ACP-EU Cooperation Programme in Higher Education (EDULINK)
A programme of the ACP Group of States, with the financial assistance of the European Union.

CHE 5110 - INTRODUCTION TO SOLID WASTE MANAGEMENT

Waste generation and composition, national and international regulations for waste, waste avoidance, collection and transport of waste, separate collection of recyclables, sorting of recyclables, recycling technologies for paper, glass, metal, plastic, biological treatment of waste, waste disposal, ecological indicator systems, principles of waste management (e.g. European Union approach), polluter and producer pays principle, the precautionary principle, waste hierarchy, concept from cradle to grave.

CONTENTS

1. WASTE GENERATION

1.1. Introduction

Solid waste generation is the common basis for activity data to estimate emissions from solid waste disposal, biological treatment, and incineration and open burning of waste. Solid waste generation rates and composition vary from country to country depending on the economic situation, industrial structure, waste management regulations and life style. The availability and quality of data on solid waste generation as well as subsequent treatment also vary significantly from country to country. Statistics on waste generation and treatment have been improved substantially in many countries during the last decade, but at present only a small number of countries have comprehensive waste data covering all waste types and treatment techniques. Historical data on waste disposal at Solid Waste Disposal Sites (SWDS) are necessary to estimate methane (CH_4) emissions from this category. Very few countries have data on historical waste disposal going back several decades.

Solid waste is generated from households, offices, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction and demolition sites, agricultural activities, etc [Pipatti et al., 2006] and include the following waste types:

- garden (yard) and park waste
- wood
- nappies (disposable diapers)
- rubber and leather
- glass (and pottery and china)
- other (e.g., ash, dirt, dust, soil, electronic waste)
- Putrescible materials (food remnants, leaves, dead animals, etc.),
- Plastics (plastics and plastic films like cellophane),
- Paper (cartons and other paper to be separated),
- Metals (ferrous and non-ferrous to be separated),
- Textiles,
- Fines (ash, dust, etc.), and
- Miscellaneous (wood, discarded hardware, discarded shoes and other footwear, stones, dry cells, batteries, etc.).

1.2. Solid Waste categories

1.2.1. Municipal waste

Municipal Solid Waste (MSW) is generally defined as waste collected by municipalities or other local Authorities (LAs). However, this definition varies by country. Typically, MSW includes waste concluding from:

- **Households.** Household waste or domestic waste is the waste generated by households. It must be discerned from MSW, which is the waste collected by the municipal collection systems. Household waste can be divided mainly into paper and cardboard, glass, plastics, organic fractions, hazardous waste, bulky waste and also garden (yard) and park waste.

- Commercial establishment. It includes waste from shops and other service providers (restaurants, etc) and it is essentially composed of packaging waste and organic waste from markets and restaurants.
- Institutions (schools, hospitals and government offices). This kind of waste includes wastes from public and private offices and institutions which belong to the so-called service sector. The amount of waste and the composition are often not very well known. Although similar to household waste, some extra fractions of paper, glass and plastics can be expected. Medical hazardous waste from hospitals should qualify for consideration, but it will not be considered throughout these guidelines.
- Industries. It is the waste from industrial production, including related functions like canteens, administration, etc. This category of waste can be split into various fractions depending on the main industries in the city concerned. They often contain a fraction of hazardous waste that has to be collected and treated separately.

Table 1 presents waste fractions of the different sources of the waste stream.

Table 1. Waste fractions [MedCities, 2001].

	Households	Commercial, institutions	Industry
Glass	x	x	
Cans	x	x	
Paper and cardboard	x	x	x
Plastics	x	x	x
Food and organic waste	x	x	x
Furniture, etc	x	x	
Refrigerators, etc	x		
Electronic waste	x	x	x
Scrap metal	x	x	x
End of life vehicles	x		x
Garden and park waste	x	x	
Hazardous waste	x	x	x
Tyres		x	x
Sludge			x
Medical waste		x	

Region-specific default data on per capita MSW generation and management practices are provided in Table 2. These data are estimated based on country-specific data from a limited number of countries in the regions.

Table 2. MSW generation and treatment data from various regions [Pipatti et al, 2006].

Region	MSW Generation Rate (1,2,3) (tones/cap/yr)	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management unspecified (4)
Asia					
Eastern Asia	0.37	0.55	0.26	0.01	0.18

Region	MSW Generation Rate (1,2,3) (tones/cap/yr)	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management unspecified (4)
South-Central Asia	0.21	0.74	-	0.05	0.21
South-Eastern Asia	0.27	0.59	0.09	0.05	0.27
Africa[5]	0.29	0.69	-	-	0.31
Europe					
Eastern Europe	0.38	0.90	0.04	0.01	0.02
Northern Europe	0.64	0.47	0.24	0.08	0.20
Southern Europe	0.52	0.85	0.05	0.05	0.05
Western Europe	0.56	0.47	0.22	0.15	0.15
America					
Caribbean	0.49	0.83	0.02	-	0.15
Central America	0.21	0.50	-	-	0.5
South America	0.26	0.54	0.01	0.003	0.46
North America	0.65	0.58	0.06	0.06	0.29
Oceania[6]	0.69	0.85	-	-	0.15

[1] Data based on weight of wet waste.
[2] To obtain the total waste generation in the country the per-capita values should be multiplied with the population whose waste is collected. In many countries, especially Developing Countries (DCs), this encompasses only urban population.
[3] The data are default data for 2000, although for some countries the year for which the data are applicable was not given in the reference, or data for the year 2000 were not available.
[4] Other, unspecified, includes data on recycling for some countries.
[5] A regional average is given for the whole of Africa as data are not available for more detailed regions within Africa.
[6] Data for Oceania are based only on data from Australia and New Zealand.

Waste composition is one of the main factors influencing emissions from solid waste treatment, as different waste types contain different amount of Degradable Organic Carbon (DOC) and fossil carbon. Waste compositions, as well as the classifications used to collect data on waste composition in MSW vary widely in different regions and countries (see Table 3).

Table 3. MSW composition data by percent - regional defaults [Pipatti et al, 2006].

Region	Food waste	Paper/cardboard	Wood	Textiles	Rubber/leather	Plastic	Metal	Glass	Other
ASIA									
Eastern Asia	26.2	18.8	3.5	3.5	1.0	14.3	2.7	3.1	7.4
South-Central Asia	40.3	11.3	7.9	2.5	0.8	6.4	3.8	3.5	21.9
South-	43.5	12.9	9.9	2.7	0.9	7.2	3.3	4.0	16.3

Region	Food waste	Paper/cardboard	Wood	Textiles	Rubber/leather	Plastic	Metal	Glass	Other
Eastern Asia									
Western Asia & Middle east	41.1	18.0	9.8	2.9	0.6	6.3	1.3	2.2	5.4
AFRICA									
Eastern Africa	53.9	7.7	7.0	1.7	1.1	5.5	1.8	2.3	11.6
Middle Africa	43.4	16.8	6.5	2.5		4.5	3.5	2.0	1.5
Northern Africa	51.1	16.5	2	2.5		4.5	3.5	2	1.5
Southern Africa	23	25	15						
Western Africa	40.4	9.8	4.4	1.0		3.0	1.0		
EUROPE									
Eastern Europe	30.1	21.8	7.5	4.7	1.4	6.2	3.6	10.0	14.6
Northern Europe	23.8	30.6	10.0	2.0		13.0	7.0	8.0	
Southern Europe	36.9	17.0	10.6						
Western Europe	24.2	27.5	11.0						
OCEANIA									
Australia & New Zealand	36.0	30.0	24.0						
Rest of Oceania	67.5	6.0	2.5						
AMERICA									
North America	33.9	23.2	6.2	3.9	1.4	8.5	4.6	6.5	9.8
Central America	43.8	13.7	13.5	2.6	1.8	6.7	2.6	3.7	12.3
South America	44.9	17.1	4.7	2.6	0.7	10.8	2.9	3.3	13.0
Caribbean	46.9	17.0	2.4	5.1	1.9	9.9	5.0	5.7	3.5

1.2.2. Sludge

Sludge from domestic and industrial wastewater treatment plants is addressed as a separate waste category. In some countries, sludge from domestic wastewater treatment is included in MSW and sludge from industrial wastewater treatment in industrial waste. Countries may also include all sludge in industrial waste. When country-specific categorisation is used, it should be documented transparently.

1.2.3. Industrial waste

In some countries, significant quantities of organic industrial solid waste are generated. Industrial waste generation and composition vary depending on the type of industry and processes/technologies in the concerned country. Countries apply various categorisations for industrial waste. For example, construction and demolition waste can be included in industrial waste, in MSW, or defined as a separate category. The default categorisation used here assumes construction and demolition waste are part of the industrial waste (Table 4). In many countries industrial solid waste is managed as a specific stream and the waste amounts are not covered by general waste statistics.

These statistics are published periodically. In most DCs industrial wastes are included in the MSW stream; therefore, it is difficult to obtain data of the industrial waste separately.

Industrial solid waste disposal data may be obtained by surveys or from national statistics. Only those industrial wastes which are expected to contain DOC and fossil carbon should be considered for the purpose of emission estimation from waste. Construction and demolition waste is mainly inert (concrete, rubble, etc.) but may contain some DOC (see Section 2.3.3) in wood and some fossil carbon in plastics. Recycling and reduction using different technologies applied to industrial waste prior to disposal in SWDS or incineration should be taken into account, where data are available.

Table 4. Industrial waste generation per region/country in 1,000 tonnes per year (data are based on weight of wet waste) [Pipatti et al, 2006].

Region/Country	Total	Manufacturing industries	Construction
ASIA			
China	1,004,280		
Japan		120,050	76,240
Singapore	1,432.5		
Republic of Korea		39,810	28,750
Israel	1,000		
EUROPE			
Austria		14,284	27,500
Belgium		14,144	9,046
Bulgaria		3,145	7
Croatia		1,600	142
Czech Republic		9,618	5,078
Denmark		2,950	3,220
Estonia	1,261.5		
Finland		15,281	1,420
France		98,000	
Germany		47,960	231,000
Greece		6,680	1,800
Hungary		2,605	707
Iceland		10	
Ireland		5,361	3,651
Italy		35,392	27,291
Latvia	1,103	422	7
Malta		25	206

Region/Country	Total	Manufacturing industries	Construction
Netherlands		17,595	23,800
Norway		415	4
Poland		58,795	143
Portugal		8,356	85
Romania		797	
Slovakia		6,715	223
Slovenia		1,493	
Spain		20,308	
Sweden		18,690	
Switzerland		1,470	6,390
Turkey		1,166	
UK		50,000	72,000
OCEANIA			
Australia		37,040	10
New Zealand		1,750	NR

1.2.4. Other waste

Medical waste: These wastes include materials like plastic syringes, animal tissues, bandages, cloths, etc. Some countries choose to include these items in the MSW. Medical waste is usually incinerated. However, some of them may be disposed in MSW stream.

Hazardous waste: Waste oil, waste solvents, ash, cinder and other wastes with hazardous nature, such as flammability, explosiveness, causticity, and toxicity, are included in hazardous waste. Hazardous wastes are generally collected, treated and disposed separately from non-hazardous MSW and industrial waste streams. Some hazardous wastes are incinerated and can contribute to the fossil CO_2 emissions from incineration [EUROSTAT, 2005]. Neutralisation and cement solidification are also treatment processes for hazardous waste.

In many countries it is prohibited to dispose hazardous waste at MSW stream without pre-treatment.

Agricultural waste: Agricultural waste which will be treated and/or disposed with other solid waste may however be included in MSW or industrial waste. For example, such waste may include manure, agricultural residues, dead body of live stock, plastic film for greenhouse and mulch.

1.3. Qualitative and quantitative analysis of Solid Waste

To develop an effective waste management strategy for a given region, it is important to know the amount of waste generated and the composition of the waste stream. Past research has shown that the amount of waste generated is proportional to the population and the average mean living standards or the average income of the people. In addition, other factors may affect the amount and composition of waste. These are climate, living habits, level of education, religious and cultural beliefs, and social and public attitudes. However, it has been shown that these are not the only governing factors. Amongst other socioeconomic factors that have been said to influence MSW generation are persons per dwelling, cultural patterns, education, and personal attitudes.

A more accurate but data intensive approach to data collection is to follow the streams of waste from one treatment to another taking into account the changes in composition and other parameters that affect emissions. Waste stream analyses should be combined with high quality country-specific data on waste generation and management. The approach is often complemented with modeling. When using this approach, it is good practice to verify the data using separately collected data on MSW generation, treatment and disposal, especially in cases where they are based largely on modeling. This method is only more accurate than the approaches given above if countries have good quality, detailed data on each end point and have verified the information [Pipatti et al, 2006].

Although models are available to predict waste generation patterns in developed countries, very little research has been done so far to develop models applicable in DCs. Models are available to predict the gross waste generation capacity of countries. But, these are not adequate for developing integrated waste management plans for municipalities or regions, since waste generation patterns are unique to regions. There is a necessity for waste generation prediction models for suburban municipalities in DCs. Such municipalities are fast growing and lack basic infrastructure for waste management.

To develop an integrated waste management plan, a variety of waste specific data is required. To determine the resources required for waste management and for sizing of waste management facilities, an accurate estimate of current and future total waste generation is required. The per capita waste generation rate is needed to predict future waste generation rates and for evaluating the waste generation trends in given communities. Once developed, such information could be extrapolated to other communities with similar socio-economic conditions [Bandara et al., 2007].

1.3.1. Quantitative analysis

Although different methods of waste characterization are discussed in literature, the most common is the classical method of direct waste analysis. A comparison of this with two alternative methods, waste product analysis (analysis of products from waste processing) and market product analysis (material balance of market products) concludes that direct waste analysis is an appropriate method to determine MSW composition and determine the effect of spatial, temporal and socio-economical variations on MSW composition [Bandara et al., 2007].

Amounts of waste are largely determined by two factors: first, the population in any given area and second its consumption patterns- which are controlled by the evolution of Gross Domestic Product per capita (GDP/c) [Mavropoulos, 2010]. As the number of people in a household increases, there is a reduction in the per capita waste generation rate, thereby establishing the fact that when waste generation parameters are considered, per household waste generation is as important as the per capita waste generation rate. The number of employed people in a household also appears to be a contributing factor to waste generation. The average amounts of waste generated per households of different income levels can be used to predict the total amount of waste generated within a municipality [Bandara et al., 2007].

Some typical waste generation rates for low-income, middle-income and high income countries are shown in Table 5. In Figure 1 is presented the Solid Waste Management (SWM) generation in a specific area of Nigeria related to the population density and the activities taking place in the area.

Table 5. Waste Generation Rates (in kg/capita/day) [MedCities, 2001].

	Low-income country	Mid-income country	High-income country
Mixed urban waste Large city (>500000)	0.50-0.75	0.55-1.1	0.75-2.2
Mixed urban waste Small to medium city (<500000)	0.35-0.65	0.45-0.75	0.65
Residential waste only	0.25-0.45	0.35-0.65	0.55-1.0

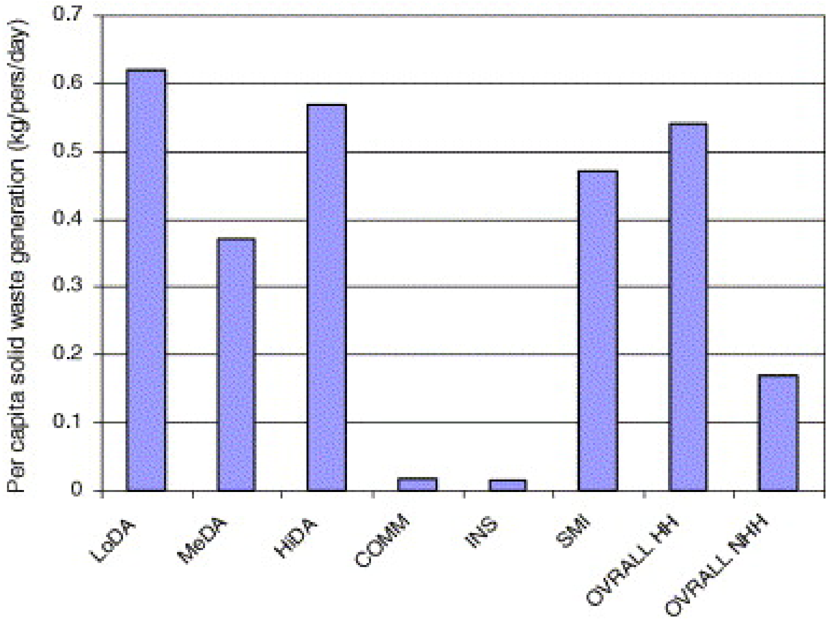

Figure 1. Per capita solid waste generation in relation to waste generator type in Makurdi Urban Area (Nigeria). (LoDA = low density residential area; MeDA = medium density area; HiDA = high density area; COMM = commercial premises; INS = institutional premises; SMI = small/medium scale industrial area; OVRALL HH = overall household areas; OVRALL NHH = overall non-household areas) [Sha'Ato et al., 2007].

According to the UN between now and 2025 the world population will increase by 20% to reach 8 billion inhabitants (from 6.5 today). It's important to note that 97% of this growth will happen in Asia and Africa which includes some of the poorest countries that have the least capability to absorb it. Besides overpopulation a remarkable increase in GDP/c especially in DC is on its way. The global average GDP/c around 2025 will be more or less one and half times the current one and in business-as-usual scenario it may be fourfold around 2050. DC GDP/c is estimated to be $40,000 which is the same as the USA GDP/c in 2005. Obviously both the increase of the population and the remarkable growth pf global GDP/c will drive an increase in waste volumes. Using macroeconomic data from 30 Organisation for Economic Cooperation and Development (OECD) countries it has been estimated that a 1% increase ion national income creates a 0.69% increase in MSW amount. Taking into consideration the WM field facts up to now (cc 2010) to reach to a conclusion that the bigger the GDP/c the more advanced and effective waste management systems are put in place. So this global GDP/c growth will certainly multiply modern landfills, efficient collection systems, MBT and WTE facilities around the world [Mavropoulos, 2010].

The most common approach to solid waste analysis is to collect a certain amount of MSW and take a number of samples, to screen, pulverize and analyze these samples for waste composition. This is known as 'Direct Waste Analysis'. The other approaches used for solid waste analysis include 'Waste Product Analysis' and 'Market Product Analysis'.

Direct Waste Analysis: In this process waste samples are collected from different communities or regions based on statistical evaluations. The sample size varies between a minimum of 50 kg to several tonnes. It consists of a full or partial content of a collection truck which follows a typical local route. These samples are classified by hand into a selected number of materials such as paper and glass. Mechanical equipment is commonly used to separate magnetic metals. In order to determine the chemical and physical parameters of each fraction, representative samples are drawn from each material. These samples are further prepared for laboratory analysis. Direct waste analysis is used for following tasks:

- To measure the concentration of most materials in MSW
- To determine the energy and water content of MSW and its fractions
- To investigate the influence of geographic, demographic and seasonal factors on the concentration of materials
- To assess changes of waste composition with time

In general, the direct waste analysis yields good results on some materials in MSW, but it is difficult and very labour intensive to determine elemental concentrations by this method.

Waste Product Analysis: In this process composition of MSW is calculated from the analysis of the composition of the products of waste treatment processing. For example analysis of the products of incineration or analysis of products of a refuse derived fuel process or analysis of compost from a MSW composting plant could yield individual elements of MSW. The waste product analysis is well suited for the determination of the elemental concentration of MSW.

Market Product Analysis: Goods are produced, consumed, and after use are recycled or discarded as a waste material. If the amount of a manufactured product can be given, and if the fate of these products during consumption is known, the amount of wastes can be calculated. Since many industries are able to supply highly accurate figures on their production, and since for certain goods the pathways of the goods are well known, it is possible to calculate the composition of MSW. For example this method could be used to determine accurately the amount of paper in MSW. The market product analysis is an inexpensive and quick method to determine with sufficient accuracy the material and elemental composition of MSW. This method is only limited to those materials where information from producing industries are available.

1.3.2. Qualitative analysis

Reliable information about factors that may influence municipal waste arising and composition is relevant for a variety of reasons such as planning of waste collection and treatment systems planning of waste analysis designs and forecasting future waste generation in a certain region.

Parameters often mentioned as effecting the arising and composition of municipal waste are: social factors such as age, sex, income, educational level, size and status of family; residential structure patterns such as one family houses vs. multi storey houses; waste management and organisational patterns such as source of waste (household waste/ commercial waste), bin size, collection system (door-to-door-system, drop-off-system, separate collection), waste fees; seasonal variations [Plöchl et al., 2003].

Density varies depending on the composition of waste. It is normally higher in residential areas where organic matter makes up a large proportion of the waste, and lower in commercial districts where waste contains more paper and cardboard. It also varies with the economic level, being less dense in high income areas where there is a higher percentage of packaging waste. Table 6 shows the density range of MSW.

Table 6. Typical density range of MSW at the generation point (in kg/m3) [UNCHS].

Country	Waste density (kg/m3)

High-income	100-175
Mid-income	175-330
Low-income	330-600

Knowing the waste density is necessary for the identification of the total weight of waste and the volume of waste included as this shall be treated separately. There is no comparable way to find out the SW density; an indicative density of various waste is presented in Table 7. The average moisture and density of MSW in a waste truck is 250-350 kg/m^3 whereas in the waste bin its 150-200 kg/m^3.

Table 7. Typical waste moisture percentiles and density per component.

Component	Moisture [%]	Density (kg/m^3)
Food waste	70	290
Paper	6	85
Cardboards	5	50
Plastic	2	65
Glass	2	195
Metals	3	210
Tins	3	90
Garden waste	60	105
Ash, dust, etc.	8	480
Leather	10	160
Textiles	10	240
Derbis (> 20 mm)	10	250
Derbis (< 20 mm)	8	480

Moisture content of solid waste is the weight loss (expressed in percent) when a sample of solid waste is dried to a constant weight at a temperature of 100 to 105 ºC. The percentage of moisture contained in a solid waste sample can be calculated on a dry or wet basis. Moisture content has a great influence on the heat of combustion as well as in the biological processes of organic matter. It depends on [MedCities, 2001]:

- organic content
- weather
- source
- Heat of combustion (= heating value)

The heating value of waste is a measure of the energy released when it is burned. A heating value of about 11.6 x 106 J/Kg is needed to sustain combustion. Waste with lower heating value can be burned, but it will not maintain adequate temperature without the addition of auxiliary fuel. The heat of combustion increases when there is more paper, cardboard and plastic in waste because they have a high heating value, and decreases when there is a high content of organic matter, and therefore, of moisture.

CN ratio is the ratio of the weight of carbon to the weight of nitrogen present in compost or in materials that are being composted. It is an important parameter in composting processes and should always be between 20 and 35. Lower ratios indicate the loss of nitrogen as ammonium gas and render composting impractical [MedCities, 2001].

Speaking again globally remarkable changes to waste composition are coming; below two of the main reasons are highlighted [Mavropoulos, 2010]:

- The first will be due to changing food culture and habits in DC. As GDP/c is growing it is expected that by 2050 the demand for agricultural goods will rise by 70% and the demand for meat will double. Besides the serious issues related to food production and sustainability, those changes will change the waste composition in a large part of the world. The organic fraction will be more dominant in MSW, more agricultural and more meat waste will create new problems that have to be faced. And of course such a change in waste composition makes the greenhouse gas challenge for waste management more difficult than it is already. It has been estimated that urban food waste is going to increase by 44% globally between 2005 and 2025. During the same period and because of its expected economic development, Asia is predicted to experience the largest increase in food waste production from 278 million to 416 million tonnes (252 million to 377 million tonnes). If present waste management trends are maintained, landfilled food waste is predicted to increase world CH4 emissions from 34 million to 48 million tonnes (31 million to 43 million tonnes) and the landfill share of global anthropogenic emissions from 8% to 10%.
- The second serious change will be due to the production, consumption and inclusion in waste streams of more and more complex products*. The plethora of new products will be rapidly expanded, consumed and finally transformed to new waste streams before an effective waste management solution is established for them. Past experience has shown that problems with managing new kinds of waste emerge after the product has been consumed. The time taken to establish new separate waste streams network or a new technical solution for new waste stream generally is by far longer than the lag-time between production of a new product and its transformation to waste.

2. SOLID WASTE MANAGEMENT

2.1. Introduction

Waste production is closely correlated with GDP but collection, recovery and recycling rates vary enormously between countries. E.g. Poland sends about 90% of its MSW to landfill sites but the Netherlands disposes just 1.7% of its waste this way. Japan incinerates the most MSW (49%), while South Korea has the best recycling rate for MSW (49%). Availability of land and suitability of soils are a major factor in deciding whether to landfill waste but ecological awareness, legal constraints, degree of economic development and climatic factors also determine the choice of disposal or recovery route [WWW, 2010].

At this time SWM must deal with the following problems and issues [Bilitewski et al., 1997]:

- Waste incineration has met acceptance problems;

* *Personalised medicine, new computer and gadgets, networked homes and full home management systems, fully customised consumer products, personal security and personal energy products are coming of are already here.*

- A landfill presents a future liability and existing landfills can only be used to a limited degree;
- Composting must produce a marketable product and only the use of bio-waste as input makes sense;
- Process like pyrolysis are still not used on a large scale;
- New low-waste processes should be used in new industrial facilities;
- The strategies for source separation have to be optimized;
- Disassembly and building deconstruction techniques can be applied to many consumer products at the end of their useful life; and
- Little effort has been made to promote waste avoidance.

2.2. Waste management in European Union

According to European Union (EU) "every year, some 2 billion tonnes of waste - including particularly hazardous waste - are produced in the Member States, and this figure is rising steadily. Stockpiling waste is not a viable solution and destroying it is unsatisfactory due to the resulting emissions and highly concentrated, polluting residues. The best solution is, as always, to prevent the production of such waste, reintroducing it into the product cycle by recycling its components where there are ecologically and economically viable methods of doing so" [EUROPA, 2010]. Also "with a view to breaking the link between growth and waste generation, the EU has provided itself with a legal framework aimed at the whole waste cycle from generation to disposal, placing the emphasis on recovery and recycling".

Towards achieving its environmental targets EU introduced the Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. This Directive establishes a legal framework for the treatment of waste within the Community. It aims at protecting the environment and human health through the prevention of the harmful effects of waste generation and waste management. The generation of waste is increasing within the EU. It has therefore become of prime importance to specify basic notions such as recovery and disposal, so as to better organise waste management activities.

It is also essential to reinforce measures to be taken with regard to prevention as well as the reduction of the impacts of waste generation and waste management on the environment. Finally, the recovery of waste should be encouraged so as to preserve natural resources. This Directive repeals directives 75/439/EEC, 91/689/EEC and 2006/12/EC.

According to a study by Eurostat 524 kg of MSW was generated per person in 2008 across the Eu-27 countries. This figure was similar to the 2007 figure of 525 kg per person. When looking at how this waste was dealt with the figures show that 40% was landfilled, 20% incinerated, 23% recycled and 17% composted. The amount generated per person varies greatly across the different countries in EU from 306 kg in the Czech Republic to 802 kg in Denmark. This reflects the different consumption patterns and the ways each country calculates their totals. Some for instance include waste from small business and public institutions. Austria, Germany and the Netherlands recycled or composted between 60 and 70% of their MSW but then member states recycling and composting was used to treat less than 10% of the waste. Member states with the highest rates of landfill were Bulgaria (100%), Romania (98%), Malta (97%), Lithuania (96%) and Latvia (93%). The highest numbers for incineration were Denmark (54%), Sweden (49%), the Netherlands (39%), Belgium and Luxembourg (36%), Germany (35%) and France (32%). Ten countries rates of less than 1% incineration. The importance of these two treatment categories varies considerably between member states. The member state with the highest recycling rates for MSW were Germany (48% of the waste treated), Belgium and Sweden (both 35%), Ireland and the Netherlands (both 32%) and Slovenia (31%). Composting of MSW was most common in Austria (40%), Italy (34%), the Netherlands (27%), Belgium (25%), Spain and Luxembourg (both 20%) [WWW, 2010].

Waste export from EU is another important issue; from 2000 to 2008 the European exports of plastic waste rose by 250% reaching 2.27 million tonnes- approximately 5 million tonnes are annually recycled in Europe. Around 87% of these exports are going to China, including Hong Kong. The global financial crisis seems to have worsened the situation as the first quarter of 2009 saw a 33% increase in exports compared to the previous year. Between 1995 and 2007 the amount of non-hazardous waste exported to Asia increased tenfold for waste paper, elevenfold for plastics and fivefold for metals. At the same time just for a comparison, the amount of paper and cardboard packaging waste recycled has increased from about 24 to 30 million tonnes (21.7 to 27 million tonnes) and the amount of plastic packaging recycled has increased from about 10 to 14 million tonnes (9 to 12.7 million tonnes) [Mavropoulos, 2010].

2.3. Waste management in developing countries

A new report commissioned by environment Services Company (VEOLIA) [WWW, 2010] states that the world market for waste is worth around € 300 billion. Almost 4 billion tonnes of municipal, industrial and hazardous waste are produced every year. In fact those figures are just an estimate as data is difficult to gather particularly in DC.

In many countries of the developed nations the management of solid and liquid wastes is being undertaken by the private sector under contracts given to the LA. There is a wide spectrum of potential areas of an investment return in the waste management sector. Some studies conducted by the World Bank and the UNDP show the existence of informal waste management networks in DCs. The LAs share their knowledge on techniques through partnerships as to how to tackle the issue of solid wastes. The informal management of waste could not only reduce the waste collection costs but it could also improve income generation and generate employment avenues among the urban poor.

MSW is a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region. The characteristics and quantity of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources. Urban wastes can be subdivided into two major components -- organic and inorganic. In general, the organic components of urban solid waste can be classified into three broad categories: putrescible, fermentable, and non-fermentable. Putrescible wastes tend to decompose rapidly and unless carefully controlled, decompose with the production of objectionable odours and visual unpleasantness. Fermentable wastes tend to decompose rapidly, but without the unpleasant accompaniments of putrefaction. Non-fermentable wastes tend to resist decomposition and, therefore, break down very slowly. A major source of putrescible waste is food preparation and consumption. As such, its nature varies with lifestyle, standard of living, and seasonality of foods. Fermentable wastes are typified by crop and market debris.

The primary difference between wastes generated in DCs and those generated in industrialised countries is the higher organic content characteristic of the former. The extent of the difference is indicated by the data in Table 8, in which is presented information relative to the quantity and composition of MSW generated in several countries.

Wastes generated in countries located in humid, tropical, and semitropical areas usually are characterised by a high concentration of plant debris; whereas those generated in areas subject to seasonal changes in temperature or those in which coal or wood are used for cooking and heating may contain an abundance of ash. The concentration of ash may be substantially higher during winter. Regardless of climatic differences, the wastes usually are more or less contaminated with nightsoil. These differences prevail even in wastes generated in large metropolitan areas of a DC.

Ideally, solid waste should not contain faecal matter or urine, and the mixing of these materials with household waste should be prohibited by law. However, enforcement difficulties, combined with variations in way of life, necessitate some tolerance in this matter.

Table 8. Comparison of solid waste characterisation world wide (%wet wt) [CalRecovery, 2005].

Location	Putres-cibles	Paper	Metals	Glass	Plastics, Rubber, Leather	Textiles	Ceramics, Dust, Stones	Wt (g/cap/day)
Bangalore, India	75.2	1.5	0.1	0.2	0.9	3.1	19.0	400
Manilla, Philippines	45.5	14.5	4.9	2.7	8.6	1.3	27.5	400
Asuncion, Paraguay	60.8	12.2	2.3	4.6	4.4	2.5	13.2	460
Seoul, Korea	22.3	16.2	4.1	10.6	9.6	3.8	33.4[a]	2,000[a]
Vienna, Austria	23.3	33.6	3.7	10.4	7.0	3.1	18.9[b]	1,180
Mexico city, Mexico	59.8[c]	11.9	1.1	3.3	3.5	0.4	20.0	680
Paris, France	16.3	40.9	3.2	9.4	8.4	4.4	17.4	1,430
Australia	23.6	39.1	6.6	10.2	9.9		9.0	1,870
Sunnyvale, California, USA	39.4[d]	40.8	3.5	4.4	9.6	1.0	1.3	2,000
Bexar County, Texas, USA	43.8[d]	34.0	4.3	5.5	7.5	2.0	2.9	1,816

[a] Includes briquette ash (average).
[b] Includes "all others".
[c] Includes small amounts of wood, hay and straw.
[d] Includes garden waste.

Solid waste collection in a manner satisfactory with respect to environmental health is made difficult when human excretory wastes are mixed with household wastes. Handling of pathological wastes, abattoir wastes, industrial wastes, and similar materials, in association with household wastes, also should not be permitted. Nevertheless, it is important to keep in mind that despite all precautions, some pathogens and chemical residues inevitably will be present in the waste.

Developed countries learned from their own experience but the DCs have an advantage of starting off from a more elevated 'ground zero': they also have the opportunity to learn from the mistakes of developed world. DCs are advised to take note of the overarching issues regarding consumption and disposal and find the value in waste.

2.4. Kyoto protocol and the Clean Development Mechanism

The Clean Development Mechanism (CDM) is an arrangement under the Kyoto Protocol allowing industrialised countries with a greenhouse gas reduction commitment to invest in ventures that reduced emissions in DCs as an alternative to more expensive reductions in their own countries. The CDM allows net greenhouse gas emissions to be reduced at a much lower global cost by financing emissions reduction projects in DCs where costs are lower than in industrialised countries. The CDM allows emission- reduction projects to DCs to earn CER credits, equivalent to one tonne of CO_2. These CERs can be traded and used by industrialised countries to a meet their emission reduction targets under the Kyoto Protocol [Kim, 2010].

The CDM, which was designed for promoting the cooperation between developing and developed countries. CDM may add to economic viability of projects that are already economically sound, while facilitating the Technology Transfer. Appropriate public–private linkage would be necessary in order to bring the CDM into full play. With the potential value of CDM taken into account there is a chance of economic viability of the combined scenario, which is also the best from the CO_2 emissions point of view. Figure 2 illustrates the CDM projects worldwide and Figure 3 the area those projects' focus.

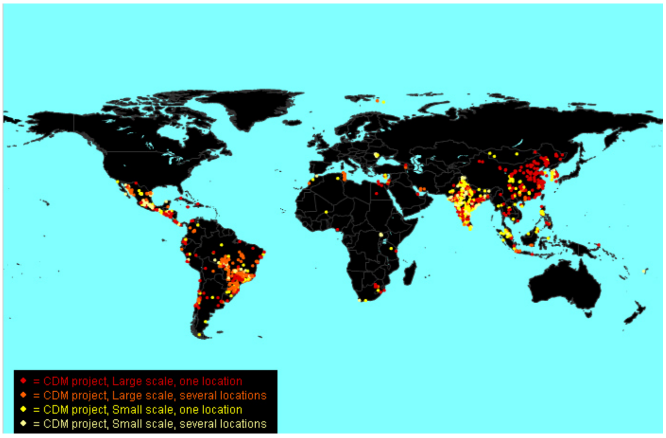

Figure 2. Clean Development Mechanism projects worldwide.

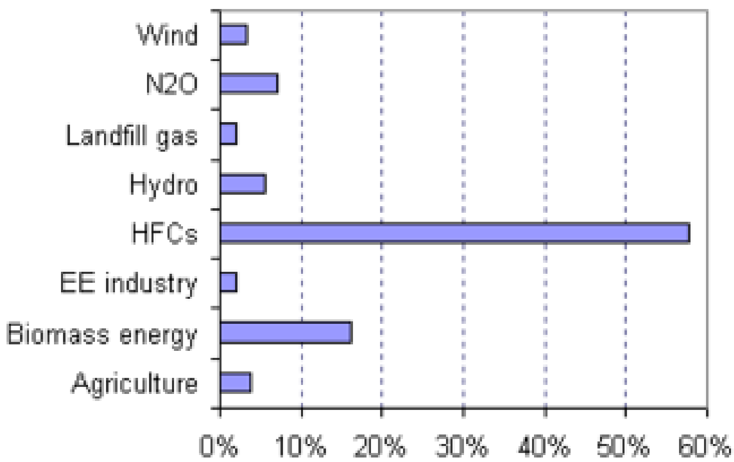

Figure 3. Clean Development Mechanism projects to date [UNFCCC , 2007].

The CDM represents an opportunity to attract investments from the public and private sectors in climate-friendly technologies, and to contribute to the global combat on climate change. In order to be eligible, CDM projects have to be above and beyond business-as-usual, and must contribute to sustainable development as defined by the host country (DC) and one of the sectors with major potential for CDM projects is the energy sector. The CDM offers a route to attracting investment to rehabilitate existing sites and new facilities [Karagiannidis et al., 2008].

Since the CDM is project-based, the host country government and business communities must have a good understanding about the mechanism and good knowledge about information search, negotiation, validation, registration, monitoring and certification. This is very challenging for many DCs.

The CDM was proposed in the Kyoto Protocol as a means of obtaining the cooperation of DCs in controlling GHG (c.f. Figure 4), but it has some intrinsic problems and has generated considerable controversy as listed below; specifically CDM projects:

- may cause carbon leakages within the host country or/and domestic carbon leakages because the CDM is project-based. Abatement activities of the CDM projects might result in a movement of the GHG emissions into the non-CDM projects. Currently, few CDM projects take account of the leakage effects as the insufficient leakage accounting will affect the evaluation of the CDM projects.
- are project-based so the host country government and business communities must have a good understanding about the mechanism and good knowledge about information search, negotiation, validation, registration, monitoring and certification. This is very challenging for many DCs.
- put forward a number of concerns for DC: (a) the CDM investors would choose the most lucrative projects and leave DCs with only high-cost options; (b) the CDM would interfere with national sovereignty and distort development priorities; (c) developed countries would transfer concerns are groundless. The CDM was proposed for environmental and development concerns, but the investment in CDM projects is mainly a business activity rather than an environmental protection action or an aid for development likely to exhaust the DCs' low-cost abatement options with little promotion for their sustainable development.

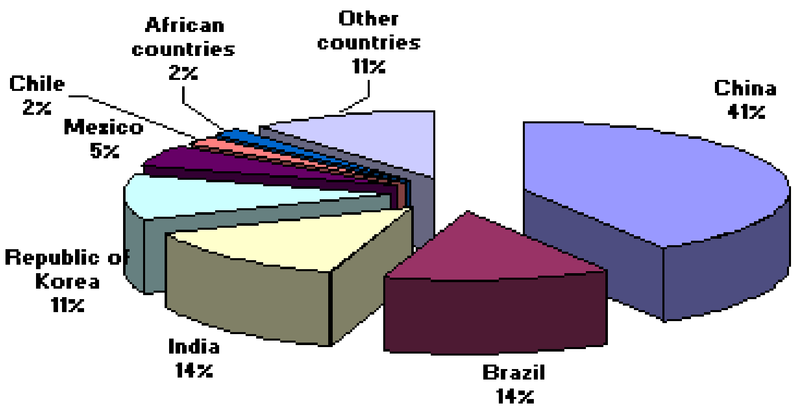

Figure 4. Distribution of CDM emission reductions, by country [UNFCCC, 2007].

3. WASTE HIERARCHY

In order to better protect the environment, the Member States of EU and all states should take measures for the treatment of their waste in line with the following hierarchy which is listed in order of priority (see Figure 5):

Figure 5. Waste hierarchy [CLEANAWAY, 2010].

- prevention. This strategy sets out guidelines and describes measures aimed at reducing the pressure on the environment caused by waste production and management. The main thrust of the strategy is on amending the legislation to improve implementation, and on preventing waste and promoting effective recycling.
- preparing for reuse;
- recycling;
- other recovery, notably energy recovery; and
- disposal.

Waste avoidance and utilization can be seen as part of a broader hierarchy of approaches to achieving sustainable development. At the highest level are approaches that seek to satisfy human needs and requirements in ways that do not waste resources or generate harmful by-products or residuals. These approaches include changing consumer behavior and re-examining the range and character of the products and services produced.

At a slightly lower level are efforts to redesign products and services and to raise consumers' awareness about the impacts of their decisions. Application of techniques such as Life Cycle Analysis (LCA) is part of the difficult analysis of the overall impacts of products and services on the environment. Such approaches are at present adopted mainly by the more advanced organizations in industrial countries.

More directly relevant to industrial activity in DCs are approaches focused on improvements in production processes. These approaches include cleaner production, pollution prevention, and waste minimization, all of which are related, to a greater or lesser degree, to better management, improvements in production processes, substitution of hazardous inputs, reuse and recycling of wastes, and so on.

The main SW reduction benefits are indicated below [TAF, 2008]:

- Saves natural resources. Waste is not just created when people throw items away. Throughout the life cycle of a product or package - from extraction of raw materials, to transportation, to processing and manufacturing facilities, to manufacture and use - waste is generated. Reusing items or making them with less material decreases waste dramatically. Ultimately, fewer materials will need to be recycled or collected and sent to disposal sites or waste combustion facilities.
- Reduces toxicity of waste. Selecting non-hazardous or less hazardous items is another important

component of source reduction. Using less hazardous alternatives for certain items (e.g. cleaning products and pesticides), sharing products that contain hazardous chemicals instead of throwing out leftovers, reading label directions carefully, and using the smallest amount necessary are ways to reduce waste toxicity.

- Reduces costs. The benefits of preventing waste go beyond reducing reliance on other forms of waste disposal. Preventing waste can also mean economic savings for LAs, businesses, schools and individual consumers (e.g in most LAs in Sri Lanka, it is estimated that 15 - 25 % of the annual budget is utilized for SWM, out of which 60 – 70 % is spent on collection and transport of waste). By reducing the amount of waste to be collected, LAs could use savings to expand or improve these services.

Industry also has an economic incentive to practice source reduction. When businesses manufacture their products with less packaging, they are buying fewer raw materials. A decrease in manufacturing costs can mean a larger profit margin, with savings that can be passed on to the consumer.

Consumers can also share in the economic benefits of source reduction. Buying products in bulk, with less packaging, or items that are reusable (not single-use) frequently means a cost saving. What is good for the environment can be good for the wallet as well.

LAs have the opportunity to see monetary, environmental and quality of life benefits by waste reduction. These opportunities will help create a cleaner environment, create efficiencies for the constituents of the LA through the advantages provided by solid waste reduction.

The next step, which should be minimized but is not to be neglected, is treatment and proper disposal of wastes. The lowest level in the hierarchy, and the one that all the other levels strive to eliminate, is remediation of the impacts of wastes discharged to the environment. Cleanup is costlier than prevention [WPG, 1998].

Waste minimization is one of a number of related terms and concepts that, despite having similar overall goals and often being used interchangeably may differ significantly in basic principles and in emphasis.

Avoidance refers to actions by the producer to avoid generating the waste.

Utilization includes the range of actions that make the waste a useful input to other processes, eliminating the need for disposal. Waste minimization thus comprises both avoidance and utilization. Processes that reduce the toxicity or potentially harmful impacts of a waste can in some cases be regarded as minimization, although in other circumstances such changes represent treatment before disposal. Although the terminology used may vary, a number of important activities can be distinguished.

Reuse refers to the repeated use of a “waste” material in a process (often after some treatment or makeup).

Recycling refers to the use by one producer of a waste generated by another.

Recovery is the extraction from a waste of some components that have value in other uses.

The need to avoid or minimize the release of complex organic or inorganic substances into the environment is all the greater because of uncertainty about their effects on human health and the natural environment and the very high costs of retrofitting or cleanup. At the same time a realistic attitude must be maintained regarding DCs. Much industrial and product design is based on industrial country practice, and almost all of the fundamental science on which regulation is based has been carried out in the more advanced economies. Although there will be some opportunities to leapfrog to more sophisticated systems, the priority in DCs should be to ensure that policymakers and regulators are up-to-date and informed and avoid repeating fundamental mistakes made in the course of industrialization elsewhere.

A particular challenge for DCs is to take advantage of affordable and productive technologies from industrial countries without allowing the importation of outdated or outlawed equipment or substances. Technologies and materials science are changing rapidly, but so are the sources of information. Environmental agencies in DCs that do not have the resources to carry out their own research can find much of the necessary information publicly available, although an investment of time and resources will frequently be needed to find the appropriate answers.

Waste management efforts are linked closely with income levels. There is a broad progression from recycling of most materials in the poorest societies, through increasing consumerism—often with little concern for waste problems—in low- and middle-income countries, to the environmental activism of some rich countries. The appropriate waste avoidance and utilization strategy for any situation must take into account the level of the economy, the capabilities of government at different levels, and the environmental circumstances. As with any other environmental strategy, there is a need for public involvement and political support in the identification of priorities and the implementation of the necessary enabling measures [WBG, 1998].

Efforts must be made to involve both producers and consumers in waste minimization and utilization. Producers can improve their performance through both management changes and technological improvement; some producers in industrial countries are now making serious efforts to examine the impacts not only of their production processes but also of the products themselves. LCA is still an evolving tool, but it does focus attention on the overall impact of the production, use, and disposal of products.

Consumers in some of the wealthier countries are moving toward a greater awareness about the need for waste reduction, as shown by participation in recycling schemes and some demand for environmentally friendly products. However, progress is often slow, and there is a need for ongoing education and awareness, as well as careful analysis of options and incentives. In DCs, the demand for resources often leads to significant recycling of materials such as glass, metals, and plastics. These recycling systems have important social and economic consequences at the local level, and their "improvement" must be approached with care.

4. THE MAIN PRINCIPLES IN SOLID WASTE MANAGEMENT

In some rural or non-industrialized areas, wastes are typically organic or inert and do not pose major disposal problems, particularly since they are often utilized for animal food or other purposes. However, as the level of industrialization increases, or even simply as a result of growing access to packaged and consumer goods, waste disposal becomes an increasing problem in virtually all societies. The problems are typically associated with non-biodegradable or bioaccumulative substances such as waste pesticides, solvents, heavy metals, and chemical sludges. These are often production wastes, but they can also arise from inappropriate application (pesticides) or poor consumer behavior (waste motor oils). The development and widespread use of new substances such as plastics and the products that they have made possible have improved the standard of living for millions, but they have also introduced new threats to the environment, as typified by the histories of DDT and polychlorinated biphenyls (PCBs).

The long-term solution to the problem of persistent or hazardous wastes must lie in efforts to find alternatives to the hazardous substances. In the meantime, high priority should be given to minimizing the use of resources and reducing the discharge of wastes.

Environmental policy measures can be ranked as follows [Bilitewski et al., 1997]:

- Regulatory measures, such as mandates and bans
- Pro-active measures initiated by public institutions through support, advice or compensatory measures
- Planning measures based on specific programs.

4.1. The Precautionary Principle

Precaution – the "Precautionary Principle" (PP) or "precautionary approach" – is a response to uncertainty, in the face of risks to health or the environment. In general, it involves acting to avoid serious or irreversible potential harm, despite lack of scientific certainty as to the likelihood, magnitude, or causation of that harm.

Precaution is now an established principle of environmental governance, prominent in law, policy and management instruments at international, regional and domestic level, across such diverse areas as pollution, toxic chemicals, food and phytosanitary standards, fisheries management, species introductions and wildlife trade [PPP, 2003].

The PP has its beginnings in the German principle of Vorsorge, or foresight. At the core of early conceptions of this principle was the belief that society should seek to avoid environmental damage by careful forward planning, blocking the flow of potentially harmful activities. The Vorsorgeprinzip developed in the early 1970s into a fundamental principle of German environmental law (balanced by principles of economic viability) and has been invoked to justify the implementation of vigorous policies to tackle acid rain, global warming, and North Sea pollution. It has also led to the development of a strong environmental industry in that country.

The PP has since flourished in international statements of policy; conventions dealing with high-stakes environmental concerns in which the science is uncertain; and national strategies for sustainable development. The principle was introduced in 1984 at the First International Conference on Protection of the North Sea. Following this conference, the principle was integrated into numerous international conventions and agreements, including the Bergen declaration on sustainable development, the Maastricht Treaty on the EU, the Barcelona Convention, and the Global Climate Change [Tickner et al., 2005].

One of the most important expressions of the PP internationally is the Rio Declaration from the 1992 United Nations Conference on Environment and Development, also known as Agenda 21. The declaration stated: «In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

A precautionary approach to environmental and public health decision-making includes these specific components:

- Taking precautionary action before scientific certainty of cause and effect. Most of the international treaties stating the PP incorporate it as a general duty on states to act under uncertainty. This provides a mechanism of accountability for preventing harm. General duties - obligations to act in a certain way even in the absence of specific laws - are not uncommon in the United States. For example, the Occupational Safety and Health Act demands that an employer "furnish each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical injury."
- Setting goals. The PP encourages planning based on well-defined goals rather than on future scenarios and risk calculations that may be plagued by error and bias (see risk assessment discussion below). For example, Sweden has set the goal of phasing out persistent and bioaccumulative substances in products by the year 2007. The government is now involving a variety of stakeholders in determining how to reach that goal. Sometimes called "backcasting" in contrast to the more usual "forecasting" of an uncertain future, this type of planning creates fewer miscalculations and spurs innovative solutions.
- Seeking out and evaluating alternatives. Rather than asking what level of contamination is safe or economically optimal, the precautionary approach asks how to reduce or eliminate the hazard and considers all possible means of achieving that goal, including forgoing the proposed activity. Needless to say, alternatives proposed to a potentially hazardous activity must be scrutinized as stringently as the activity itself.
- Shifting burdens of proof. Proponents of an activity should prove that their activity will not cause undue

harm to human health or ecosystems. Those who have the power, control, and resources to act and prevent harm should bear that responsibility. This responsibility has several components:

- Financial responsibility. Regulations alone are not likely to spur precautionary behavior on the part of governments or those who are proponents of a questionable activity. However, market incentives, such as requiring a bond for the worst possible consequences of an activity or liability for damages, will encourage companies to think about how to prevent impacts. Such assurance bonds are already used in construction projects as well as in Australia to minimize damage from development projects.
- The duty to monitor, understand, investigate, inform, and act. Under a precautionary decision-making scheme, those undertaking potentially harmful activities would be required to routinely monitor their impacts (with possible third party verification), inform the public and authorities when a potential impact is found, and act upon that knowledge. Ignorance and uncertainty are no longer excuses for postponing actions to prevent harm (see uncertainty discussion below).

- Developing more democratic and thorough decision-making criteria and methods. The PP requires a new way of thinking about decisions and weighing scientific and other evidence in the face of uncertainty. This type of precautionary decision-flow, addressing both new and existing activities, is described in a later section. Because difficult questions of causality are in essence policy decisions, potentially impacted publics must be involved in the decision process. Thus, structures to better involve the public in decision-making are required under a precautionary approach.

In summary, the PP applies when the following conditions are met [COMEST, 2005]:

- there exist considerable scientific uncertainties;
- there exist scenarios (or models) of possible harm that are scientifically reasonable (that is based on some scientifically plausible reasoning);
- uncertainties cannot be reduced in the short term without at the same time increasing ignorance of
- other relevant factors by higher levels of abstraction and idealization;
- the potential harm is sufficiently serious or even irreversible for present or future generations or otherwise morally unacceptable;
- there is a need to act now, since effective counteraction later will be made significantly more difficult or costly at any later time.

4.2. Concept from Cradle to Grave

For years, the cleaning marketplace focused solely on performance and cost. However, one of the contributions made by the "green" movement was a new thought process called "lifecycle thinking" or "cradle to grave."

This new way of thinking not only considers the impact of products resulting during their use or disposal stages, but introduces the fact that many products have significant impacts throughout their entire lives. Beginning with the extraction of the raw materials that actually comprise the product, to its manufacturing, use of energy and water, its waste and emissions, transportation impacts, the actual use of the product and finally, ending with the ultimate disposal of the product — thus, from cradle to grave.

This thinking was codified in Presidential Executive Order 12873 issued in 1993 and reauthorized as EO 13101 in 1998, which defines green products. Over the years as product manufacturers have invested in green cleaning, the result has been an increasing number of products that have reduced raw material use and impacts from manufacturing, concentrating products which reduced transportation impacts, toxicity and waste. Cradle-to-grave thinking resulted in a large array of options for contractors in addition to better product performance and lower costs.

"Cradle-to-cradle" thinking would design the products and systems in a way which results in taking-back products at the end of its useful life and turning it into new products of equal, if not greater, value.

The impact that cradle-to-cradle thinking will have on cleaning products is likely to include equipment with components that can be taken back and reused, while all other components will be recycled and reused in other equipment of equal or greater value; chemicals made from biological organisms, which become nutrients in the environment and whose waste is simply water and carbon dioxide; or plastic components, bags and packaging materials made from rapidly renewable non food agricultural products that can be recycled into products of equal or greater value or composted at the end of their lives.

While cradle to cradle is just emerging as a concept within the cleaning industry, it is an inevitable next step for the green cleaning movement [Ashkin, 2008].

4.3. Public (Polluter and Producer) Pays Principle

Polluter- Pays- Principle is a rule stating that the cost of pollution control, prevention, and remediation should be borne by the entity which profits from the process that causes pollution.

Producer- Pays- Principle is a pollution-control rule stating that the manufacturer should pay the cost of ensuring recycling and proper disposal of its products at the end of their life cycle.

The environmental policy instruments based on the "Public Pays Principle (PPP)" are:

- Direct or indirect public protection of the environment financed with tax revenues;
- Subsides to companies for foregoing environmental damage;
- Environmental subsidies for supporting the development of environmentally friendly production processes, products and raw materials;
- Public support for innovations in environmental engineering; and
- Public expenditures for subsequent remediation of environmental damage.

The PPP is normally implemented through two different policy approaches:

Command-and-control approach. This approach focuses on preventing environmental problems by specifying how a company should manage a pollution-generating process. The approach lays down detailed regulations and an ongoing inspection program follows. In the United States, the Resource Conservation and Recovery Act (RCRA) is a prime example of this kind of regulation.

The alternative to "command and control" regulation is "performance oriented" regulation which specifies the environmental performance goals. This tends to be much more difficult to enforce because it requires an intimate understanding of the process and alternatives to the process.

Market-based approach. Manufacturers pollute the environment because it is available to them without cost. A market-based approach would charge a valid price to the producer for using the environment, rather than the zero prices which firms have been accustomed to. Under this method the Government can establish a discharge fee or tax which every polluter has to pay.

However, calculating the cost of pollution damages is extremely difficult. Therefore, choosing the correct tax level is fraught with difficulty. It is, therefore, felt that a quantity-based approach is much easier. At the international level the Kyoto Protocol, which requires the offending parties to bear the cost of reducing their greenhouse gas emissions, is an example of application of the PPP.

5. PLANNING A SOLID WASTE MANAGEMENT PROGRAM

In most DC there is limited or conflicting information to make reliable management decisions so there is need for reliable, scientifically based information in order strategies used by most industrialized countries to be implemented (i.e. waste minimization, recycling (including bio treatment), waste diversion from landfill, etc). Certain strategies already implemented in most economically developed countries should be put forward and comply with DC local conditions.

The range of issues to be considered in designing such a well functioning SWM system can be overwhelming, even to planners who have considerable resources available. In most of the world, where such resources and expertise are scarce SWM issues are even harder to resolve. SWM despite its prominent position as an urban problem is not the only problem competing for the attention of urban managers. Its low status as a field of work has meant that SWM issues often receive less attention than other urban problems [Karagiannidis et al., 2008].

SWM includes a wide range of individual activities as already mentioned:

- Waste generation
- Temporary storage
- Collection
- Transport and Transhipment
- Treatment and recover
- Final disposal

Politicians, decision makers and analysts are those who are responsible to recognize and to comprehend the important relations that should be evaluated at the process of planning. The basic aim of management planning is to ensure the adoption of the best system taking into consideration the restrictions from its users and by those that are influenced by its application or that check its effectiveness.

To develop an effective waste management strategy for a given region, it is important to know the amount of waste generated and the composition of the waste stream. Past research has shown that the amount of waste generated is proportional to the population and the average mean living standards or the average income of the people. In addition, other factors may affect the amount and composition of waste. These are climate, living habits, level of education, religious and cultural beliefs, and social and public attitudes [Bandara et al., 2007].

To develop an integrated waste management plan, a variety of waste specific data is required. To determine the resources required for waste management and for sizing of waste management facilities, an accurate estimate of current and future total waste generation is required. The per capita waste generation rate is needed to predict future waste generation rates and for evaluating the waste generation trends in given communities. Once developed, such information could be extrapolated to other communities with similar socio-economic conditions.

A large amount of research on the development of Decision-Making Support Systems (DMSS) focuses on organizational issues, technical issues, or both kinds of issues at the same time. Whereas it is widely recognized that these two categories represent the dominant sources of issues that DSS builders had to overcome in the past, a third category, knowledge-management issues, gradually surfaces. Bolstered by advances in information technology in general, and artificial intelligence in particular, the field of knowledge management increases the number of development issues previously dealt with partly from an organizational perspective and partly from a technical perspective, but rarely as a perspective of its own[Gachet et al., 2006].

5.1. Planning methodology

In order the analysts and decision makers to be able to correspond to the community needs and to ensure the most optimal application of the system given the provided time and available resources they follow the steps indicated below:

STEP 1: Definition and specification of the problem.

The most critical step in any study of planning is the guarantee of explicit formulation of the problem and of the corresponding specifications from those in charge of decision-making. The formulations and specifications of problem are usually exported from the public concerns. The resulting difficulties are usually owed to the incomplete comprehension of the plan in most levels of decision-making. Accordingly, the analyst is probably found in the need to re-define a problem that was initially determined from decision-makers.

STEP 2: Collection of data.

In this step an inventory is held in all responsible and relative SWM stakeholders of the community, while the same moment several data are collected in order to specify the problem. The basic aim of the inventory is the achievement of the precise description of the existing SWM plan and at the same time the collection of basic information (eg demographic data). Estimates by analysts are highly involved in this step. This step is particularly important for planning all the consequent proposals for further action are based on that. Consequently, it is of major importance to estimate all the functional elements that compose the potential plan.

STEP 3: Synthesis and evaluation of the alternative solutions.

This step includes the detailed evaluation and analysis of data that was assembled during step 2. In certain cases is probably essential the collection of additional data and information. Before the formulation of the plans it is important the examination and review of the initial problem, the formulation and its specifications. Often it is realised that certain revisions should be made in view of the data that were collected during the inventory. While some of the problems have probably more than one solutions and it is judged as safe for decision-makers to develop alternative scenarios. In any case the administrative and/or functional activities should be evaluated. The development of the alternative plans for one or more activities should mind the sustainability and success of the total SWM planning.

STEP 4: System selection.

In this step the analyst selects a specific number of alternative plans in order to be evaluated by him, the decision makers and other local stakeholders. The alternative solutions are judged for their sustainability, their consistency and their coherency. The analyst is called upon developing a detailed conscience regarding the social and political structure of community. The final activity of this step is the selection of various plans in order one of them or a combination of them to form the final solution plan of the problem.

STEP 5: Development of the implementation's timetable.

When the total planning of a SWM scheme fails the main cause is the insufficient development of the timetable. The degree of each timetable's documentation is highly related to the type of program that is developed as presented below:

- Local planning require a simple timetable of concretisation, probably without complicated steps for fabric changes:
- Local and regional planning which include more than one operational element requires the development of drawings thorough timetables of concretisation, which will be enforced by more than one administrative and operational stakeholder.
- The national planning include few in number but very concrete timetables of concretisation, because they deal with multiple political and jurisdiction issues. While those plans are developed in line with

legislation they include specific dates of implementation, adopting certain European Directive [Karagiannidis et al., 1995].

After the completion of step 5, the analyst has completed the most exigent work but he continues in any case involved in the process of planning eventhough the decision makers are the one responsible now.

STEP 6: Organisation of the implementation's process.

The organisation of the planning procedure in most SWM studies is the responsibility of some planning director who answers to a public institution or to a private company of advisers. The director should monitor the implementation of the planning throughout its duration. The local plans are simple and are usually developed only for a functional element (e.g. personnel, organisation of work, etc.). The regional and national planning are complicated and they usually include more functional elements: they require enough personnel for the estimation of various activities which should be taken into account, while the organisation of work should be checked closely, so that overshooting of deadlines and budget will not occur.

The control of the planning process is therefore an administrative issue for which an activity chart might prove precious. This chart should indicate the main tasks and their interrelations, as well as the related deadlines. The planning director is informed by this chart on the progress of tasks and he is assisted into assigning further tasks to his team.

5.2. Decision making process

The main purpose of the planning is the collection, evaluation and presentation of data relevant to a certain problem which requires action by a responsible decision maker. Thereby the design procedure is an important part of the decision making procedure. The necessary needs and facts related to the selection and implementation of SWM programs are analysed below:

Prerequisite elements in decision-making.

The understanding of the objective targets of the community should be kept in mind throughout the total process. The introduction of new terms and technologies as well as the social sensitivity and the value of natural resources can become a major problem in the planning procedure; those in charge of planning may be consumed into the development of reports in order to find the best solution. This is considered inefficient for the local community where a practical approach of the problem and the implementation of a dynamic plan/program is more appropriate.

Final decision consequential

Planning is a procedure that leads to the development of alternative treatment solutions. Decision making is a process which leads to implementation actions related to equipment, personnel, etc. There are four basic to wards the competition of all actions:

- the adoption of a SWM plan which includes alternative scenarios;
- the adoption of an appropriate implementation timetable;
- the selection of a stakeholder(s) who will manage the implementation of the plan and of the specific programmes; and
- the selection of: personnel, funding and means resources.

Not all the elements of an action plan such as management, implementation and operation, should be coordinated by Local Authority (LA) but it should be mentioned that the fist two indicated are the most important of all in terms of local planning. When it comes to regional or national planning the personnel and funding resources are very important elements and as a consequence all steps above indicated should be minded.

6. RISK OF IMPLEMENTING A SOLID WASTE MANAGEMENT PLAN

Attitudes towards risks vary across cultures. Some people have a risk-seeking attitude whereas others have a riskaverse attitude. The cultural plurality in risk attitudes implies that the question of how society ought to deal with risks can only be answered in public debate – a debate in which people will necessarily discuss their perception of risks and risk management from different points of view and different conceptual and ethical frameworks. One should further be aware that being risk-averse to ecological risks is not the same as being risk-averse to economic risks.

A given risk tends to be seen as less acceptable if the (perceived) controllability of consequences is lower; if the nature of the consequences is unfamiliar and dreadful; if one is exposed to the risk involuntarily; if the benefits of the activity are less clear and smaller; if the effects are more acute and more nearby in space and time; if risk and benefits are unfairly distributed; and if the likely harm is intentional.

Decision theory purports to study human decisions descriptively and provide a normative framework for rational decision-making. The elements of decision theory are quite simple: a choice between different courses of action; some knowledge about different outcomes or consequences of these options; and, finally, an evaluation of each outcome, that is a value attached to every consequence based on p references. Generally four types of practical decision problems can be distinguished:

- a decision under certainty;
- a decision under risk;
- a decision under uncertainty; and
- a decision under ignorance.

In the case of certainty we know the outcomes of different choices and the only challenge is to be clear about one's preferences. In the case of risk we know the outcomes (benefits and adverse effects) and the probability of various outcomes. In the case of uncertainty we know the possible outcomes but have no objective ground to estimate their probability. In the case of ignorance we do not even know what adverse effects to anticipate or we don't know their magnitude or relevance and have no clue of their probability. When both the utility and the probability of the various outcomes of a decision are known, maximizing expected utility is generally advocated as a rational decision rule [COMEST, 2005].

In both developing and developed countries the ratio of economical/environmental cost and benefit as well as the public acceptance and participation are two fundamental elements towards the SWM plans success.

6.1. Costs and benefits

The regulation of risky activities, such as the introduction or implementation of new technologies, always involves some form of consideration of costs and benefits. The potential positive and negative effects resulting from certain activities should always be judged in view of the potential benefits they offer.

Cost Benefit Analysis (CBA) is one of the most widely used formalized methods that aim to support decision-makers in weighing the costs and benefits of different policy options. In theory the potential and scope of CBA are quite large. In practice CBA is often applied in ways that make it difficult to assess the distant, uncertain, or irreversible harms that characterize situations requiring the PP.

CBA relies on quantification of all aspects that one wants to consider in the analysis. Often this occurs in monetary terms o r in terms o f expected utility. When environmental values are converted into monetary terms in a CBA, it implicitly assumes that environmental 'goods' are interchangeable with manufactured goods and replaceable without overall loss of welfare. The methods for quantification and monetarization are highly disputed. CBA does not deal with who gets the benefits and who suffers the costs. CBA typically favours a risky activity as long as the sum of the benefits outweighs the sum of the costs, even if a small group of people get the benefits and a whole community suffers the costs. Thus aggregation of costs and benefits may obscure ethical issues of fairness and equity. Given the limits of CBA, its use should always be interpreted with caution and should be complemented by other methods that may be better suited to tackle the thorny political, social and ethical issues. These methods can include public and transparent debate on options, particularly when phenomena are difficult to quantify and values are at stake [COMEST, 2005].

6.2. Social acceptance

The term social acceptance includes two different concepts 'social' and 'acceptance' with potentially different approaches. While social refers to the society consisting different groups like consumers and producers, acceptance may range between a passive consent and an active approval in the form of an active involvement. The societal acceptance, therefore, implies a broad spectrum of social groups considered and the degree of their accepting, a new initiative, involved. Social acceptance may have few dimensions like socio-political, community and market acceptance [Wüstenhagen et al., 2007].

Each and every SWM plan requires the host country's support and boost the initiatives and acceptance from the public [INVENT, 2009]. Therefore, the challenge of the local municipalities and the scientific communities of the DCs will be to provide information and opportunities on this field while ensuring that adverse effects are eliminated or minimised.

To this the role of educational institutions in raising awareness among the public and accelerating societal acceptance of SWM plans is quite significant. They can act as a bridge between governmental/ LAs and citizens by disseminating information in such a way so as to raise the societal acceptance and motivate the citizens. Implementations of SWM projects should include practices which could motivate the residents of a rural area, with emphasis on poorer communities; e.g. in Thailand citizens bring recyclables for exchange of eggs [Mongkolnchaiarunya, 2005]. This signifies the community empowerment through self-reliance establishing new relationships of more equality and less dependence between poor communities and local municipal administration.

Education can empower the local communities to enforce higher environmental standards thereby acting as informal regulation [Pargal et al., 1995]. The discussions on technology transfer (e.g. CDM) often, overlook the most significant aspect i.e. the societal acceptance. Stimulating societal acceptance is the prerequisite in the introduction and adoption of new technologies. The acceptance and adoption is preceded by processes like information dissemination, knowledge sharing, interaction among various groups discussing the advantage and complexity of the net benefit. The acceptance may be reflecting in the attitudes, behaviour and their willingness to investing in such projects. Despite an active participation of a large group of people from the developed and the DCs in various discussions and seminars there is, still, a reluctant passive attitude for alternative energy sources and the renewable energy technologies prevalent. This can be due to finding site for the installations, outlay of the up-front capital investments to quote the most significant reasons [INVENT, 2009].

7. ROADMAP TO SUSTAINABLE SOLID WASTE MANAGEMENT IN DEVELOPING

COUNTRIES

The status of development of a country may be categorised in several ways. With respect to its impact on SWM emphasis should be given to the availability of economic resources and on degree of industrialisation. Degree of industrialisation is measured in terms of extent of mechanisation and availability of technological resources. Status of economic development is more a measure of the permanent economic framework than of the existing condition of the economy (recession vs. prosperity). SWM is adapted to the nature and quantities of waste generated and to the availability of technology for handling and processing characteristic of non-industrial settings. Figure 6 presents the elements that should be kept in mind when implementing a SWM plan in DCs'. The way SSWM influencing the aforementioned element is presented below [Cointreau, 2001]:

Support of Good Governance

- SSWM is an integral part of good local governance and one of the most visible urban services influencing local perception of governance
- SSWM provides a minimum level of acceptable service to all urban residents and establishments, with higher levels of service where there is either a greater need (e.g., in terms of business development or tourism) or a greater desire to pay for a higher level
- SSWM is conducted in a transparent and accountable manner to minimize opportunity for corruption and unwarranted political interference
- SSWM provides workers with uniforms, clear-cut performance tasks and outputs, and predictable routes and schedules so that the public can participate in performance monitoring
- SSWM is responsive to the service levels and conditions desired by the residents and establishments receiving service

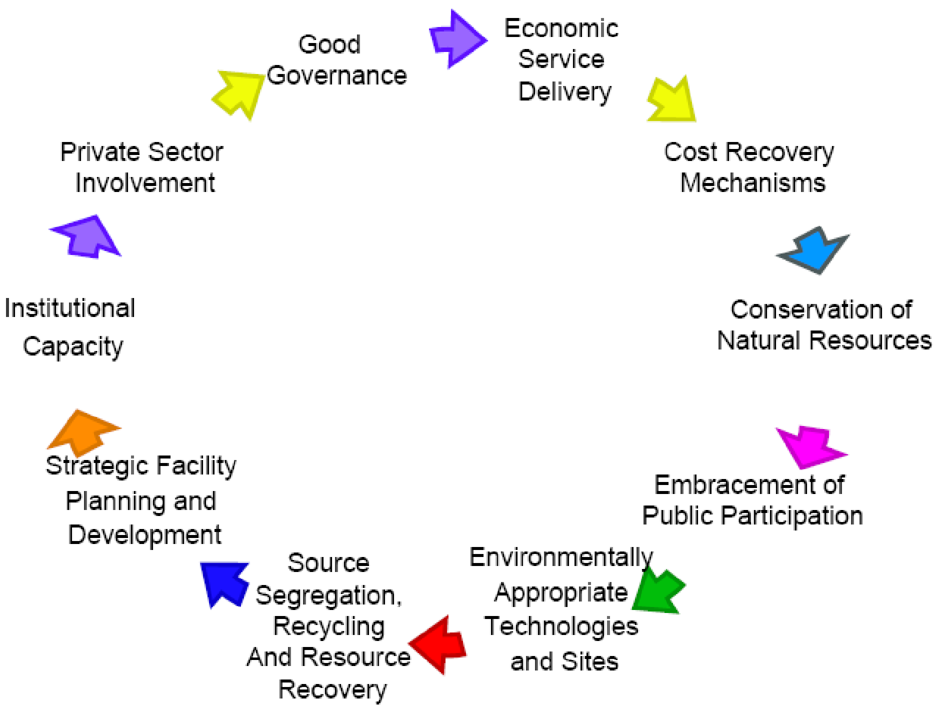

Figure 6. Important elements in SWM plan implementation in DCs' partly based on [Cointreau, 2001].

- SSWM is affordable within the context of available customer funds to meet the necessary range of basic urban services and compatible with the service levels desired
- SSWM establishes management information systems that enable cost-effective accounting of costs and overall cost-related performance monitoring
- SSWM is open to all viable parties, including women and micro-enterprises, that could contribute to the economic provision of services
- SSWM recognizes that willingness to pay is affected by perception of service quality being received and involvement of stakeholders in decision-making, and therefore places a high priority on keeping stakeholders informed and involved regarding issues and proposals
- SSWM looks for ways to enable communities to be responsible and for individuals to take action in ways that build public cooperation with the service

Economic Service Delivery

- SSWM considers economies-of-scale in facility sizing and route designs, and seeks to decentralize or bundle services as needed to optimize such economies
- SSWM recognizes that collection is the major cost element of the solid waste system and requires comprehensive cost analysis for continuous rationalization of routing, crew sizes and technologies, with appropriate planning and supervisory staffing and technical resources applied to enable this outcome
- SSWM includes pre-collection systems, to the extent that they enhance willingness to pay and obtain cooperation of the public with the service
- SSWM ensures that sufficient resources are devoted to preventative maintenance of vehicles and facilities, and that skills, spare parts and consumables are available to assure steady and reliable provision of service
- SSWM recognizes that systems and equipment should be selected according to local conditions, and not be transplanted from other situations without careful consideration of local conditions
- SSWM builds local capacity to engineer and produce equipment and spare parts, to the extent economically viable, so that the skills to maintain and replace such equipment shall be readily available

Establishment of Cost Recovery Mechanisms for Long-Term Financial Sustainability

- SSWM is sustainable through a range of revenue sources, including direct fees, indirect general taxes, and revenues from recycling and resource recovery
- SSWM tariffs establish fair distribution of costs according to ability to pay, the service provided, and level of waste pollution generated
- SSWM lets all parties know the costs of the services and what level of service can reasonably be expected for the costs incurred
- SSWM minimizes hidden costs and subsidies, making all costs as transparent as possible
- SSWM sets up cost recovery mechanisms and financial management systems that are leakproof and constrain the potential for undue political intervention
- SSWM uses segregated accounts for solid waste revenues to ensure reliable cash flow remains available to meet service needs

Conservation of Natural Resources

- SSWM encourages indigenous manufacturing capacity for vehicles, machines, and parts required by the service
- SSWM is conducted in an environmentally conscientious manner that conserves natural resources and recovers wastes where appropriate
- SSWM provides incentives for waste minimization, recycling, and resource recovery at the source, or as near to the source as possible
- SSWM involves comprehensive cost analysis of alternatives as essential to sound decision-making; for example, smaller collection systems using more labor and less fuel may have costs that are comparable to larger collection systems using less labor and more fuel
- SSWM seeks disposal sites that minimize area required by optimizing the depth of fill

Embracement Public Participation

- SSWM planning and operations consider gender, children and cultural aspects of the local population, and avoids inconveniencing or placing the work burden unduly on any specific group
- SSWM planning and operations are participatory and enable continuous feedback from those involved in receiving and providing service
- SSWM provides a forum for handling and tracking complaints and related responses
- SSWM provides incentives, education, and public sensitization to foster cooperation with services provided and cost recovery mechanisms
- SSWM sensitizes the public to environmental issues, occupational health and safety issues waste minimization opportunities, and the values of recycling and resource recovery
- SSWM enables the public to perform its role in monitoring service delivery, environmental impacts, and costs

Fostering Environmentally Appropriate Technologies and Sites

- SSWM conducts environmentally appropriate facility siting investigations and ensures that facilities are designed to meet environmentally cost-effective discharge and impact standards
- SSWM monitors the emissions and environmental changes related to all waste storage, handling, and disposal activities
- SSWM recognizes that landfill is an anaerobic technology that generates methane, that methane is a significant greenhouse gas, and that efforts to recover or flare landfill gases containing methane need to be addressed in landfill design
- SSWM recognizes that compost has benefits to the rural economy outside of the municipal service area, for replenishment of soils, minimization of erosion, development of high nutrient foods, and reduction of water irrigation needs; thus every effort to enhance the cost-effective production of high quality compost and the development of compost markets needs to be made
- SSWM involves environmental impact assessment and public involvement for all new transfer, treatment, and disposal facilities
- SSWM addresses traffic and queuing impacts of all new facilities and routing changes
- SSWM involves the phased closure of all open dumps unless they can be upgraded to controlled

landfills that pose no significant environmental threat

- SSWM involves the curtailment of dumpsite waste picking, with interim steps to upgrade their status, earning power and working conditions
- SSWM prevents children and domestic animals from having access to waste disposal sites and other waste handling facilities
- SSWM employs systems to track and document hazardous wastes to ensure that significant quantities are not mixed with other wastes but are taken to secured facilities for hazardous wastes treatment and disposal
- SSWM recognizes the need for reliable data to ensure effective planning and management
- SSWM recognizes that the state of literature on the health and safety consequences of waste management is still developing and that cautious health and safety obligates cautious measures, such as providing a buffer zone between people and other living creatures and any significant waste storage and handling facilities or disposal sites
- SSWM requires minimum occupational safety and health be met for all waste workers and waste pickers, whether engaged by the public or private sector

Seeking Appropriate Levels of Source Segregation, Recycling and Resource Recovery

- SSWM requires separate transport, treatment and disposal of significant quantities of medical, hazardous, or construction/demolition wastes from general municipal wastes
- SSWM optimizes waste minimization and segregation of recyclable materials at the source of waste generation
- SSWM encourages the development of markets for recyclable materials in major centers of waste generation, including the provision of incentives for increased industrial demand of secondary materials as feedstock

Conduction Strategic Facility Planning and Development

- SSWM invites structured participation of key stakeholders in the strategic planning process
- SSWM requires long-term strategic planning so that the lands necessary for handling wastes are set aside for the future
- SSWM requires acceptable resettlement, property compensation, and livelihood assistance standards be applied to siting of any new facilities and closure of any existing facilities
- SSWM does not include incineration of general municipal wastes unless the year-round calorific value supports self-sustainable combustion at temperatures adequate to protect air quality
- SSWM recognizes that modern and environmentally safe landfill is a part of every long-term disposal strategy, and that there will always be some wastes that can not be otherwise economically treated, recycled, or recovered

Building Institutional Capacity

- SSWM has adequate local authority and autonomy provided to enable good municipal governance over the solid waste sector and self-sustainable financing and cost recovery
- SSWM allows local governments to enter into multi-year private sector arrangements that match periods of depreciation for investments provided

- SSWM strengthens local capacity in planning, operations, rationalization of operations, maintenance and repair of equipment, labor management, performance monitoring, tendering, procurement, accounting, management information systems, and private sector involvement
- SSWM places key functions at the appropriate level within municipal government, so that access to cash flow and decision-making powers are commensurate with the work required
- SSWM separates planning, operations, performance monitoring, and regulatory functions to avoid conflicts of interest
- SSWM has a supportive and equitable foundation of clear regulations, licensing arrangements, procurement procedures, and sanctions
- SSWM receives appropriate central government support for its regulatory framework, and avoids duplication of efforts by central government activities to conduct research, establish norms, and provide technical assistance
- SSWM provides a level playing field and a fair and supportive investment climate for private sector involvement

Invitation of Private Sector Involvement

- SSWM invites private sector involvement as a means of increasing investment, human resources, and expertise in the planning and operations, particularly where cost savings and service improvements are expected to result
- SSWM recognizes that a mix of small and large, local and foreign private sector partners is one way to optimize competition and minimize collusion
- SSWM requires that the private sector and public sector operations meet the same minimum standards for environment, health and safety
- SSWM monitors the performance of the private and public sector in a comparable, equitable, competitive, and transparent manner
- SSWM requires that transitions to private sector involvement fairly accommodate the needs of labor for security of earned retirement benefits and rights to earned severance pay
- SSWM requires that the private sector does not unfairly exploit labor by relying on daily workers or involving child labor
- SSWM considers jobs creation in the assessment and selection of technologies
- SSWM supports opportunities for small and micro enterprise development
- SSWM explores private sector involvement in dumpsite reclamation and development through public/private partnerships
- SSWM obliges the private sector to the same environmental impact assessment requirements as the public sector, and does not fast-tract private sector systems to avoid normal public review and participation processes.

8. ON-SITE HANDLING/ STORAGE OF SOLID WASTE

Waste handling refers to any activities associated with managing wastes until they are placed in containers used for their storage before collection or recycling. Waste separation refers to separating components such as wastepaper, cardboard, aluminium cans, glass and plastic containers at the source of generation. Waste processing is used to reduce the volume, recover usable materials and alter the physical form of the solid wastes. When on-site handling of solid waste is considered following types of residential dwellings are taken into account:

- Low-Rise (under 4 storeys)
- Medium-Rise (from 4 to 7 storeys)
- High-Rise (over 7 storeys)

In low rise detached dwellings the residents or tenants are responsible for placing the solid wastes and recyclables. In low and medium rise apartments handling methods are similar to low-rise dwellings. In addition, the building owner may provide a basement storage room or area for storage of solid waste, which is then moved by the maintenance for curbside collection. In many low and medium-rise apartments, large waste storage containers are located outdoors in special enclosures. These are then emptied mechanically using collection vehicles equipped with unloading mechanisms. In high rise apartments most common methods of handling solid wastes include the following:

- wastes picked up by building maintenance people from various floors
- wastes taken to the basement storage area by tenants
- wastes placed by tenants in specially designed vertical chutes

In a chute system, wastes, usually bagged, are placed by the tenants in specially designed circular chutes with openings located on each floor.

Factors to be considered in on-site storage of solid waste include the effects of storage on waste components, type of container used, location of container, public health and aesthetics. The effects of storage on waste components include biological decomposition, absorption of fluids and contamination of waste components. Food and other wastes placed in on-site storage will putrefy almost immediately. Because the components of solid wastes have differing initial moisture contents, redistribution of moisture takes place as wastes are stored onsite. If watertight container lids are not used, wastes can also absorb water from rainfall. Major waste components can get contaminated by small amounts of motor oils, household cleaners and paints. Following are some guidelines for on-site storage of solid wastes:

- Stored waste does not create offence either by emission of dust, leachate or odour, or by unsightliness.
- Putrescible wastes are stored in shaded, ventilated, waterproof and vermin-proof conditions.
- Storage containers are conveniently located both for the user and waste collector.
- Storage containers can be readily manoeuvred from the storage area to the collection vehicle.
- Storage containers are constructed to fully enclose their contents and to protect their contents from vermin attack.
- Lids for storage containers should prevent the entry of water and be of light weight or such construction as to be readily operated by the use.

The following factors should be considered in evaluating storage containers:

- Efficiency (Containers should help maximise overall collection efficiency).
- Convenience (Containers must be manageable for both residents and collection crews).
- Compatibility (Containers must be compatible with collection equipment).
- Public Health and Safety (Containers should be secularly closed and stored).

Types of storage containers used for solid waste include the following (Figure 7):

- Containers for Mechanised Collection (usually involves plastic roll-out containers that are tipped into the collection vehicle automatically by an arm attached to vehicle).

- Metal or Plastic Cans (these are designed with tight-fitting lids and made from galvanised metal or plastic).

Figure 7. On-site waste collection bins.

9. WASTE COLLECTION

Solid waste collection includes the gathering or picking up of solid waste from various sources and hauling them to locations where collection vehicles are emptied. Collection is considered to be the most expensive part of the system at about 50% of the total cost of waste management. Efficient, sanitary and customer-responsive collection of solid waste is at the heart of a well-run waste management system. Collection services are provided to residents in virtually all urban and suburban areas in the major cities as well as some rural areas either by private haulers or by municipal governments. The types of collection services have expanded in many communities in recent years to include special collection of recyclables and yard wastes.

To better manage the waste, it is necessary to collect it in a segregated manner. There are many factors that influence the success and failure of sanitation programmes. The main factors are [Agarwa et al., 2008]:

- economic and political factors,
- the attitudes and expectations of municipal officials, and
- the community.

DCs in their majority have substantial number of poor families. The waste management model has got wide acceptance amongst these groups, which had generally been ignored by the municipal authorities. They were treated as difficult areas and thus authorities never paid attention to their needs. These communities had no voice. People living in these areas were mainly concerned about finding and keeping employment.

For this reason manual workers are drawn from the most deprived segment of society. They have great difficulty in earning enough to provide for their families and do not have any job security. Gaining employment in the projects that are described here makes them financially sound and provides stability. They are employed for monitoring, supervising and garbage collection. They have grown up in an environment where behavioural aspects of life are not considered, so they often treat their wives and children badly and are prone to drunkenness. After engaging them in this service, their family life has also improved.

Waste management in poor areas is easier than in affluent areas. Only brief sensitisation raised demand for community-based waste management services. Revenue collection from poor communities is easier and smoother than in affluent areas. There are hardly any defaulters. They subscribe to services honestly. They have the apprehension in mind that if they do not pay the service, it will be stopped and then there will be no one to listen to their problem. Community support on this is very important for the programme success especially when the later is supported through managerial and monitoring assistance. The communities are satisfied with the services provided by the support organization. Given that as the country is developing, at the same time, corruption is also increasing among politicians, government officials and many others, communities do not have influence at higher levels to get their work done so they do it themselves.

Last but not least infrastructure is rather important; these days, much technically sophisticated equipment is available in the market but sometime it may not be fit for local conditions. Such equipment is not designed for the actual conditions found in many places. It can be expensive and difficult to use and maintain. The selection of inappropriate equipment can lead to high manpower costs as well as high maintenance costs [Agarwal et al., 2008].

10. TYPES OF SOLID WASTE COLLECTION SERVICES

Decisions about how residents prepare waste for pickup and which methods are used to collect it affect each other and must be coordinated to achieve an efficient, effective system. For example, a community may decide to use self-loading compactor trucks in certain neighbourhoods. As a result, residents will have to prepare wastes by placing them in containers that fit the trucks' container- lifting mechanisms. These decisions about vehicle and container types would affect the selection of crew size, allowing a smaller crew than manual systems would.

To establish uniform and efficient collection, communities normally develop guidelines and enact ordinances that specify how residents must prepare solid waste and recyclables for collection. Although the requirements vary from one community to another, set-out requirements usually address the types of containers to be used, separation of recyclables or other wastes for separate collection, how frequently materials are collected, and where residents are to set materials out for collection [EPA, 2010].

Storage Container Specifications

Many municipalities enact ordinances that require using certain solid waste storage containers. Most important, containers should be functional for the amount and types of materials they must hold and the collection vehicles used. Containers should also be durable, easy to handle, and economical, as well as resistant to corrosion, weather, and animals (Figure 8).

Figure 8. Solid waste storage containers types

In residential areas where refuse is collected manually, either plastic bags or standard-sized metal or plastic containers are typically required for waste storage. Many cities prohibit the use of other containers, such as cardboard boxes, because they are difficult to handle and increase the chance of worker injury.

If cans are acceptable, they should be weatherproof, wider at the top than bottom, fitted with handles and a tightly fitting lid, and maintained in good condition. Many municipalities limit cans to a maximum specified total weight. Some municipalities also limit the total number of containers that will be collected under normal service; sometimes additional fees are charged for additional containers.

If plastic bags are acceptable, they must be in good condition and tied tightly. Some communities require that bags meet a specified minimum thickness to reduce the propensity for tearing during handling. Some programs require the use of bags because they do not have to be emptied and returned to the curb or backyard and are therefore quicker to collect than cans.

Some communities require that residents purchase metered bags or stickers so that residents pay fees on a per-container basis. The price of the bags or stickers usually includes costs for waste collection and disposal services. A related option is to charge different rates for various sizes of cans or other containers. Communities that also collect recyclables usually do so at no, or reduced, cost to residents as a financial incentive for recycling instead of disposal.

When automatic or semiautomatic collection systems are used, solid waste containers must be specifically designed to fit the truck-mounted loading mechanisms. Automatically loading compactor trucks are commonly used to pick up waste from apartment buildings and commercial establishments [EPA, 2010].

Solid Waste Separation Requirements

Communities may wish to collect some portions of solid waste separately, which requires that residents separate wastes before the collection. As more communities implement recycling programs, mandatory separation of recyclable materials such as paper, cardboard, glass, aluminium, tin, and plastic is also increasing. Communities may also require residents to separate yard trimmings, bulky items, and household hazardous wastes for separate collection or drop-off by residents. Bulky items are usually placed at the same point of collection as other solid wastes [EPA, 2010].

Frequency of Collection

Communities can select the level of services they wish to provide by choosing how often to collect materials and the point from which materials will be collected at each residence. The greater the level of service, the more costly the collection system will be to operate. Factors to consider when setting collection frequency include the cost, customer expectations, storage limitations, and climate. Most municipalities offer collection once or twice a week, with collection once a week being prevalent. Crews collecting once per week can collect more tons of waste per hour, but are able to make fewer stops per hour than their twice-a-week counterparts. A USEPA study found that once-a-week systems collect 25% more waste per collection hour, while serving 33% fewer homes during that period. Personnel and equipment requirements were 50% higher for once-a-week collection. Some communities with hot, humid climates maintain twice-a-week service because of health and odor concerns [EPA, 2010].

Pick-up Points for Collection

In urban and suburban areas, refuse is generally collected using curbside or alley pickup. Backyard service, which was more common in the past, is still used by some communities. Curbside/alley service is more economical but requires greater resident participation than backyard service. In fact the productivity of backyard systems is about one-half that of curbside or alley systems. Therefore, as municipal budgets have tightened and service costs increased, most municipalities have chosen or switched to curbside/alley collection. However, some municipalities have traditionally offered backyard service to residents and decide to continue offering this service. Rural areas face special challenges because of low population densities and limited budgets for solid waste operations. When pick-up service is offered in rural areas, residents usually are required to place bags or containers of wastes near their mailboxes or other designated pick-up points along major routes. Other municipalities prefer a drop-off arrangement in which wastes are dropped off at a smaller Transfer Station (TS) (described in next unit). Drop-off service is much less expensive than a collection service but also less convenient for residents.

Some municipalities also offer collection service to larger apartment buildings and commercial establishments. In other communities, service to these customers is provided by private collection companies. In general, wastes from such buildings are stored in dumpsters or roll-off containers and collected using either front-loading compactors or roll-off hoist trucks, respectively [EPA, 2010].

11. SOLID WASTE COLLECTION SYSTEMS

11.1. Existing systems

Numerous types of collection vehicles and optional features are available. Manufacturers are continually refining and redesigning collection equipment to meet changing needs and to apply advances in technology. Trends in the collection vehicle industry include increased use of computer-aided equipment and electronic controls. Now, some trucks even have onboard computers for monitoring truck performance and collection operations.

Truck chassis and bodies are usually purchased separately and can be combined in a variety of ways. When selecting truck chassis and bodies, municipalities must consider regulations regarding truck size and weight. An important objective in truck selection is to maximize the amount of wastes that can be collected while remaining within legal weights for the overall vehicle and as distributed over individual axles. Also, because they are familiar with equipment, collection crews and drivers should be consulted when selecting equipment that they will be using.

Compactor trucks are by far the most prevalent refuse collection vehicles in use. Widely used for residential collection service, they are equipped with hydraulically powered rams that compact wastes to increase payload and then push the wastes out of the truck at the disposal or transfer facility. These trucks vary in size depending on the service application. Compactor trucks are commonly classified as front-loading, side-loading, or rear-loading, depending on where containers are emptied into the truck.

Before compactor trucks were developed, open and closed non-compacting trucks were used to collect solid waste. Although these trucks are relatively inexpensive to purchase and maintain, they are inefficient for most collection application because they carry a relatively small amount of waste, and workers must lift waste containers high to dump the contents into the truck. Non-compacting trucks are still used for collecting bulky items like furniture and appliances or other materials that are collected separately, such as yard trimmings and recyclable materials. Non-compacting trucks can also be appropriate for small communities or in rural areas. Recently, many new types of non-compacting trucks have been designed specifically for collecting recyclable materials.

Waste set-out requirements, waste quantities, and the physical characteristics of the collection routes are likely to be key considerations in the selection of collection vehicles. For example, suburban areas with wide streets and little on-street parking may be ideally suited to side-loading automatic collection systems. Conversely, urban areas with narrow alleys and tight corners may require rear loaders and shorter wheelbases. For large apartment buildings and complexes, and for commercial and industrial applications, hauled-container systems are often used. The roll-off containers used with these systems have capacities of up to 35 cu.m. They are placed on the waste generator's property, and when full, are transported directly to the transfer/disposal site. Special hoisting trucks and a cable winch or hydraulic arm are required to load the containers.

The optimum crew size for a community depends on labour and equipment costs, collection methods and route characteristics. Crew sizes must also reflect conditions in contracts with labor unions. As previously mentioned, crew size can have a great effect on overall collection costs. As collection costs have risen, there has been a trend toward:

- decreasing frequency of collection,
- increasing requirements on residents to sort materials and transport them to the curb, and
- increasing the degree of automation used in collection.

These three factors have resulted in smaller crews in recent years. Generally, a one-person crew can spend a greater portion of its time in the productive collection of wastes than a two- or three-person crew can. Multiple-person crews tend to have a greater amount of non-productive time than do single-person crews because non-driving members of the crew may be idle or not fully productive during the haul to the unloading point. Some communities address this problem by requiring that non-drivers perform other duties, such as cleaning alleys, while the driver hauls collected wastes to the disposal or transfer facility.

Although the one-person crew has the greatest percentage of productive time, many municipalities use larger crews, mainly for three reasons: some trucks (for example, rear-loading packers) do not readily support use of a single-person crew, the municipality wants to provide a higher level of service than one-person crews can provide, or labour contract provisions require more than one person on each crew. These multi-person crews can be efficient if properly trained and provided with suitable performance incentives. In more efficient multiple-person crews, the driver helps with waste loading and the crew carries some containers to the truck instead of driving to each pick-up location.

11.2. Considered factors

To receive a satisfactory service, citizens should be aware of the collection schedule. It is important to provide a regular schedule each week and minimise back tracking and dead headings in collection i.e. spend more time on collection. Detailed route configurations and collection schedules should be developed for the selected collection system. Efficient routing and rerouting of solid waste collection vehicles can decrease labour, equipment and fuel costs, and increase customer satisfaction by making pick-up predictable. The size of each route depends on [TAF, 2008]:

- The amount of waste collected per stop.
- Distance between stops.
- Loading time.
- Traffic conditions.
- Method of collection.

In addition, physical barriers such as railroad embankments, rivers and roads with heavy competing traffic, can be used to divide route territories.

Collection programs in different communities vary greatly depending on the waste types collected, the characteristics of the community, and the preferences of its residents. Often, different collection equipment, methods, or service providers are required in the same community to serve different customers (single-family, multi-family and commercial) or to collect different materials (solid waste and recyclables) from the same customers. Collection systems are often complex and difficult to design because many factors must be considered and a wide range of collection options are available.

Defining Community Goals and Constraints

Each community should clearly define the goals for its collection system, periodically review the system's performance in meeting those goals, and regularly review and adjust the system's goals to conform to changes in the community's needs. Similarly, constraints should be identified and incorporated in the decision-making process. Some constraints, such as funding, can possibly be adjusted to meet changing needs. Identifying goals, objectives, and constraints can help guide the planning process. Issues that should be considered include the following:

- Level of service: What level of services is required to meet the community's needs? What materials need to be collected and what are the requirements for separate collection of these materials? What needs and expectations exist with respect to the frequency of pickup and the convenience of set-out requirements for residents.
- Roles for the public and private sectors: Is there a policy preference regarding the roles of the public and private sectors in providing collection services for wastes and recyclables? If collection is to be performed by private haulers, should the municipality license, franchise, or contract with haulers.
- Waste reduction goals: What are the community's waste reduction goals and what strategies are necessary or helpful in achieving those goals? For example, source reduction and recycling can be facilitated by charging customers according to the volume of wastes discarded, by providing convenient collection of recyclables, and by providing only limited collection of other materials such as yard trimmings and tyres.
- System funding: What preferences or constraints are attached to available funding mechanisms? Are there limits on the cost of service based on local precedence, tax limits, or the cost of service from alternative sources?
- Labour contracts: Are there any conditions in existing contracts with labour unions that would affect the types of collection equipment or operations that can be considered for use? How significant are such constraints and how difficult would they be to modify.

Characterizing Waste Types, Volumes, and the Service Area

Data concerning waste generator types, volumes of wastes generated and waste composition should be gathered so that community collection needs can be determined. Estimates of generation and composition can usually be developed through a combination of (1) historical data for the community in question, (2) data from similar communities, and (3) published "typical" values. Adjust data as necessary to correspond as closely as possible to local and current circumstances. City street and block maps should also be obtained to determine information on specific block and street configurations, including number of houses, location of one-way and dead-end streets, and traffic patterns.

Public and Private Collection/Transfer: Determining Options

Before or while the technical aspects of the solid waste collection system are being developed, a municipality should evaluate alternative roles for the public and private sectors in providing collection services. The collection system may be operated by a municipal department, a contracted private firm, one or more competing private firms, or a combination of public and private haulers. The following terms are commonly used when referring to these different collection systems:

- Municipal collection: A municipal agency uses its own employees and equipment to collect solid waste.
- Contract collection: A municipal agency contracts with a private collection firm to collect waste. Larger communities may issue multiple collection contracts, each for a different geographic area, type of customer (single-family versus multi-family units), or material collected (recyclables versus refuse).
- Private collection: Residents directly engage the services of private collection firms. Some communities using this approach give residents the complete freedom to choose haulers and the level of service provided; some require that all haulers obtain a license to operate from the municipality. This system relies on competition to control prices and quality of service.

Other communities, wishing to reduce truck traffic and the costs of service through eliminating duplication of service, allow haulers to competitively bid to provide a specified level of service to residents within a defined "franchise" area. Residents then contract directly with the designated hauler for their area for the price and level of service specified in the hauler's franchise agreement with the municipality.

The collection system that is most appropriate for a particular community depends on the needs of the community and availability of qualified private collection firms. No single system type is best for all communities. In fact, one community may wish to consider the use of different systems for different customer types or different areas of the community. For example, many municipalities provide municipal service to single-family residences, small apartment buildings and small commercial customers, but require that larger apartment buildings and commercial and industrial customers arrange separately for their collection services. In addition, municipalities may wish to explore options for working with other nearby communities to provide collection service on a regional basis. Development of a regional collection system can be particularly cost-effective if several small communities are located close to each other and use the same disposal site.

Determining the System Funding Structure

Selecting the method of funding is a key step in developing a solid waste collection system. The goal of a funding plan is to generate the money necessary to pay for collection services. In addition, a well-designed funding method can also help a community achieve its waste reduction and management goals. The three principal alternatives for funding solid waste services are (1) property tax revenues, (2) flat fees, and (3) variable-rate fees.

- Property taxes: A traditional way of funding solid waste collection is through property taxes, especially in communities where collection has been performed by municipal workers. A principal attraction of this method is its administrative simplicity; no separate system is necessary to bill and collect payments, since funds are derived from moneys received from collection of personal and corporate property taxes. Despite its ease of administration, however, communities are increasingly moving away from this funding method, at least as their sole funding source. Many municipalities have shifted to covering part or all of their costs through user fees, largely because of statutorily or politically imposed caps on property tax increases. In addition, municipal officials realize that funding from property taxes provides no incentives to residents to reduce wastes through recycling and source reduction. Whereas this was generally tolerated when disposal was relatively cheap, the increased cost to properly manage wastes has caused many communities to find ways to give meaningful pricing signals and incentives to residents.
- Flat fees: Flat fees are a common method for funding collection in many communities served by private haulers and in many municipalities where a separate authority or special purpose fund is used for solid waste services. Although this method does a better job than property taxes in communicating the real cost of solid waste services, it still does not provide an incentive for reducing wastes.

- Variable-rate fees: With a variable-rate fee system, generators pay in proportion to the amount of wastes they set out for collection. Variable rates are also called unit rates and volume-based rates. Variable-rate systems typically require that residents purchase special bags or stickers, or they offer generators a range of service subscription levels. When bags or stickers are used, their purchase price is set high enough to cover most or all program costs, including costs for bags and stickers and for an accounting system. Systems that offer generators a range and choice of subscription levels have less administrative complexity than systems that use bags and stickers. However, when generators use bags and stickers, they may be more aware of how much waste they are producing and, therefore, have more incentive to reduce it. In addition, by using smaller or fewer bags or fewer stickers, generators can realize savings from their source reduction efforts immediately.

Sometimes communities combine various elements of the above funding methods to form a hybrid system specially tailored for their communities. Many variable-rate programs are adapted to mute the potential negative impacts of such systems. For example, a basic level of service offering a certain number of bags or one can per week could be provided to all residents and paid for from property taxes. Generators could then be required to place any additional wastes in special bags sold by the municipality. Municipalities that choose to provide collection, either on their own or through a municipal contract with a hauler, might find it advantageous to segregate solid waste funds in an enterprise account. With this method, costs and revenues for solid waste services are kept separate from other municipal functions, and mangers are given authority and responsibility to operate with more financial independence than when traditional general revenue departments are used. Some local governments have found that this approach increases the accountability and cost-effectiveness of their solid waste operations.

The importance of accurately tracking the full costs of waste collection services cannot be overstated. For most communities, the costs of collecting wastes or recyclables are significantly higher than the costs of disposal or processing. Accurate cost accounting can provide managers with the information necessary to compare performance with other similar communities and the private sector and to identify opportunities for improving efficiency. Full-cost accounting provides residents and decision makers with more complete information on waste collection by including indirect costs, such as administration, billing, and legal services along with such direct costs as labour, equipment, tipping fees, and supplies. In communities where garbage collection is funded from property taxes, this information helps residents understand that “free” garbage collection is, in reality, not possible. Using full-cost accounting, many communities have demonstrated that the costs of recycling collection and processing are less than those for solid waste collection and disposal. However, even when the costs of recycling are shown to be greater, the information helps communities better understand and weigh the cost/benefit tradeoffs of the alternative systems being considered [EPA, 2010].

<u>Analyzing Crew and Truck Requirements</u>

The community can use the number of houses per block or route, along with waste density and quantity information, to determine an average quantity of waste generated (in kg or cubic metres) for all or portions of the service area. This average waste quantity can be used to estimate the number of stops to be serviced per vehicle load. The number of services per load and other block configuration data will be used to develop collection routes and schedules. Seasonal variations in generation rates should be considered when estimating staff and equipment needs.

<u>Loading Time Requirements</u>

For each collection method and crew size being considered, a loading time should be estimated using data from another, similarly configured system, or, if necessary, using a time study of proposed collection procedures. Time studies are usually performed only if historic data is not available for comparable systems and when the potential cost impacts of the decisions at hand warrant the cost of a time study. Estimates of the loading time and average generation per household can be used to determine the average time required to fill a truck. If distances between stops vary significantly, different loading times and total vehicle filling times should be estimated for each area. These estimates and block configuration data are used to determine collection routes.

Hauling Time and Other Travel Time Requirements

To estimate hauling times for collection vehicles, consider the following:

- Travel time from the garage to the route at beginning of day
- Travel time from the route to the disposal site (include daily traffic fluctuations)
- Time spent queuing, weighing, and tipping at the disposal/transfer site
- Travel time to the collection route from the site
- Travel time returning to the garage at end of day.

Overall Time Requirements

The loading and hauling times can be used to calculate the number of loads that each crew can collect per day. To make this calculation, managers will need to estimate administrative and break time, hauling route and other travel time, and actual collection time. Labour and equipment costs should be estimated for each collection system being considered. First, using the total quantity of waste that will be generated and number of loads that can be collected each day, collection managers should calculate the number of vehicles and crews that will be required to collect waste. Then, these numbers, along with equipment and cost information, can be used to calculate the annual cost of each collection alternative [EPA, 2010].

11.3. Methods of solid waste collection routing

Detailed route configurations and collection schedules should be developed for the selected collection system. Efficient routing and rerouting of solid waste collection vehicles can decrease costs by reducing the labour expended for collection.

Routing procedures usually consist of two separate components: Micro-routing and Macro-routing.

Macro-routing, also referred to as route balancing, consists of dividing the total collection area into routes sized so they represent one day's collection for one crew. The size of each route depends on the amount of waste collected per stop, distance between stops, loading time, and traffic conditions. Barriers, such as railroad embankments, rivers, and roads with heavy competing traffic, can be used to divide route territories. As much as possible, the size and shape of route areas should be balanced within the limits imposed by such barriers. For large areas, macro-routing can be best accomplished by first dividing the total area into districts, each consisting of the complete area to be serviced by all crews on a given day. Then, each district can be divided into routes for individual crews.

Using the results of the macro-routing analysis, micro-routing can define the specific path that each crew and collection vehicle will take each collection day. Results of micro-routing analyses can then be used to readjust macro-routing decisions. Micro-routing analyses should also include input and review by experienced collection drivers. Micro-routing analyses and planning can do the following:

- Increase the likelihood that all streets will be serviced equally and consistently
- Help supervisors locate crews quickly because they know specific routes that will be taken

- Provide theoretically optimal routes that can be tested against driver judgment and experience to provide the best actual routes.

The method selected for *micro-routing* must be simple enough to use for route rebalancing when system changes occur or to respond to seasonal variations in waste generation rates. For example, growth in parts of a community might necessitate overtime on several routes to complete them. Rebalancing can perhaps consolidate this need for increased service to a new route. Also, seasonal fluctuations in waste generation can be accommodated by providing fewer, larger routes during low-generation periods and increasing the number of routes during high-generation periods.

Heuristic Route Development: A Manual Approach

The heuristic route development process is a relatively simple manual (i.e., not computer-assisted) approach that applies specific routing patterns to block configurations. USEPA developed the method to promote efficient routing layout and to minimize the number of turns and dead space encountered. When using this approach, route planners can use tracing paper over a fairly large-scale block map. The map should show collection service garage locations, disposal or transfer sites, one-way streets, natural barriers, and areas of heavy traffic flow. Routes should then be traced onto the tracing paper using the following rules:

- Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.
- Total collection plus hauling times should be reasonably constant for each route in the community (equalized workloads).
- The collection route should be started as close to the garage or motor pool as possible, taking into account heavily travelled and one-way streets.
- Heavily travelled streets should not be collected during rush hours.
- In the case of one-way streets, it is best to start the route near the upper end of the street, working down it through the looping process.
- Services on dead-end streets can be considered as services on the street segment that they intersect, since they can only be collected by passing down that street segment. To keep right turns at a minimum, collect the dead-end streets when they are to the left of the truck. They must be collected by walking down, backing down, or making a U-turn.
- Waste on a steep hill should be collected, when practical, on both sides of the street while vehicle is moving downhill. This facilitates safety, ease, and speed of collection. It also lessens wear of vehicle and conserves gas and oil.
- Higher elevations should be at the start of the route.
- For collection from one side of the street at a time, it is generally best to route with many anticlockwise turns around blocks. It is better to develop a series of anticlockwise loops in order to minimize right turns, which generally are more difficult and time consuming than left turns.
- For collection from both sides of the street at the same time, it is generally best to route with long, straight paths across the grid before looping anticlockwise.

Computer-Assisted Routing

Computer programs can be helpful in route design, especially when routes are rebalanced on a periodic basis. Programs can be used to develop detailed micro-routes or simpler rebalances of existing routes. To program detailed micro-routes, planners require information similar to that needed for heuristic routing. This information might include block configurations, waste generation rates, distance between residences and between routes and disposal or transfer sites, topographical features, and loading times. Communities that already have a Geographic Information System (GIS) database are in an especially good position to take advantage of computerized route balancing. Municipalities can also use computers to do simple route rebalancing. For smaller communities, rebalancing can be accomplished using manual methods [EPA, 2010].

12. COLLECTION SCHEMES

12.1. Main collection schemes

Some communities are accustomed to a collection seven days a week, whilst other collection agencies are striving for just once each week. If fly breeding is to be controlled, the waste should be collected twice a week in hot climates. Other factors to consider are the odours caused by decomposition and the accumulated quantities. If residents are accustomed to daily collection it may not be politically feasible to reduce the frequency to twice a week. In some cities waste is collected on the day of rest (Sunday or Friday). Some collect waste at night, perhaps for cultural reasons or because of the weather or traffic congestion. Table 9 presents the advantages and disadvantages of the main collection systems.

However there are certain factors that decision makers should keep in mind when implementing a collection system. This has to do with its Cost Effectiveness, the impacts in workers' health and safety, its environmental appropriateness, its effectiveness, its public acceptance and its efficiency. Those factors are analytically presented in Table 10.

Table 9. Key points concerning main collection systems [Hann et al., 1998].

		System	Description	Advantages	Disadvantages
SHARED	Residents can bring out waste at any time	Dumping at designated location	Residents and other generators are required to dump their waste at a specified location or in a masonry enclosure.	Low capital costs	Loading the waste into trucks is slow and unhygienic. Waste is scattered around the collection point. Adjacent residents and shopkeepers protest about the smell and appearance.
		Shared container	Residents and other generators put their waste inside a container which is emptied or removed.	Low operating costs	If containers are not maintained they quickly corrode or are damaged. Adjacent residents complain about the smell and appearance.
The generators need a suitable container and must store the waste on their property until it is		Block collection	Collector sounds horn or rings bell and waits at specified locations for residents to bring waste to the collection vehicle.	Economical. Less waste on streets. No permanent container or storage to cause complaints.	If all family members are out when collector comes, waste must be left outside for collection. It may be scattered by wind, animals and waste pickers.
		Kerbside collection	Waste is left outside property in a	Convenient. No permanent public	Waste that is left out may be scattered by wind,

System	Description	Advantages	Disadvantages
	container and picked up by passing vehicle, or swept up and collected by sweeper.	storage.	animals, children or waste pickers. If collection service is delayed, waste may not be collected or some time, causing considerable nuisance.
Door to door collection	Waste collector knocks on each door or rings doorbell and waits for waste to be brought out by resident.	Convenient for resident. Little waste on street.	Residents must be available to hand waste over. Not suitable for apartment buildings because of the amount of walking required.
Yard collection	Collection labourer enters property to remove waste.	Very convenient for residents. No waste in street.	The most expensive system, because of the walking involved. Cultural beliefs, security considerations or architectural styles may prevent labourers from entering properties.

Table 10. Compatibility of points of collection options [TAF, 2008].

Factors to be Considered	Door to Door	Adjacent to the Building	Waste Pooling Sites
Cost Effectiveness	Highest cost. Most beneficial.	Moderate cost.	Lowest cost. Least convenient to service users.
Health and Safety	Most injuries to service crews as a result of carrying and climbing stairs with a load.	Manual labour and injury risk reduced, especially with use of handcarts.	When compared to collection at buildings, waste pooling sites can be dangerous to service users and crews, particularly if the sites are not properly designed.
Environmental Appropriateness	Most environmentally sound. Controls waste at the source. No waste litter.	Environmentally sound, but if service is not frequent, some litter may remain around containers.	Potential for waste overflow, littering, insects, birds, rodents and communicable diseases.
Effectiveness	Effective if residents follow rules i.e. must put waste outside door within restricted hours.	Very effective if handcarts used. Waste can be put out at residents' convenience.	Very effective if collection is properly scheduled.
Public Acceptance	Very high. Most	Moderate convenience.	Not very convenient.

Factors to be Considered	Door to Door	Adjacent to the Building	Waste Pooling Sites
	convenient for public.		Residents complain in having to walk to the site, aesthetics of site, pests and odours.
Efficiency	Not efficient from productivity standpoint. Requires the most labour and equipment resources	Very efficient, reduces labour and vehicle requirements.	Low cost. Most efficient. Depends on collection frequency and citizen practice.

12.2. Collection equipment

Primary, secondary, and direct collection systems are available for collecting waste from households. Primary collection refers to individual households placing raw solid waste into their personal refuse bins. Secondary collection refers to the collection of solid waste from refuse bins or other primary sites and its transport to the TS, dumping site, or landfill. Direct collection is defined to be the collection of raw solid waste from households by the collection vehicles of SWM organizations and its subsequent transport to the final disposal site. The organizations involved in the collection of waste generated use various types of equipment for waste collection activities [Alam et al., 2008]. Figure 9 presents certain waste collection practices whereas Table 11 summarizes the different equipment involved in the collection process.

(a) (b)

(c)

Figure 9. (a) Door-to-door collected waste; (b) A Container for communal waste collection; and (c) Truck laborer collecting waste from a householder in the block collection system [Alam et al., 2008].

Table 11.Organizations involved in the waste collection process [Alam et al., 2008].

Activity	Equipment in use	Implementation body		
		Generator	Municipality	Private sector
Primary collection	By hand	x		
	Handcart		x	x
	Tricycle			x
Direct collection	Tricycle			x
	Tractor			x
	Open truck		x	
Secondary collection	Tractor		x	
	Open truck		x	x
	Container carrier		x	

Understanding existing conditions is the first step to better planning. Solid waste collection systems in most towns/cities requires LAs to collect waste from wherever it is discarded, including roadside, drains, public bins, etc. LAs need to document [TAF, 2008]:

- Storage/handling practices (types of containers and wastes).
- Collection Service Methods (Point of Collection and Method of Collection).
- Frequency of collection.
- Service Standards.
- Special Considerations (accumulated waste, waste diversion systems, special occasions).
- Present disposal methods.
- Public awareness and education programmes.
- Use of TSs.

Table 12 presents the advantages and disadvantages of the potential waste collection and transportation method (see Figure 10) each LA may choose.

Table 12. Waste collection and transport methods [EPA, 2002].

METHOD	ADVANTAGES	DISADVANTAGES
Trucks	• Appropriate for hauling over long distances typical in rural areas • Require a few workers	• Have moderate maintenance costs • Require established roadways
Trains	• Carry large loads. • Appropriate for transporting waste long distances.	• Expensive to operate and maintain. • Railroad proximity to customers a must.
Barges	• Carry large loads. • Appropriate for transport between coastal communities or on large rivers	• Expensive to operate and maintain. • Not appropriate for land transport. • Must be used in combination with other transport methods.
Transfer stations	• Serve as an intermediate collection point for small-scale waste haulers (e.g., carts). • Appropriate for urban areas where	• Require a dedicated site, maintenance, and site management. • May have public opposition due to odors, increased traffic, and illegal

METHOD	ADVANTAGES	DISADVANTAGES
	disposal is located far away. • Can further support the secondary materials markets (i.e., recycling).	dumping and/or open burning.

Figure 10. Vehicles currently in use by SWM [Alam et al., 2008].

When disposal sites are close by, this reduces or eliminates the need for TSs. Transfer is beneficial when the combined costs of hauling from the route to the TS and then to its final destination is less than the cost to haul waste directly from the collection route to the processing or disposal facility. Waste transfer sites are now a feature of most urban areas so its traffic congestion, the demands of recycling and the costs associated with legal action by staff injured while working, that are priorities. Transfer and transportation systems vary significantly among TSs, but they all consist of the following components [TAF, 2008]:

- A site near waste collection routes.
- A receiving area where waste collection vehicles discharge their loads.
- Equipment to move waste from the receiving area and load it into larger vehicles.
- Transportation equipment, typically a semi-tractor and transfer trailer, to take waste from the TS to the processing or disposal facility.
- Equipment to unload waste from transport vehicles (if not self-unloading) at the processing or disposal facility.

12.3. Cost estimation

When looking at SW collection and transportation costs, it is useful to consider the following:

- Currently, for most LAs the processing/treatment cost is zero (i.e. there is no centralized composting or recycling facilities).
- Similarly, most LAs do not have TSs. Hence, this cost is usually zero. However, by providing TSs the LA may be able to increase service and/or reduce costs.

- Most LAs are not spending enough money on the final disposal of waste. Spending on the final disposal needs to be increased as LAs progress from open dumping to other more environmentally sustainable methods of disposal.
- Typically, SWM collection/transportation makes up more than 60% of the total SWM costs.
- Generally, in Sri Lanka, SWM costs are somewhat low compared to developed countries as these countries use TSs and set a high standard for the disposal of waste.

Table 13 presents an indicative view of the cost categories in a case study performed in Sri Lanka.

Table 13. List of Operating Cost Items (case study: Sri Lanka) [TAF, 2008].

Category	Items
Collection: • Handcarts • Hand Tractors • Tractors/Trailers • Lorries • Compactor Trucks	Driver and labourer salaries. Staff equipment (gloves, aprons, boots, etc.). Diesel/oil. Vehicle repair/maintenance. Trailer repair/maintenance (including periodic frame rebuilding). Periodic handcart frame rebuilding (some LAs only). Tyres. Insurance/License. Depreciation. Overheads.
Transfer Station	All staff salaries – supervisor, vehicle drivers, labourers. Staff equipment. Tractor wheel loader costs. Transfer vehicle costs. Chemicals for odour/pest control. Land rental. Security. Overheads.

13. TRANSFER AND TRANSPORT OF SOLID WASTE{PRIVATE }

A TS is simply a facility where collection trucks bring collected materials for loading into larger vehicles and subsequent shipment, usually to a landfill, waste-to-energy plant or composting facility. Waste TSs play an important role in a community's total waste management system, serving as the link between community's solid waste collection program and a final disposal facility. This unit will examine the basic concepts of a solid waste TS and describes the types of sold waste TSs, its design requirements and the location of such facilities.

13.1. Basic concepts of a solid waste Transfer Station

Sometimes, for efficiency or convenience, municipalities find it desirable to transfer waste from collection trucks or stationary containers to larger vehicles before transporting it to the disposal site. To determine whether a transfer system is appropriate for a particular community, decision makers should compare the costs and savings associated with the construction and operation of a transfer facility. Benefits that a TS can offer include lower collection costs because crews waste less time travelling to the site, reduced fuel and maintenance costs for collection vehicles, increased flexibility in selection of disposal facilities, the opportunity to recover recyclables or compostables at the transfer site, and the opportunity to shred or bale wastes prior to disposal. These benefits must be weighed against the costs to develop and operate the facility. Also, transfer facilities can be difficult to site and permit, particularly in urban areas. Obviously, the farther the ultimate disposal site is from the collection area, the greater the savings that can be realized from use of a TS. The minimum distance at which use of a TS becomes economical depends on local economic conditions. However, most experts agree that the disposal site must be at least 25 km from the generation area before a TS can be economically justified. TSs are sometimes used for shorter hauls to accomplish other objectives, such as to facilitate sorting or to allow the optional shipment of wastes to more distant landfills.

13.2. Types of solid waste Transfer Stations

The type of station that will be feasible for a community depends on the following design variables:

- Required capacity and amount of waste storage desired
- Types of wastes received
- Processes required to recover material from wastes or prepare it (e.g. shred or bale) for shipment
- Types of collection vehicles using the facility
- Types of transfer vehicles that can be accommodated at the disposal facilities
- Site topography and access.

Following is a brief description of the types of stations typically used for three size ranges:

- Small capacity (less than 100 tonnes/day)
- Medium capacity (100 to 500 tonnes/day)
- Large capacity (more than 500 tonnes/day).

13.2.1. Small to Medium Transfer Stations

Typically, small to medium TSs are direct-discharge stations that provide no intermediate waste storage area. These stations usually have drop-off areas for use by the general public to accompany the principal operating areas dedicated to municipal and private refuse collection trucks. Depending on weather, site aesthetics, and environmental concerns, transfer operations of this size may be located either indoors or outdoors.

More complex small TSs are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, the station might include a recyclable materials separation and processing center. Usually, direct-discharge stations have two operating floors. On the lower level, a compactor or open-top container is located. Station users dump wastes into hoppers connected to these containers from the top level.

Smaller TSs used in rural areas often have a simple design and are often left unattended. These stations, used with the drop-off collection method, consist of a series of open-top containers that are filled by station users. These containers are then emptied into a larger vehicle at the station or hauled to the disposal site and emptied. The required overall station capacity (i.e., number and size of containers) depends on the size and population density

of the area served and the frequency of collection. For ease of loading, a simple retaining wall will allow containers to be at a lower level so that the tops of the containers are at or slightly above ground level in the loading area.

13.2.2. Larger Transfer Stations

Larger TSs are designed for heavy commercial use by private and municipal collection vehicles. In some cases, the public has access to part of the station. If the public will have access, the necessary facilities should be included in the design. The typical operational procedure for a larger station is as follows:

- When collection vehicles arrive at the site, they are checked in for billing, weighed, and directed to the appropriate dumping area. The check-in and weighing procedures are often automated for regular users.
- Collection vehicles travel to the dumping area and empty wastes into a waiting trailer, a pit, or onto a platform.
- After unloading, the collection vehicle leaves the site. There is no need to weigh the departing vehicle if its tare (empty) weight is known.
- Transfer vehicles are weighed either during or after loading. If weighed during loading, trailers can be more consistently loaded to just under maximum legal weights; this maximizes payloads and minimizes weight violations.

Several different designs for larger transfer operations are common, depending on the transfer distance and vehicle type. Most designs fall into one of the following three categories:

- Direct-discharge non-compaction stations,
- Platform/pit non-compaction stations, or
- Compaction stations.

Direct-Discharge Non-compaction Stations

Direct-discharge non-compaction stations are generally designed with two main operating floors. In the transfer operation, wastes are dumped directly from collection vehicles (on the top floor), through a hopper, and into open-top trailers on the lower floor. The trailers are often positioned on scales so that dumping can be stopped when the maximum payload is reached. A stationary crane with a clamshell bucket is often used to distribute the waste in the trailer. After loading, a cover or tarpaulin is placed over the trailer top. These stations are efficient because waste is handled only once. However, some provision for waste storage during peak time or system interruptions should be developed. For example, excess waste may be emptied and temporarily stored on part of the tipping floor. Facility permits often restrict how long wastes may be stored on the tipping floor (usually 24 hours or less). Advantages and Disadvantages of those TSs are presented in Table 14.

Table 14. Advantages and Disadvantages of Direct Dump Transfer Stations.

Direct Dump Stations: Waste is dumped directly from collection vehicles into waiting transfer trailers.

Advantages	Disadvantages
• Because little hydraulic equipment is used, a shutdown is unlikely. • Minimizes handling of wastes. • Relatively inexpensive construction costs. • Drive-through arrangement of transfer vehicles can be easily provided. • Higher payloads than compactor trailers.	• Requires larger trailers than compaction station. • Dropping bulky items directly into trailers can damage trailers. • Minimizes opportunity to recover materials. • Number and availability of stalls may not be adequate to allow direct dumping during peak periods. • Requires bi-level construction.

Platform/Pit Non-compaction Stations

In platform or pit stations, collection vehicles dump their wastes onto a floor or area where wastes can be temporarily stored, and, if desired, picked through for recyclables or unacceptable materials. The waste is then pushed into open-top trailers, usually by front-end loaders. Like direct discharge stations, platform stations have two levels. If a pit is used, the station has three levels. A major advantage of these stations is that they provide temporary storage, which allows peak inflow of wastes to be levelled out over a longer period. Although construction costs for this type of facility are usually higher because of the increased floor space, the ability to temporarily store wastes allows the purchase of fewer trucks and trailers, and can also enable facility operators to haul at night or other slow traffic periods. These stations are usually designed to have a storage capacity of one-half to two days' inflow. Advantages and Disadvantages of those TSs are presented in Table 15.

Table 15. Advantages and Disadvantages of Pit or Platform Non-compaction Transfer Stations.

Pit or Platform Non-compaction Stations: Waste is dumped into a pit or onto a platform and then loaded into trailers using waste handling equipment.	
Advantages	Disadvantages
• Convenient and efficient waste storage area is provided. • Un-compacted waste can be crushed by bulldozer in pit or on platform. • Top-loading trailers are less expensive than compaction trailers. • Peak loads can be handled easily. • Drive-through arrangement of transfer vehicles can be easily provided. • Simplicity of operation and equipment minimizes potential for station shutdown. • Can allow recovery of materials.	• Higher capital cost, compared to other alternatives, for structure and equipment. • Increased floor area to maintain. • Requires larger trailers than compaction station.

Compaction Stations

Compaction TSs use mechanical equipment to densify wastes before they are transferred. The most common type of compaction station uses a hydraulically powered compactor to compress wastes. Wastes are fed into the compactor through a chute, either directly from collection trucks or after intermediate use of a pit. The hydraulically powered ram of the compactor pushes waste into the transfer trailer, which is usually mechanically linked to the compactor.

Other types of equipment can be used to compact wastes. For example, wastes can be baled for shipment to a balefill or other disposal facility. Baling is occasionally used for long-distance rail or truck hauling. Alternatively, some newer compactors produce an extruded, continuous "log" of wastes, which can be cut to any length. Bales or extruded wastes can be hauled with a flat-bed truck or a trailer of lighter construction because, unlike with a traditional compactor, the side walls of the trailer do not need to restrain the wastes as the hydraulic ram pushes them.

Compaction stations are used when:

- wastes must be baled for shipment (e.g., rail haul) or for delivery to a balefill,
- open-top trailers cannot be used because of size restrictions such as viaduct clearances, and
- site topography or layout does not accommodate a multi-level building conducive to loading open-top trailers.

The main disadvantage to a compaction facility is that the facility's ability to process wastes is directly dependent on the operability of the compactor. Selection of a quality compactor, regular preventive maintenance of the equipment, and prompt availability of service personnel and parts are essential to reliable operation. Advantages and Disadvantages of those TSs are presented in Table 16 and Table 17.

Table 16. Advantages and Disadvantages of Hopper Compaction Transfer Stations.

Hopper Compaction Station: Waste is unloaded from the collection truck, through a hopper, and loaded into an enclosed trailer through a compactor.	
Advantages	Disadvantages
• Uses smaller trailers than non-compaction stations un-compacted. • Extrusion/"log" compactors can maximize payloads in lighter trailers. • Some compactors can be installed in a manner that eliminates the need for a separate, lower level for trailers.	• If compactor fails, there is no other way to load trailers. • Weight of ejection system and reinforced trailer reduces legal payload. • Capital costs are higher for compaction trailers. • Compactor capacity may not be adequate for peak inflow. • Cost to operate and maintain compactors may be high.

Table 17. Advantages and Disadvantages of Push Pit Compaction Transfer Stations.

Push Pit Compaction Station: Waste is unloaded from the collection truck into a push pit, and then loaded into an enclosed trailer through a compactor.	
Advantages	Disadvantages

• Pit provides waste storage during peak periods. • Increased opportunity for recovery of materials. • All advantages of hopper compaction stations.	• Capital costs for pit equipment are significant. • All other disadvantages of hopper compaction stations.

13.3. Transfer stations' equipment

Transfer Vehicles

Although most transfer systems use tractor trailers for hauling wastes, other types of vehicles are sometimes used. For example, in collection systems that use small satellite vehicles for residential waste collection, the transfer (or "mother") vehicle could simply be a large compactor truck. At the other extreme, some communities transport large quantities of wastes using piggyback trailers, rail cars, or barges. The following discussion presents information on truck and rail transfer vehicles. Although smaller vehicles may also be used for transfer, their use is more typically limited to collection.

Trucks and Semi-trailers

Trucks and semi-trailers are often used to carry wastes from TSs to disposal sites. They are flexible and effective waste transport vehicles because they can be adapted to serve the needs of individual communities. Truck and trailer systems should be designed to meet the following requirements:

- Wastes should be transported at minimum cost.
- Wastes must be covered during transport.
- The vehicles should be designed to operate effectively and safely in the traffic conditions encountered on the hauling routes.
- Truck capacity should be designed so that road weight limits are not exceeded.
- Unloading methods should be simple and dependable, not subject to frequent breakdown.
- Truck design should prevent leakage of liquids during hauling.
- The materials used to make the trailers and the design of sidewalls, floor systems, and suspension systems should be able to withstand the abusive loads innate to the handling and hauling of MSW.
- The number of required tractors and trailers depends on peak inflow, storage at the facility, trailer capacity, and number of hauling hours. Most direct-discharge stations have more trailers than tractors because empty trailers must be available to continue loading, but loaded trailers can, if necessary, be temporarily parked and hauled later.

It is important to select vehicles that are compatible with the TS. There are two types of trailers used to haul wastes: compaction and non-compaction trailers. Non-compaction trailers are used with pit or direct dump stations, and compaction trailers are used with compaction stations. Non-compaction trailers can usually haul higher payloads than compaction trailers because the former do not require an ejection blade for unloading. The legal payloads for compaction trailers are typically 16-20 tonnes, while legal payloads for open-top livebottom trailers are 20-22 tonnes. Possum-belly trailers (which must be tilted by special unloaders at the disposal site) can have legal payloads up to 25 tonnes. Transfer vehicles should be able to negotiate the rough and muddy conditions of landfill access roads and should not conflict with vertical clearance restrictions on the hauling route.

Rail Cars

In some countries railroads are used transfer wastes. As the distance between sanitary landfills and urban areas increases, the importance of railroads in transporting wastes to distant sites also grows. Rail transfer is an option that should be considered, especially when a rail service is available for both the TS and the disposal facility, and when fairly long hauling distances are required (80 km or more). Rail TSs are usually more expensive than similarly sized truck TSs because of costs for constructing rail lines, installing special equipment to remove and replace roofs of rail cars for loading or to bale wastes, and installing special equipment to unload rail cars at the disposal facility. Transfer trailers, however, can usually transport a payload of only 20-25 tonnes of waste, whereas a railcar can transport approximately 90 tonnes of waste. Wastes can be transported via rail using either dedicated boxcars or containerized freight systems. Most facilities use boxcars to transport baled wastes. Rail cars with removable roofs can be directly loaded in a rail direct discharge station. Containerized systems require double-handling of wastes because wastes must first be loaded into the containers and the containers then loaded onto rail cars; this process must be reversed at the destination. Therefore, handling costs usually prohibit the use of containerized shipment unless the TS or disposal facility is not accessible by rail. If the transfer facility or disposal facility is not served by rail, trucks must be used to transport either containers or non-containerized bales. In this situation, containers are usually less expensive to handle than are bales; also, bales become susceptible to breakage with increased handling [EPA, 2010].

13.4. Transfer Station design requirements

Transfer Station Design Considerations

This section discusses factors that should be considered during station design. In general, these factors were developed for designing large stations, but many also apply to smaller TSs. The main objective in designing a TS should be to facilitate efficient operations. The operating scheme should be as simple as possible; it should require a minimum of waste handling, while offering the flexibility to modify the facility when needed. Equipment and building durability are essential to ensure reliability and minimize maintenance costs. With modification, the facility should be capable of handling all types of wastes.

Site Location and Design Criteria

Local residents are most likely to accept the facility if the site is carefully selected, the buildings are designed appropriately for the site, and landscaping and other appropriate site improvements are made. These design features should be accompanied by a thorough plan of operations. When selecting a site, municipalities should consider the following factors:

- Proximity to waste collection area: Proximity to the collection area helps to maximize savings from reduced hauling time and distance.
- Accessibility of haul routes to disposal facilities: It should be easy for transfer trucks to enter expressways or other major truck routes, which reduces haul times and potential impacts on nearby residences and businesses. When considering sites, determine if local road improvements will be necessary, and if so, whether they will be economically and technically feasible. Accessibility to rail lines and waterways may allow use of rail cars or barges for transfer to disposal facilities.
- Visual impacts: The TS should be oriented so that transfer operations and vehicle traffic are not readily visible to area residents. To a great extent, visibility can be restricted if the site is large enough. The area required will depend on vehicle traffic and storage needs, necessary buffer areas, and station layout and capacity.

- Site zoning and design requirements: Municipalities should confirm that the proposed use meets the site zoning requirements. In addition, the local site plan ordinance should be reviewed to identify restrictions that could affect design, such as building height and setback, and required parking spaces.
- Proximity to utility tie-ins: The TS may require the following utility services: electricity and gas, water (for domestic use and fire fighting), telephone, and sanitary and storm sewers. Station designers should determine the cost of connecting to these utilities and the continuing service charges associated with them.

In some cases, municipalities may wish to consider the construction of more than one TS. For example, two TSs may be economically preferable if travel times from one side of the city to the other are excessive. One of the most time-consuming aspects of transfer facility design is site permitting. The permitting process should, therefore, be started as soon as a suitable site is selected. States usually require permits, and some local governments may require them as well. The project team should work closely with regulatory agency staff to determine design and operating requirements, and to be sure that all submittal requirements and review processes are understood. Some additional considerations for TS site design are as follows:

Office Facilities

- Space should be adequate for files, employee records, and operation and maintenance information.
- Office may be in same or different building than transfer operation.
- Additional space needed if collection and transfer billing services included.

Employee Facilities

- Facilities including lunchroom, lockers, and showers should be considered for both TS and vehicle personnel.

Weighing Station

- Scales should be provided to weigh inbound and outbound collection vehicles and transfer vehicles as they are being loaded or after loading.
- Number of scales depends on traffic volume. Volume handled by one scale depends on administrative transaction time, type of equipment installed, and efficiency of personnel. A rough rule-of-thumb estimate for collection vehicle scales is about 500 tonnes/ day. Another estimate that can be used for design purposes is a weighing time of 60 to 90 seconds/vehicle.
- Length and capacity of scales should be adequate for longest, heaviest vehicle. Different scales can be used for collection and transfer vehicles.
- Computerized scale controls and data-recording packages are becoming increasingly common. Computerized weighing systems record tare weight of vehicle and all necessary billing information.

On-site Roads and Vehicle Staging

- If the public will use the site, separate the associated car traffic from the collection and transfer truck traffic
- Site roads should be designed to accommodate vehicle speed and turning characteristics. For example, pavement should be wider on curves than in straight lanes and have bypass provision on operational areas.
- Ramp slopes should be less than 10% (preferably 6% max. for up-ramp)
- The road surface should be designed for heavy traffic.
- Minimize intersections and cross-traffic. Use one-way traffic flow where possible.
- Assure adequate queue space. For design purposes, assume that 25 to 30% of vehicles will arrive during each of two peak hours, but check against observed traffic data for existing facilities.

Site Drainage and Earth Retaining Structures

- Drainage structures should be sized to handle peak flow with no disruption in station operation.
- Provide reliable drainage at bottom of depressed ramps.
- For most TS designs, earth retaining structures will be required. Elevation differences will vary depending on station design.

Site Access Control

- A chain-link fence, often with barbed wire strands on top, is usually required for security and litter control.
- Consider installing remote video cameras and monitoring screens to watch access gates.
- A single gate is best for controlling security and site access.
- Signs stating facility name, materials accepted, rates, and hours of operation are usually desirable and often required. Ordinances may specify the size of such signs.

Buffer and Landscaping Areas

- Landscaped barriers (shrub buffers) provide noise and visual buffers, and are often required by local ordinance.
- Fast-growing trees that require minimal maintenance are the best choice. Evergreens provide screening throughout the year.

Fuel Supply Facilities

- Fuel storage and dispensing facilities are often located at TSs.
- Adequate space to accommodate transfer vehicles is very important.

Water Supply and Sanitary Sewer Facilities

- Water must generally be supplied to meet the following needs: fire protection, dust control, potable water, sanitary facilities use, and irrigation for landscaping.
- Fire protection needs usually determine the maximum flow.
- Sanitary sewer services are usually required for sanitary facilities and wash-down water.
- A sump or trap may be required to remove large solids from wash-down water.

Electricity and Natural Gas

- Electricity is necessary to operate maintenance shop, process and other auxiliary equipment and provide building and yard lighting.
- Natural gas is often required for building heat.

Transfer Station Building Design

Whenever putrescible wastes are being handled, larger TSs should be enclosed. Typically, TS buildings are constructed of concrete, masonry or metal. Wood is not generally desirable because it is difficult to clean, is less durable, and is more susceptible to fire damage. Key considerations in building design include durability of construction, adequate size for tipping and processing requirements, minimization of column and overhead obstructions to trucks, and flexibility and expandability of layout.

Transfer Station Sizing

The TS should have a large enough capacity to manage the wastes that are expected to be handled at the facility throughout its operating life. Factors that should be considered in determining the appropriate size of a transfer facility include:

- Capacity of collection vehicles using the facility
- Desired number of days of storage space on tipping floor
- Time required to unload collection vehicles
- Number of vehicles that will use the station and their expected days and hours of arrival (design to accommodate peak requirements)
- Waste sorting or processing to be accomplished at the facility
- Transfer trailer capacity
- Hours of station operation
- Availability of transfer trailers waiting for loading
- Time required, if necessary, to attach and disconnect trailers from tractors, or to attach and disconnect trailers from compactors
- Time required to load trailers.

Following formulas can be used for determining TS capacity:

Pit Stations:	Based on rate at which wastes can be unloaded from collection vehicles:
	C = Pc x (L/W) x (60 x Hw/Tc) x F
	Based on rate at which transfer trailers are loaded:
	C = (Pt x N x 60 x Ht)/(Tt + B)
Direct Dump Stations:	C = (Nn x Pt x F x 60 x Hw)/ [((Pt/Pc) x (W/Ln)) x Tc + B]
Hopper Compaction Stations:	C = (Nn x Pt x F x 60 x Hw)/[(Pt/Pc x Tc) + B]
Push Pit Compaction Station:	C= (Np x Pt x F x 60 x Hw)/[(Pt/Pc x W/Lp x Tc) + Bc + B]

Where,

B = Time to remove and replace each loaded trailer (minutes)

Bc = Total cycle time for clearing each push pit and compacting waste into trailer

C = Station capacity (tonnes/day)

F = Peaking factor (ratio of number of collection vehicles received during an average 30-minute period to the number received during a peak 30-minute period)

Ht = Hours per day used to load trailers (empty trailers must be available)

Hw = Hours per day that waste is delivered

L = Total length of dumping space (m)

Ln = Length of each hopper (m)

Lp = Length of push pit (m)

N = Number of transfer trailers loading simultaneously

Nn = Number of hoppers

Np = Number of push pits

Pc = Collection vehicle payload (tonnes)

Pt = Transfer trailer payload (tonnes)

Tc = Time to unload each collection vehicle (minutes)

Tt = Time to load each transfer trailer (minutes)

W = Width of each dumping space (m)

These formulas should be adapted as necessary for specific applications and do not reflect the effects of using the tipping floor to store wastes.

When selecting the design capacity of a TS, decision makers should consider tradeoffs between the capital costs associated with the station and equipment and the operational costs. The optimum capacity will often be a compromise between the capital costs associated with increased capacity and the costs associated with various operational parameters (for example, collection crew waiting time and hours of operation).

Facility designers should also plan adequate space for waste storage and, if necessary, waste processing. TSs are usually designed to have one-half to two days of storage capacity. The collection vehicle unloading area is usually the waste storage area and sometimes a waste sorting area.

When planning the unloading area, designers should allow adequate space for vehicle and equipment maneuvering. To minimize the space required, the facility should be designed so that collection vehicles back into the unloading position. For safety purposes, traffic flow should be such that trucks back to the left (driver's side). Adequate space should also be available for offices, employee facilities, and other facility-related activities.

Additional Processing Requirements

Solid waste transfer facilities can be designed to include additional waste processing requirements. Such processes can include waste shredding or baling, or the recovery of recyclable or compostable materials. At a minimum, transfer facilities should provide a sufficient area for the dump-and-pick recovery of targeted recyclables. For example, haulers servicing businesses usually reserve an area of the floor where loads rich in old corrugated containers can be deposited. Labourers then pick through the materials to remove the corrugated containers for recycling. Dump-and-pick operations are a low-capital way to begin the recovery of recyclables, but they are hard on workers' backs and inefficient for processing large volumes of materials.

Newer transfer facilities often include mechanically assisted systems to facilitate the recovery of recyclables. Some facilities use only conveyors to move the materials past a line of workers who pick designated materials from the conveyor and drop the sorted material into a bin or onto another conveyor. Other facilities use mechanical methods to recover certain materials; for example, a magnetic drum or belt can be used to recover tin cans and other ferrous metals, and eddy current separators can be used to remove aluminum. Shredders or balers are sometimes used to reduce the volume of wastes requiring shipment or to meet the requirements of a particular landfill where wastes are being sent. Shredders are sometimes used for certain bulky wastes like tree trunks and furniture. Solid waste facilities using shredders must take special precautions to protect personnel and structures from explosions caused by residual material in fuel cans and gas cylinders. Commonly used measures include inspecting wastes before shredding, explosion suppression systems, wall or roof panels that blow out to relieve pressure, and restricted access to the shredder area [EPA, 2010].

ACRONYMS

CBA	Cost Benefit Analysis
CDM	Clean Development Mechanism
DC	Developing Countries
EU	European Union
GHG	Greenhouse Gas
LA	Local Authorities
LCA	Life Cycle Analysis
MSW	Municipal Solid Waste
PP	Precautionary Principle
PPP	Public Pays Principle
SWDS	Solid Waste Disposal Sites
SWM	Solid Waste Management
TS	Transfer Stations

REFERENCES

[Agarwal et al., 2008] Agarwal V. and Mathur V., 2008. From two thousand to five million: failure and success in primary collection of waste. Proceedings of the Waste-The Social Context, Edmonton, Alberta, Canada, 11-15 May, CD-ROM edition.

[Alam et al., 2008] Alam R., Chowdhury M.A.I., Hasan G.M.J., Karanjit B. andShrestha L.R., 2008. Generation, storage, collection and transportation of municipal solid waste – A case study in the city of Kathmandu, capital of Nepal. Waste Management, Volume 28 (6), p. 1088-1097

[Ashkin, 2008] Ashkin S., 2008. Cradle To Grave Vs. Cradle To Cradle. Contracting Profits Magazine, July

[Bandara et al., 2007] Bandara N. J. G. J. , Patrick J. , Hettiaratchi A. , Wirasinghe S. C. and Pilapiiya S., 2007. Relation of waste generation and composition to socio-economic factors: a case study. Environmental Monitoring and Assessment Journal, Vol. 135, Numbers 1-3 / December, p.31-39.

[Bilitewski et al., 1997] Bilitewski B., Härdtle G., Marek K., Weissbach A. and Boeddicker H., 1997. Waste Management. Published by Springer-Verlang Berlin Heindelberg, Germany. ISBN: 9783540592105

[CalRecovery, 2005] CalRecovery Inc., 2005. Principles of Municipal Solid Waste Management. United Nations Environment Programme.ISBN 92-807-2676-5

[CLEANAWAY, 2010] CLEANAWAY, 2010. Available on: http://www.cleanaway.com.au/clwywr/lib51004/waste%20avoidance.pdf

[Cointreau, 2001 Cointreau S., 2001. Declaration of Principles For Sustainable and Integrated Solid Waste Management (SISWM). Available on http://www.worldbank.org/

[COMEST, 2005] COMEST (World Commission on the Ethics of Scientific Knowledge and Technology)/UNESCO, 2005. The Precautionary Principle. Published by the United Nations Educational, Scientific and Cultural Organization, Paris, France. Available on: http://unesdoc.unesco.org/images/0013/001395/139578e.pdf

[EPA, 2002] Environmental Protection Agency (EPA), 2002. What Are the Components of Waste Collection and Transport?. Leaflet . Available on http://www.epa.gov

[EPA, 2010] Environmental Protection Agency (EPA). Fact sheets. Available on http://www.epa.gov (Assessed on April 2010)

[EUROPA, 2010] EUROPA, 2010. Legislation summaries: Environment- waste management. Available on: http://europa.eu/legislation_summaries/environment/waste_management/ (Assessed on April 2010)

[Eurostat, 2005] Eurostat, 2005. Waste Generated and Treated in Europe. Data 1995-2003. European Commission -Eurostat,Luxemburg. 131 p.

[Gachet et al., 2006] Gachet Alexandre and Haettenschwiler Pius, 2006. Inteligent Decision-making Support Systems. Published by Springer London. ISBN: 978-1-84628-228-7

[Hann et al., 1998] Hann, H.C., Coad A. and Lardinois I., 1998. Involving micro- and small enterprises in Municipal solid waste management: Guidelines for municipal managers. International Training Center of the ILP, SKAT, WASTE. Turin, Italy. pp 90.

[INVENT, 2009] INVENT- Innovative Education Modules and Tools for the Environmental Sector, Particularly in Integrated Waste Management, in Different Courses of Study at Institutions of Higher Education, Designed to Enhance Competence in the Environmental Area and Increase Utilisation of Renewable Energy, 2009. Teaching Modules. ASIA Link project. Available on: http://www.invent.hs-bremen.de/ (Assessed on April 2010)

[Karagiannidis et al., 1995] Karagiannidis A. and Moussiopoulos N. (1995), Mediterranean Logistics Issues in the Management of Municipal Plastic Waste, Final Report to the Institute for Prospective Technological Studies, CEC, DG-XII, JRC, Thessaloniki, October.

[Karagiannidis et al., 2008] Karagiannidis A., Diaz L. and Kontogianni S. (2008), Solid waste management in developing countries: A review of current issues and a view on future perspectives, Proceedings of the Waste-The Social Context, Edmonton, Alberta, Canada, 11-15 May, CD-ROM edition.

[Kim, 2010] Kim Y.H., 2010. Trashy tourism. Waste Management World Journal, January-February issue, p.48-49.

[Mavropoulos, 2010] Mavropoulos A., 2010. 'Waste management 2030+: the future of waste management on an overcrowded planet', Waste Management World Journal, March-April issue, p.32-37

[MedCities, 2001] MedCities, 2001. Guidelines for Municipal Solid Waste Management in the Mediterranean Region. Available on: http://www.medcities.org/ (Assessed on April 2010)

[Mongkolnchaiarunya, 2005] Mongkolnchaiarunya J, 2005. Promoting a community-based solid-waste management initiative in local government: Yala municipality, Thailand. Habitat International, Volume 29, Issue 1, Pages 27-40

[Pargal et al., 1995] Pargal S and Wheeler D., 1995. Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia. Available on: http://www.jstor.org/stable/2138941?cookieSet=1(Assessed on April 2010)

[Pipatti et al., 2006] Pipatti R., Sharma C., Yamada M., Wagner J., Alves S., Gao Q., Sabin Guendehou G.H., Koch M., López Cabrera C., Mareckova K., Oonk H., Scheehle E., Smith A., Svardal P. and Manso Vieira S.M., 2006. Waste Generation, Composition And Management Data. 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[Plöchl et al., 2003] Plöchl Cl., Dobson G. and Buell U., 2003. Factors influencing municipal waste arising and composition. Proceedings of the 8th International Conference on Environmental Science and Technology, Lemnos Island, Greece, 8 – 10 September, Vol. B, pp. 682 – 689.

[PPP, 2003] Precautionary Principle Project, 2003. Available on: http://www.pprinciple.net/index.html (Assessed on April 2010)

[Sha'Ato et al., 2007] Sha'Ato R., Aboho S.Y., Oketunde F.O., Eneji I.S., Unazi G.and Agwa S., 2007. Survey of solid waste generation and composition in a rapidly growing urban area in Central Nigeria. Waste Management Journal, vol. 27(7), p. 352-358.

[TAF, 2008] TAF (Asia Foundation), 2008. Solid Waste Reduction Service Delivery Training Module 2 of 4. Available on http://asiafoundation.org

[Tickner et al., 2005] Tickner J., Raffensperger C. and Myers N., 2005. The Precautionary Principle in Action. HANDBOOK, Science and Environmental Health Network. Available on: http://www.biotech-info.net/handbook.pdf (Assessed on April 2010)

[UNFCCC, 2007] UNFCCC (United Nations Framework Convention on Climate Change), 2007. CDM Statistics. Available from http://cdm.unfccc.int/Statistics/index.html [10 November 2007].

[UNCHS] UN-Habitat, United Nations Settlement Programme (UNCHS), available on: http://www.unhabitat.org/ (Assessed on April 2010)

[WBG, 1998] WBG (World Bank Group), 1998. Principles of waste avoidance and utilization. Pollution Prevention and Abatement Handbook, p.29-31. Available on: http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/p_ppah_basicWasteAvoidance/$FILE/HandbookPrinciplesOfWasteAvoidanceAndUtilization.pdf (Assessed on April 2010)

[Wüstenhagen et al., 2007] Wüstenhagen R., Wolsink. M. and Bürer. M.J., 2007. Social acceptance of renewable energy innovation: An introduction to the concept. Energy Policy 35, pp 2683-2691.

[WWW, 2010] WWW, 2010. Waste Management World Editorial, May- June issue