., paint, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-waste (e.g., computers, phones, TVs)
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants (excluding specific process waste when the municipality does not oversee their collection)	Housekeeping waste, packaging, food waste, construction and demolition materials, hazardous waste, ash, special waste
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food waste, glass, metals, special waste, hazardous waste, e-waste
Institutional	Schools, hospitals (non-medical waste), prisons, government buildings, airports	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, bricks, tiles
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweeping, landscape and tree trimmings, general waste from parks, beaches, and other recreational areas, sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process waste, scrap materials, off-specification products, slag, tailings
Medical waste	Hospitals, nursing homes, clinics	Infectious waste (bandages, gloves, cultures, swabs, blood and body fluids), hazardous waste (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food waste, agricultural waste (e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous waste (e.g., pesticides)

Source Adapted from *What a Waste* (2012)

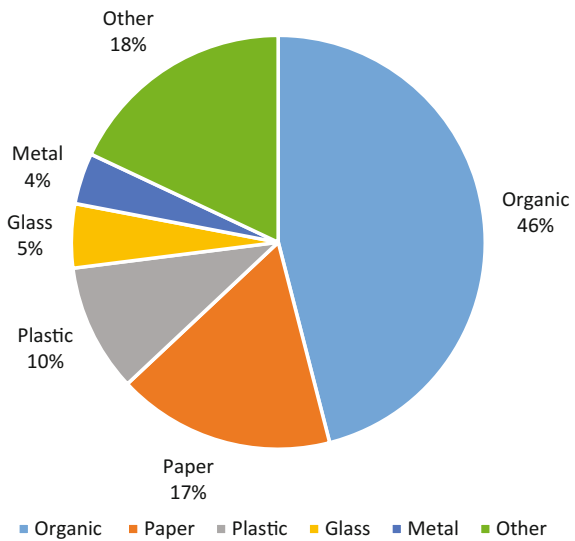
high-income countries. Figure 2.1 shows the makeup of global waste. Organic waste makes up the highest proportion (46%) among all types of waste followed by paper (17%), plastic (10%), glass (5%), metal (4%), and other (18%).

Table 2.4 Type of waste composition linked to sources

Composition	Sources
Organic	Food scraps, yard (leaves, grass, brush) waste, wood, process residues
Paper	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping paper, telephone books, shredded paper, paper beverage cups
Plastic	Bottles, packaging, containers, bags, lids, cups
Glass	Bottles, broken glassware, light bulbs, colored glass
Metal	Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railings, bicycles
Other	Textiles, leather, rubber, multilaminates, e-waste, appliances, ash, other inert materials

Source Adopted from *What a waste*, 2012

Fig. 2.1 Global solid waste composition. Source Adapted from *What a Waste* (2012)



In addition to the impact of waste composition on waste management, waste weight and volume are also important to the management system. This is because they affect the entire waste management lifecycle from frequency of collection, numbers of transportation vehicles and schedule, sizes and location of transfer stations, temporary storage and pretreatment, and distance to final disposal.

Table 2.5 summarizes the makeup of MSW in different groups of countries based on income and in selected cities. It shows that the makeup of Thailand’s MSW is similar to other developing countries in which organic waste is the dominant waste type in almost all groups of countries. Plastic and paper, however, have a higher share in the waste stream in more urbanized towns/higher income countries.

Table 2.5 Composition of MSW in countries and selected cities

Country/location	Gen rate (kg/cap.day)	Organic (%)	Paper (%)	Plastic (%)	Glass (%)	Metal (%)	Other (%)	Source
Average low income	0.6	64	5	8	3	3	17	Hoomweg and Bhada-Tata (2012)
Average lower middle income	0.79	59	9	12	3	2	15	Hoomweg and Bhada-Tata (2012)
Average upper middle income	1.2	54	14	11	5	3	13	Hoomweg and Bhada-Tata (2012)
High income	2.1	28	31	11	7	6	17	Hoomweg and Bhada-Tata (2012)
Bangkok, Thailand	1.57	50	11.3	22.5	2.7	1.7	12	BMA (2012)
Delhi, India	0.5	38.6	5.6	6	1	0.2	49	Talyan et al. (2008)
Beijing, China	0.85	63.4	11.1	12.7	1.8	0.3	11	Zhen-shan et al. (2009)

2.3 Waste Management Practices

There are a number of alternatives available for technology and practices throughout the waste management cycle from reduction, collection, and transportation to final disposal. To manage solid waste effectively and efficiently depends on several factors such as financial support, social norms, policy priority, and so on. From the typical waste management hierarchy, waste reduction is the most preferred practice. However, not all communities and countries have similar supporting settings and potentials to achieve the same waste reduction target. System performance is affected by different practices in waste management. Table 2.6 presents a comparison of waste management practices in different countries based on income level. It shows that higher income countries tend to be more advanced in managing waste by following the concept of the circular economy which involves recirculating waste to resource.

The source reduction practice in high-income countries has achieved a higher level of progress in organizing educational programs to raise 3R awareness for consumers and in redesigning products and processes for producers to help minimize wastage. Whereas in low-income countries the practice of source reduction has shown much less movement. However, the rate of waste generation in low-income countries is relatively lower than that in high-income countries.

Table 2.6 Comparison of solid waste management practices by income level

Activity	Low income	Middle income	High income
Source reduction	No organized programs, but reuse and low per capita waste generation rates are common	Some discussion of source reduction, but rarely incorporated into an organized program	Organized education programs emphasize the three ‘R’s’—reduce, reuse, and recycle. More producer responsibility and focus on product design
Collection	Sporadic and inefficient. Service is limited to high visibility areas, the wealthy, and businesses willing to pay. High fraction of inerts and compostables impact collection. Overall collection below 50%	Improved service and increased collection from residential areas. Larger vehicle fleet and more mechanization. Collection rate varies between 50 and 80%. Transfer stations are slowly incorporated into the SWM system	Collection rate greater than 90%. Compactor trucks and highly mechanized vehicles and transfer stations are common. Aging collection workers often a consideration in system design

(continued)

Table 2.6 (continued)

Activity	Low income	Middle income	High income
Recycling	Although most recycling is through the informal sector and waste picking, recycling rates tend to be high both for local markets and for international markets and imports of materials for recycling, including hazardous goods such as e-waste. Recycling markets are unregulated and include a number of 'middlemen'. Large price fluctuations	Informal sector still involved; some high technology sorting and processing facilities. Recycling rates are still relatively high. Materials are often imported for recycling. Recycling markets are somewhat more regulated. Material prices fluctuate considerably	Recyclable material collection services and high technology sorting and processing facilities are common and regulated. Increasing attention towards long-term markets. Overall recycling rates higher than low and middle income. Informal recycling still exists (e.g. aluminum can collection.) Extended product responsibility common
Composition	Rarely undertaken formally even though the waste stream has a high percentage of organic material. Markets for, and awareness of, compost lacking	Large composting plants are often unsuccessful due to contamination and operating costs (little waste separation); some small-scale composting projects at the community/neighborhood level are more sustainable. Composting eligible for CDM	Becoming more popular at both backyard and large-scale facilities. Waste stream has a smaller portion of compostables than low- and middle-income countries. More source segregation makes composting easier. Anaerobic digestion increasing in popularity. Odor control critical
Incineration	Not common, and generally not successful because of high capital, technical, and operation costs, high moisture content in the waste, and high percentage of inerts	Some incinerators are used, but experiencing financial and operational difficulties. Air pollution control equipment is not advanced and often by-passed. Little or no stack emissions monitoring. Governments include incineration as a possible waste disposal option but costs prohibitive	Prevalent in areas with high land costs and low availability of land (e.g., islands). Most incinerators have some form of environmental controls and some type of energy recovery system. Governments regulate and monitor emissions. About three (or more) times the cost of landfilling per tonne

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Table 2.6 (continued)

Activity	Low income	Middle income	High income
Landfill/ dumping	Low-technology sites usually open dumping of wastes. High polluting to nearby aquifers, water bodies, settlements. Often receive medical waste. Waste regularly burned. Significant health impacts on local residents and workers	Some controlled and sanitary landfills with some environmental controls. Open dumping is still common. CDM projects for landfill gas are more common	Sanitary landfills with a combination of liners, leak detection, leachate collection systems, and gas collection and treatment systems. Often problematic to open new landfills due to concerns of neighboring residents. Post closure use of sites increasingly important, e.g. golf courses and parks
Cost	Collection costs represent 80 to 90% of the municipal solid waste management budget. Waste fees are regulated by some local governments, but the fee collection system is inefficient. Only a small proportion of budget is allocated toward disposal	Collection costs represent 50–80% of the municipal solid waste management budget. Waste fees are regulated by some local and national governments, more innovation in fee collection, e.g. included in electricity or water bills. Expenditures on more mechanized collection fleets and disposal are higher than in low-income countries	Collection costs can represent less than 10% of the budget. Large budget allocations to intermediate waste treatment facilities. Up front community participation reduces costs and increases options available to waste planners (e.g., recycling and composting)

Source Adapted from *What a Waste* (2012)

Waste collection involves the collection of solid waste from the point of production (residential, industrial, commercial, institutional) to the point of treatment or disposal. MSW is collected in several ways (see Table 2.7). According to the data analysis report by Hoornweg and Bhada-Tata (2012), regions where there are low-income countries tend to have low collection rates. The average waste collection rates are directly related to income levels. Low-income countries (i.e., African regions) have low collection rates of around 41%, while high-income countries (i.e., OECD countries) have higher collection rates averaging 98%.

Recycling practices in high-income countries is more advanced in using technology to help sorting and processing recycle materials. The recycling rate in high-income countries is higher than that in low-income countries. Most of the recycling operators in low-income countries are from the informal sector. The waste-recycling process is not properly handled nor well operated which potentially

Table 2.7 Different methods of waste collection

Method of collection	Details
House to house	Waste collectors visit each individual house to collect garbage. The user generally pays a fee for this service
Community bins	Users bring their garbage to community bins that are placed at fixed points in a neighborhood or locality. MSW is picked up by the municipality, or its designate, according to a set schedule
Curbside pickup	Users leave their garbage directly outside their homes according to a garbage pickup schedule set by the local authority (secondary house-to-house collectors not typical)
Self-delivered	Generators deliver the waste directly to disposal sites or transfer stations, or hire third-party operators (or the municipality)
Contracted or delegated service	Businesses hire firms (or municipality with municipal facilities) who arrange collection schedules and charges with customers. Municipalities often license private operators and may designate collection areas to encourage collection efficiencies

Source Adapted from *What a Waste* (2012)

can increase adverse impacts on community and environmental health. The greater the environmental awareness, the more marked the recovery and recycling policies applied. Some countries, such as Japan, have prioritized the recycling of industrial waste ahead of municipal waste.

Composting/anaerobic digestion can help reduce the amount of waste sent to landfill. If waste separation at source is done effectively, by-products from composting (e.g., methane recovery) can be very advantageous. In low-income countries, although there is waste with high organic composition, the practice of composting is rarely carried out. Whereas the practice of composting/anaerobic digestion in high-income countries is carried out more widely.

Incineration in low-income countries is inefficient due to the limited waste separation capacity at source. The high moisture content in MSW affects the performance of incineration that converts waste to energy. Moreover, the cost of waste management using incinerators is greater than landfilling. Therefore, incinerators are commonly implemented in high-income countries where land areas are limited and the cost of land is high. Incinerators aimed at energy recovery are commonly found in high-income countries. Generally, the choice of incineration corresponds to high urban population densities and a relative shortage of space, such as is the case in Japan.

Landfilling is a popular waste treatment method in low-income/developing countries. Open dumping or uncontrolled landfill sites are commonly found in low-income countries. Whereas high-income countries have at their disposal controlled landfills using cutting-edge techniques to recover biogas and convert waste to energy. This is because priority has been given to a clear energy and environmental policy and stringent regulation is enforced.

From Waste to Resource: World Waste Survey (2009) indicated that the poorer a country, the less it possesses effective waste policies and the higher the proportion

of waste landfilled with a very high percentage placed in open dumping sites. The greater the size of a country, the greater the attraction of using space for controlled landfill sites such as Australia. In Japan, three quarters of all waste treatment involves incinerators. Growth in material recovery (composting and recycling) is very strong (over 50%) not only in Northern Europe, but also in South Korea and Singapore.



Description: Condition at an open dumping site. Photo by: Chanathip Pharino

2.4 Formal and Informal MSW Recycling

Improving the efficiency of MSW separation and recycling has become one of the approaches to enhance the co-benefits from waste management systems (i.e., reducing MSW landfilling) and energy in the production of raw materials and so on. Since the MSW generation rate is on the increase while the availability of land for landfilling and management resources (i.e., governmental budgets for MSW collection and disposal) are limited. Many countries, such as Japan, South Korea, and the U.S.A., tackle the challenges through mandating waste separation and charging a relatively higher fee for landfilling MSW as a deterrence against landfilling mixed or unsorted waste. Nauc  r and Enkvist (2009) reported that MSW recycling is a cost-effective measure for solving the MSW crisis and can also reduce greenhouse

gas emissions concurrently. Nevertheless, 3R programs are still not widely successful for social structure/culture reasons, such as the lack of appropriate education on the management of MSW and the lack of incentives from utilizing the 3R approach. In general, global recycling and the policy for source reduction programs around the world can be summarized as in Table 2.8. Table 2.8 shows the recycling rate of Thailand is low compared with most high-income nations. Most countries with good recycling records often set targeted recycling rates. Thailand has yet to establish a mandatory targeted rate for recycling.

Recycling in developing countries tends to be practiced on a community or on a for-profit basis. The typical model of for-profit recycling involves informal waste workers, both in terms of ragpickers at landfills and itinerant recyclable buyers, diverting a portion of recyclable MSW from being sent to landfills. There are many settlements where informal waste workers perform multiple roles in servicing MSW collection processes, such as hauling waste from households, scavenging waste, and eventually discarding rejected waste to dumpsites, resulting in high diversion rates

Table 2.8 Recycling statutes and policies toward MSW reduction in various countries

Countries	Statutory required	Target recycling rates	Current rates	Source
Wales, U.K.	Yes	52	56	BBC (2015)
European Union	Yes	50	39	European Environment Agency (2013)
Virginia, U. S.A.	Yes	25	41.2	Virginia Department of Environmental Quality (2014)
Thailand	No	30	18.4	PCD (2015)
Vancouver, CA	Yes	70	60	Nagel (2014)
Singapore	Yes	70	60	National Environment Agency (2015)

Table 2.9 Estimated costs for MSW disposal (in USD)

	Low-income countries	Lower middle-income countries	Upper middle-income countries	High-income countries
Collection	20–50	30–75	40–90	85–250
Sanitary landfill	10–30	15–40	25–65	40–100
Open dumping	2–8	3–10	N/A	N/A
Composting	5–30	10–40	20–75	35–90
Waste-to-energy incineration	N/A	40–100	60–150	70–200
Anaerobic digestion	N/A	20–80	50–100	65–150

Source Adapted from Hoornweg and Bhada-Tata (2012)

of recyclables compared with those of urban settlements that do not allow informal recycling (Gunsilius et al. 2011).

For non-scavenging informal waste workers, itinerant recyclable buyers function as service providers for curbside recycling where households sell or donate recyclables to itinerant recyclable buyers. Itinerant recyclable buyers then gather those recyclables and resell them to recyclable buying centers, which is the equivalent of a drop-off recycling center in a formal recycling system. Nevertheless, the strong advantage of itinerant recyclable buyers and recyclable center buying is that they are self-funded, and the cost of running them is not a burden on the government or taxpayers, which is in contrast to the official curbside or drop-off recycling that may incur great costs to the public (Kinnaman and Fullerton 2000). The research by Chalcharoenwattana and Pharino (2016) employed an analytic hierarchical process (AHP) to nominate the best informal recycling modes. Itinerant recyclable buying is recommended for all urban settlements as an effective, informal MSW collection activity.

2.5 Waste Management Cost

In terms of MSW disposal, landfilling remains the most popular choice with waste management authorities in developing countries (Agamuthu 2013). Table 2.9 shows the cost of open dumping and landfilling tending to be at the lower range compared with other waste disposal methods (i.e., waste-to-energy or anaerobic digestion). Low-income countries continue to spend most of their SWM budgets on waste collection, with only a fraction going toward disposal. This is the opposite in high-income countries where the main expenditure is on disposal.

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Challenges for Sustainable Solid Waste Management

Lessons from Thailand

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