2-1 Introduction

Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area. It may be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic, paper etc.); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc.). Management of solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life. A number of processes are involved in effectively managing waste for a municipality. These include monitoring, collection, transport, processing, recycling and disposal. [**http://www.cyen.org/innovaeditor/assets/Solid%20waste%20management.pdf].**

2-2 Origin of municipal solid wastes

Municipal solid waste refers to waste arising from domestic, commercial, industrial and institutional (including hospital) activities in an urban area. Municipal solid waste encompasses all waste that is neither wastewater discharges nor atmospheric emission.

Municipal solid waste includes non-hazardous waste generated in house. Commercial and business establishments, institutions and non-hazardous industrial waste, agriculture waste and sewage sludge. The composition of municipal solid waste is a heterogeneous mixture of different types of discarded materials. The composition depends on the conditions of the city in general.[**K.Sasikumar, and Sanoop Gopi Krishna 2012]**

There are eight major classifications of solid waste origins as listed below and detailed in the following sections[**Tchobanoglous, G., and Kreith, F., 2002].**

Household waste, Industrial waste, Commercial waste, Institutional waste, Hospital waste, Construction and demolition waste, municipal services waste, Agricultural waste.

2-2-1 Household Waste

Household waste constitutes the majority of the solid waste collected in urban areas. The percentage of household waste for large cities is in the range of 55 to 65% of the total amount of Municipal Solid Waste generated [**Oladele Osibanjo, December 2006]**. Clearly, residential areas within the city would have a larger percentage of such waste when compared with commercial or industrial neighborhoods.

The waste falling under this category includes primarily food waste. However, other wastes also fall in this category such as cardboard, plastic, textiles, leather, yard wastes, wood, glass, metals, ashes, occasional special wastes (e.g., bulky items, consumer electronics, white goods, tires), and household hazardous wastes (e.g., batteries, oil). This waste is typically generated by single or multifamily dwellings. The quantities of such waste are usually proportional to the number of persons living in each dwelling although different dwellings would generated different types and quantities of such waste**[Tchobanoglous, G., 1993]**

2-2-2 Industrial Wastes

Industrial solid waste is solid waste resulting from or incidental to any process of industry, manufacturing, mining, or agricultural operations. Industrial solid waste is classified as either *hazardous* or *nonhazardous.*

For the purpose of the MSW landfill site selection, industrial waste to be considered in this study should be limited to the non-hazardous components of the waste that can be assimilated to MSW. Hazardous waste generated at

Industrial facilities should not find their way into the MSW stream [**Tecobanoglous, G., and Kreith, F., 2002] .**

The range of industrial wastes generated as broad as the manufacturing industries that generate them, and as the waste management options used – which combine recycling, recovery and disposal techniques.

Although industrial waste can include process waste, chemicals, ashes and other special and hazardous wastes, the industrial waste that could be accepted as part of the MSW stream should be limited to housekeeping wastes, packaging, and food waste. Construction and demolition materials and non-hazardous off-specifications products.

2-2-3 Commercial Wastes

Commercial wastes are those wastes that are generated by stores, hotels, restaurants, markets and office building. Wastes generated from offices typically include large quantities of paper. Wastes generated from stores include a larger percentage of packaging materials, while waste generated from restaurants and markets would typically include larger percentage of food wastes. Commercial waste typically constitutes the largest percentage of MSW in central business districts of the city. Commercial waste could be a source of recyclable material. Large institution could be given an incentive to separate packaging or paper waste at the source thus facilitating the potential for recycling of such waste while at the same time reducing their waste management fees [**Tchobanoglous, G., 1993**] .

2-2-4 Institutional wastes

Institution wastes include the waste generated from schools, prisons and government centers. Institutional wastes are very similar in composition to commercial wastes and include mainly paper products and to a lesser extent food waste [**Tchobanoglous, G., 1993**] .

2-2-5 Hospital wastes

Hospital waste refers to the waste, which is generated in the diagnosis, treatment or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biological. Hospital wastes include:

(i) General or non-hazardous wastes, and (ii) infectious or sanitary / hazardous wastes[**WHO, 2005**].

- **General or non- hazardous waste:** are those wastes that are not contaminated with blood, body fluids, or other infectious agents or materials. These often include latex gloves, papers, fabrics, glass, food residues, and containers. According to a[**WHO, 2005**], around 75 to 85% of the hospital wastes are actually non-hazardous wastes comparable to domestic wastes. These wastes come mostly from the administrative and housekeeping functions of healthcare establishments, and may also include wastes generated during maintenance of healthcare premises. Such waste needs no special management other than proper separation from the hazardous waste. Once properly separated. They can be disposed off` in a similar manner to municipal solid wastes.
- **Hazardous medical waste includes infectious and non- infectious wastes**: The term sanitary" waste is often used to refer to this category of` hazardous wastes, According to a [**Nasima Akter, 2000**], about l0 to 20% of`the hospital wastes are infectious, and 5 to l0% are non-infectious but hazardous.

Hospital wastes are not generated only in hospitals. They are generated from different sources including the following [**Solid Waste Management Act, 2005**]

Major sources are: (a) hospitals, (b) other healthcare establishments, e.g.emergency medical care services, healthcare centers and dispensaries, obstetric and maternity clinics, outpatient clinics, dialysis centers,first-aidposts and sick bays, long-term healthcare establishments and hospices, transfusion centers, military medical services; (c) related laboratories and research centers;(d) mortuary and autopsy centers; (e) animal research andtesting facilities; (f) blood banks and blood-collection services; and (g)nursing homes for the elderly.

Minor sources are: (a) small healthcare establishments e.g. physician's office. dental clinics, and acupuncturists; (b) specialized healthcareestablishments and institutions with low waste generation, e.g. convalescent nursing homes, psychiatric hospitals, institutions for disabled persons; (c)non-health activities involving intravenous or subcutaneous interventions.

Support service sources are: pharmacy, laundry, kitchen, engineering, administration, and patient‘s attendance.

The composition of hospital waste includes variable percentages of"general" and "sanitary" waste depending on the type of medical establishment. Indicative percentages of hospital waste can be summarized as in table (2-l). Generation of wastes differs not only from country to country, but also by region and by hospital type. Generation of wastes depends on numerous factors, such as waste-management methods, type of healthcare establishments, hospital specializations, proportion of reusable items employed in healthcare, and proportion of patients treated on a daily basis [**WHO, 2005**].

Table (2-1): Classification of Hospital Waste] WHO, 2005**].**

Type of waste	percentage	Classification
Medication materials and single – use items	32%	General
Paper and packaging	25%	General
Food and kitchen waste	15%	General
Glassware	7%	General
Pathological	8%	Sanitary
Others: chemical, radioactive	8%	Sanitary
Sharp –edged items	5%	Sanitary

Generation of wastes also varies according to the type of healthcare establishments with university hospital typically generating more waste per bed than general private hospitals, which, in turn, generates more waste than public hospitals. Similarly, maternity wards are reported to generate significantly more waste per bed than any other hospital establishment. The total generation rate of hospital waste is often reported in terms of kg per bed per day. Some statistics factor in the occupancy of the beds in the hospital, in order to express the ratio in kg/patient/day. Typical waste generation rates in the Middle East are in the order of 1.3 to 3 kg / bed / day [**Jack McGurk, Darice bailey, Cindy Garcia, Steve Kubo and Mike Schott December 2002**].

2-2-6 Construction And Demolition Wastes

Wastes from the construction, reconstruction, remodeling, and repairing of residences, commercial buildings, and other structures are classified as construction wastes. The quantities produced are difficult to estimate due to

the prevailing economic situation [**Patrick J. Dolan, Richard G. Lampo, and Jacqueline C. Dearborn, June 1999**].

The composition is variable but may include dirt, stones, concrete, bricks, plaster, lumber, shingles, and plumbing heating and electrical parts. Wastes from razed buildings, broken out streets, sidewalks, bridges, and other structures are classified as demolition waste. The composition of demolition wastes is similar to construction wastes, but may include broken glass, plastics, and reinforcing steel[**Patrick J. Dolan, Richard G. Lampo, and Jacqueline C. Dearborn, June 1999**] .

Construction and Demolition (C&D) waste may contain dangerous substances, such as asbestos, which may be present when old buildings or industrial facilities are demolished or renovated. C&D wastes are likely to constitute a large percentage of the MSW to be collected in the near future.

In many countries, C&D waste is mainly disposed off in landfills, despite its suitability for recycling. Some Western European countries such as Germany,Denmark and The Netherlands, have achieved up to 90% recycling of C&D waste.

Many components of C&D waste are readily recyclable and have the potential to replace up to 10% of virgin raw materials. Special initiatives (incentives,legislations, or landfill taxes) may be needed to drive up the recycling rate [**Kreith, F., l994**].

2-2-7 Municipal Service Wastes

Other community wastes, resulting from the operation and maintenance of municipal facilities and the provision of other municipal

services, include street weeping's, road-side and wind-blown litter, spilled waste, dust, mud, landscape and tree trimmings, river clean up, dead animals, and abandoned vehicles[**Tecobanoglous, G., 1993**].

2-2-8 Agricultural Wastes

Agricultural waste typically consists of spoiled food Waste and crops. It also contains some limited amount of packaging waste [**Kreith, F., 1994**].

2-2-9 Summary of Solid Wastes Origin

The actual percentages of the aforementioned Waste types are expected to vary from one district to another. Table (2-2) summarizes the eight main waste origins that areto be taken into consideration in the assessment for MSW management.

Table (2-2): Summary of Waste Composition by Origin

[http://web.mit.edu/urbanupgrading/urbanenvironment/sectors/solid-waste-sources.html**]**

Source	Typical waste generators	Types of solid wastes
Household	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes.).
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, Industrial process wastes, scrap materials ,off specification products.
Commercial	Stores, hotels, restaurants,	Paper, cardboard, plastics, wood,

	markets, office buildings, etc.	food wastes, glass, metals, special wastes, hazardous wastes.
Institutional	Schools, hospitals, prisons, government centers.	Same as commercial.
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
Hospital	Hospital, clinics, healthcare centers, Maternity	If properly separated , non-hazardous hospital waste includes food, paper, and textiles
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., Pesticides.

2-3 Typical waste composition

The composition of MSW varies throughout the year with season and climate. It also varies within a city because purchasing, eating habits, and lifestyle are affected by income and education. The types of food people eat determine the type of garbage (kitchen waste), which they produce. The types of work people do affect the composition of the waste, which they generate. For example waste from banks and most offices will comprise mostly paper.On the other hand motor mechanics will produce scrap metal, old tires and disused motor parts. Similarly, food waste could account for up to 70% of the solid waste in residential areas and as little as 10% in city centers [**Olar Zerbock, April 2003**] .

The change in waste composition is also time related. In the 1960's - 1970's plastics waste were hardly generated. At the time, food was wrapped in paper. Nowadays, plastic has become the popular food wrap its percentage is increasing in waste composition. The composition of municipal waste depends to a large extent on the affluence of the population contributing to the waste stream. The composition of waste, both at the source and at disposal sites will impact the option for disposal and recovery. For example, the feasibility of composting is determined by a combination of the quantities of waste generated and the proportion of organic waste, amongst other factors [**Nickolas J. Themelis and Scott M. Kaufman, October 2004**].

Organic material forms 50-90% of urban refuse in many cities [**Martin Medina, l999**]. The organic fraction includes raw kitchen waste generated in the preparation and consumption of food: food leftovers, rotten fruit, vegetables, leaves, crop residues and animal excreta and bones. The bulk quantity of organic wastes is commonly generated by households, restaurants and markets. Analysis of waste composition in a number of countries aroundthe world has been compiled in order to better estimate the expected waste composition of Khartoum.

Table (2-3) shows the composition of Municipal Solid Waste in several cities with various income levels.

It is apparent that the biodegradable organic content is very high, due to the fact that reusable materials such as glass, hard plastics, metal scraps, paper and cardboard are retrieved and reused or recycled into valuable items[**Adrie Veeken, Pim Hamminga and Zhang Mingshu, 2006**].

Table (2-3): Compositions of Municipal Solid Waste (Percentage by Weight), [Martin Medina, 1999**]**

Category	Bangkok (1989)	Dar Al Salaam (1988)	Jakarta (1989)	Mexico City (1980)
Paper	12.4	6.2	2	19.2
Organics	**39.2**	**62.5**	**60**	**43.1**
Textiles	3.2	1.8		5.7
Plastics	9.4	0.3	2	5
Leather / rubber	1.9			
Metals	1.7	1.2	2	3.7
Glass	3.2	0.3	2	8.4
Others	29	27.7	32	14.9

Note: *Numbers in bold represent the highest percentages*

According to a [**World Bank, 1985**], the typical distribution of components in residential MSW based on per capita income is as presented in the table (2-4). In comparing the data presented above, the high percentage of food waste in lower income countries is justified because most vegetables and fruits are not pre-trimmed. Modern technological advances in the packaging of goods constantly change the composition of solid waste.

Table (2-4): Percentage of Waste Constituents per Income Level [World Bank, 1985]

component	<750$(monthly) Per capita income	>750$-<5000$ (monthly) Per capita income	>5000$(monthly) Per capita income
Food waste	**40-85**	**20-65**	6-30
Paper and Cardboard	1-1	8-30	**25-60**
Plastics	1-5	2-6	2-8
Textiles	1-5	2-10	2-6

Rubber / Leather	1-5	1-4	0-4
Yard waste/ wood	1-5	1-10	11-24
Glass	1-10	1-10	4-12
Metals	1-5	1-5	3-13

Note: *Numbers in bold represent the highest percentages*

Of particular significance are the increasing use of plastics and the use of frozen foods and pre-trimmed and processed food, which reduce the quantities of food wastes in homes but increase the quantities in agricultural processing plants. Another example of waste composition variations with income levels is presented in tables (2-5and 2-6). This is one of the reasons why waste studies have to be conducted on a regular basis in order to track such changes in the waste being generated. The percentage distribution values for the components in MSW vary with location (rural, urban, residential, commercial, industrial or agricultural zone), with season, economic conditions and many other factors.

Table (2-5): Waste Composition of Low, Middle, and High Income Countries[International Bank for Reconstruction and Development, 1999]

Current Waste Quantities and Composition	High Income Countries	Middle Income Countries	Low Income Countries
Paper	**36%**	15%	5%
Organic	28%	**58%**	**47%**
Plastic	9%	11%	4%
Glass	7%	2%	2%
Metals	8%	3%	1%
Others	12%	11%	41%

Notes: *Number in bold represent the highest percentage*

Table (2-6): Changes in the Composition of Solid Waste

[Indian Statistical Institute, 2003]

countries	Components					
	Organic	Paper	Plastic	Glass	Metal	Others
Low Income						
Myanmar(1993)	**80**	4	2	0	0	14
India(1995)	41.8	5.7	3.9	2.1	1.9	**44.6**
Estimate for India in 2025	**60**	15	6	3	4	12
Middle Income						
Indonesia(1993)	**70.2**	10.9	8.7	1.7	1.8	6.2
Philippines(1995)	**41.6**	19.5	13.8	2.5	4.8	17.9
Estimate for the philippines2025	**50**	20	9	3	5	13
High Income						
Japan (1993)	26	**46**	9	7	8	12
Hong kong(1995)	**37.2**	21.6	15.7	3.9	3.9	17.6
Estimate for Hong kong	33	**34**	10	7	5	11

Notes: *Number in bold represent the highest percentage*

2-4 Population size

According to the Central Bureau Statistics of Sudan, a census conducted on 2008 indicated that the total population of Sudan was around 39 million. The total population of Khartoum state was recorded as being (5,274,321), with the rural population of Khartoum state being (1,001,593) and urban population being(4,272,728).A study conducted by Central Bureau Statistics to estimate

the population of Khartoum state for years (2009-2018) and reported in 2013 that the population was in the order of 6.5 million.

2-5 Waste Generation Rate

2-5-1 Unit of Measure of Waste Generation

MSW is usually expressed in terms of kilograms per capita per day. The unit of measure is easily applicable for household waste where the per capita value can be directly multiplied by the population to obtain the total amount. In the case of SW of urban areas, household wastes constitute the largest percentage of waste types. It is for this reason that the unit of kilograms per capita per day is adopted. In the case of the other waste types such as industrial, hospital, commercial municipal services or institution waste, the relation is not direct. Industrial waste is usually expressed as a percentage of the production [**International Bank for Reconstruction and Development, 1999**].

Hospital waste is usually expressed as a weight per hospital bed.Commercial waste is often expressed per employee and municipal services wastes are usually expressed in terms of kilometers of roadways. When the objective is to develop an assessment for estimating the total amount of MSW reach the landfill sites, the waste quantities generated from non-household sources are back calculated in order to be expressed as a function of the population serviced. Another method is to increase the amount of household waste by the pro-rata of the waste from other sources in order to obtain an easily comparable unit of measure [**Nickolas J. Themelis and Scott M. Kaufman, October 2004**].

2-5-2 Comparison with International Waste Generation Rates

In the present state, daily per capita generation of MSW is much lower in developing countries than in developed countries. Differences also arise between high and low income countries in terms of waste composition and physical characteristics of wastes.

Table (2-7) shows the difference in these items between the developed and developing countries [**Christian Zurbrugg, 2002 and Nickolas J. Themelis and Scott M. Kaufman, October 2004**]. Data from nearby and other countries are presented in the subsequent sections.

Table (2-7): Typical Waste Generation Rates from a Number of Countries, [Christian Zurbrugg,2002 and Nickolas J. Themelis and Scott M. Kaufman, October 2004]

(Amounts are expressed in kg/capita/day)

Category	Bangladesh (1999)	Pakistan (2001)	Indonesia (2001)	Thailand (2003)	United States (2002)
Amount of waste Generation	0.5	0.6-0.8	0.8-1.0	1.6	3.26

Another example of generation rate in many neighbors' states and countries with similar socio-economic indicators are illustrated in table (2-8):

Table (2-8): Generation Rate of Different States

State	Date	Generation Rate (kg/capita/day)	Reference
Turkey	2001	1.31	[Turkey State Institute of Statistics, 2001]
Jordan	1999	0.60	[Atiyat N., and M. Mosa, 1999]
United Arab Emirate	2000	2.30	[UNEP , 2000]
Yemen	2000	0.80	
Egypt	2003	0.50	[African Studies Association of Austrasia and the Pacific, 2003]
Tunisia	2003	0.50	
Morocco	2003	0.60	
India	1998	0.50	[Ministry of Environment and Forests, 1998]

2-5-3 Variation with Income Level

High-income countries produce the most waste per capita, while low income countries produce the least solid waste per capita. Although the total waste generation for lower middle income countries is higher than that of upper middle Income countries, likely skewed as a result of China's inclusion in the lower middle income group, the high, upper-middle, lower-middle, and low income designations are somewhat inaccurate as these classifications are country-wide, and in several countries average national affluence can be very different from average affluence of theurban populations. Only the affluence of urban residents is important in projecting MSW rates.

Countries are classified into four income levels according to World Bank estimates of 2005 GNI per capita. High: $10,726 or above; Upper middle:$3,466-10,725; Lower middle: $876-3,465; and Lower: $875 or less. Relationship between income level and waste generation shown in table (2-9).

Table (2-9):Average Waste Generation Rate by Income Level

[World Bank, 2005]

Income Level	Range Waste Generation (kg/capita/day)
Low -Income	0.6 – 1.0
Middle -Income	0.8 – 1.5
High - Income	1.1 – 4.5

2-6 Recycling Market

Almost all waste is ultimately recyclable or reused one way or another.The main drive is the financial and technical feasibility of such recycling, the legislative requirements and the demand for the recycled material. Before even talking of recycling, one should mention the need for waste reduction through reuse and changes in behavior and not just transferring the burden of waste minimization on Municipalities or waste management companies[**Mathew V. Brooks, 2005**].

The constraint for recycling is not always technical; it is often related to the financial justification of the waste separation and recycling and the availability of a market for the products in the conditions they can be separated. In general the following categories of waste can be recycled oneway or another [**Tchobanoglous, G., Kreith, F., 2002; and Mathew V. Brooks, 2005**]:

- **Paper and cardboard**: Once separated from the waste stream these wastes can either be recycled into paper products or incinerated in the industry for energy production based on their relatively high calorific value and low air emissions. Paper and cardboard can also be mixed with the organic waste stream and be composted.

- **Glass**: Once separated from the waste stream, glass is recycled into glass products.
- **Aluminum:** Once separated from the waste stream, aluminum is recycled into aluminum and reused in the industry.
- **Metals**: Once separated from the waste stream, metals are also recycled into metal products and reused in the industry.
- **Plastics**: Once separated from the waste stream certain types of plastics can be recycled into pellets to be reused in the industry.
- **White Goods**: Once separated from the waste stream, white goods need further handling to be dismantled into plastics, metals and other components for separate recycling. White goods are often repaired and reused or dismantled for the recovery of spare parts.
- **Construction and Demolition Waste**: Separation of these wastes is usually easier as the bulk of the C&D waste is not considered as part of the household waste. It is often collected separately and could be recycled into aggregates and other products used once again in the construction or road industry.
- **Organic Waste**: Once separated from the waste stream, organic waste can be composted to produce soil enhancer.

Textiles, rubber, leather and other inorganic wastes have no directrecycling market and are therefore not considered in this study.

2-7 Recycling Issues

Recycling is the process by which materials otherwise destined for disposal are collected, processed and remanufactured or reused one way or another. Whether publicly or privately operated, a well-run recycling program can divert a

significant percentage of municipal, institutional and business waste from disposal and can help control waste management costs by generating revenue through the sale of recyclables [**Peter Van Beukring, and Vinod Sharma, l996**].

2-7-1 Recycling Objective

The objective of recycling is to reduce the amount of waste disposed in landfills. For it to be successful, legislation, public participation, and a sustainable market have all to be in place in order to ensure a high recycling rate for the waste at a cost lower than the cost of the raw materials. Subsidizing a recycling program to keep it running is not a recommended plan as the financial resources required to keep such a program running would be better spent on other programs [**Olympia's Waste Resource Plan, 2007**].

2-7-2 Recycling Feasibility

In order to justify the feasibility of recycling certain waste; first, there must be a market for the material. Without a market, there is no reason to collect a material for recycling. lf` a wide variety of materials are separated for recycling but no one wants them, there is a lot of wasted time and effort in getting this clean and sorted material ultimately to the landfill for disposal[**Peter Van Beukring, and Vinod Sharma, l996**].

The reason that plastics, metals, corrugated cardboard, newspaper, etc.,are commonly separated from the waste stream, is that there is a recycling infrastructure processors and manufacturers who want these materials and make them into products that are sold for profit. Without this infrastructure or market recycling cannot be sustained. Markets for collected recyclable materials will grow only by creating a need for recycled material [**Bill Sheehan, 2000**].

If there is a system in place for using collected materials, the next thing that is needed is having enough volume of a material to make it worth collecting and transporting to market. Recycling has a bottom line that goes beyond the environmental benefits. The more uncontaminated material there is,the more likely there will be a system in place to process it and make it into a usable product [**Tchobanoglous, G., l993**].

For a recycling program to be sustainable in the long run, recycling at the source is a justified investment as the operating costs under this scheme become lower than having to centrally collect all the waste and sort them manually and mechanically at a Material Recovery Facility (MRF).

Furthermore, this scheme encourages the public to be part of the system. Such public participation is important, as they are ultimately the final beneficiaries of the recycling program [**Cascadia Consulting Group, Inc., November 2006**].

2-8 Separation at Source Versus MRF

Materials targeted for recycling can be separated at the generator, known as "separation at source", or from the general waste stream at a mixed waste Material Recovery Facility, often referred to as an MRF. MRFs are further classified into "dirty" MRFs and "clean" MRFs. Dirty MRFs receive unsorted commingled waste. The term dirty is used because organic wastes are mixed with non-organic wastes. Clean MRFs receive pre-sorted waste consisting of non-organic waste only. A clean MRF requires the presence of an at-source waste separation program. Organic waste does not usually transit by clean MRFs. The absence of odors and moisture/leachate associated with the organic waste makes such MRF a much cleaner environment [**Rethink Education Center, 2006**].

There are advantages and disadvantages to source separation and material recovery from mixed wastes. These are summarized in the table (2-10) [**Rethink Education Center, 2006]**.

In general, cities tend to adopt a phased approach. The introduction of the recycling Concept is usually accompanied by the development of a dirtyMRF. As the population starts getting used to the concept and need of recycling, separation at source of the waste are introduced as pilot programs in selected neighborhoods or with selected users (commercial and industrial) before being implemented as a general waste management practice [**Cascadia Consulting Group, Inc., November 2006**].

Table (2-10): Advantages and Disadvantages of Source Separation Versus MRF, [Rethink Education Center, 2006]

Source Separation	Mixed Waste Material Recovery
Advantages	**Advantages**
• Cleaner recyclables with higher market demand • Generators bear the cost and responsibility for partial separation • Higher recovery rates than mixed waste separation	• Requires least changes in generators habits • No need for education of generators • No changes in collection waste separation system
Disadvantages	**Disadvantages**
• Separate collection system required • Requires education of generators and adequate participation • Added cost of recyclablecontainers • Requires clean material recovery facility • Theft of bins and materials	• Contamination of recyclables resulting in lower market demand or unmarketable materials • Requires "dirty" material recovery facilities • Lower recovery rates than source separation

Clearly, recycling based on at source waste separation would generate a higher percentage of recyclable products as the waste would be better separated and there would be less contamination of the waste by other unwanted wasteproducts. The main drawbacks of such a system are that it requires strong public participation and motivation and requires additional budgets and logistics for separate collections. For the population to be adequately motivated to actively participate in such a program, legislations and specific fee structures must be put in place, otherwise, there would be no or little incentive (other than environmental awareness) to push the population to adopt the recycling program. The costlier system is based on a separation at the source that has to be double checked at an MRF as in this case the costs represent the cost of bothsystems combined [**PA Department of Environmental Protection. 2004**]

2-9 Recycling of Organic Waste

The term recycling organic waste is not very accurate as the transformation of the food waste, yard waste and other organic material does not result in other food waste but in compost most of the time. Therefore, the term transformation or composting of organic waste may be more accurate in this ease [**Adrie Veeken, Pim Hamminga and Zhang Mingshu, 2006**].

Food waste consists of both perishable and non-perishable food items and is highly variable, due to the variety of foods and the numerous commercial and household activities involved in processing and preparing foods for consumption. According to [**CET, 1999 (b)**] the general characteristics of food waste include: highly putrescent; rapidly degradable; high moisture content; potential to produce liquid leachate; high bulk density (288 kg/m3). Generators are numerous and

diverse, including residential dwellings, commercial and institutional kitchens, restaurants, grocery stores, and food product manufacturers.

Food waste is often contaminated with paper, metal, glass, or plastic food packaging. Poor sorting of these could result in a significant reduction in the market price of the compost and in some cases the refusal by end-users touse such a material.

There is no major incentive to separate organic waste at source for the sake of the organic waste especially as the organic wastes are often discarded in plastic bags. The main reason for the separation at the source is to avoid the contamination of recyclable waste by organic waste [**CET, 1999 (a)**].

Once received at an MRF, organic waste is sorted by size and often as a residue of other sorting activities that are designed to separate metals, plastics, glass and paper. Once sorted, organic waste has to be shredded in order to increase its surface area for faster biodegradation [**Resource Management Group, Inc., April 2004**].

2-10 Recycling of Paper Products

The paper grades addressed in this section include: old newspaper (ONP),old corrugated containers (OCC), and high-grade office paper.

- OCC includes corrugated containers, Kraft paper such as brown paper grocery bags, and carrier stock as well as cuttings for each. Corrugated cardboard is made from strong, good quality wood fiber and includes un-waxed cardboard boxes and brown paper bags [**Daniel G. Pennington, and Robert C. Frazee, October 1996 (d)**].

- High-grade paper includes office paper and computer paper. Other paper grades typically fall in the mixed paper category for which the market is notvery significant. Paperboard cartons such as cereal boxes, waxed cardboard used for packaging fresh vegetables and other non-corrugated boxes cannot be recycled as cardboard but may be recycled with mixed paper products [**Robert Graf, and Bette Fishbein, l99l**].

Mixing paper with other waste or even simply other recyclables only to separate them again into product recycling streams increases the risk of contamination. Based on the above, it is almost impossible to recycle good quality paper if such paper is collected in a commingled way with other wastes.

Unless sorted at the source, paper is generally processed at material recovery facilities. Incoming paper can be sorted manually or mechanically.Mechanical systems allow lighter paper, such as magazines, newspaper, andmixed paper, to be separated from the heavier chipboard and corrugated cardboard. Further sorting into various grades could take place [**Daniel G. Pennington, and Robert C. Frazee, October 1996 (d)**].

2-11 Recycling Plastics Products

The plastics discussed in this section include thermoplastics that are the most commonly recycled. Thermoplastics are plastics that can be meltedor that get deformed at elevated temperatures. Other plastics are thermosetplastics that are chemically compounded after molding and are not sensitive to temperature anymore [**Daniel G. Pennington, and Robert C. Frazee, October 1996 (c)**].

The plastics industry has developed identification codes to label different types of plastic. The identification system divides plastic into seven distinct types and uses a number code generally found on the bottom of containers.

The seven categories of thermoplastics are [Information on Plastics &Environment]:

1. **Polyethylene Terephthalate (PET)**: Common uses - soda and water bottles. Cooking oil bottles, detergent bottles. This is the most widely recycled plastic. Wide sources in household and commercial Wastes.
2. **High Density Polyethylene (HDPE)**: Common uses - detergent bottles, milk jugs, and plastic bags. Wide sources in household, commercial and hospital wastes.
3. **Polyvinyl Chloride [PVC)**: Common uses - plastic pipes, outdoor furniture, shrink wrap, water bottles and liquid detergent containers. Wide sources in C&D, household, commercial and hospital wastes.
4. **Low Density Polyethylene (LDPE)**: Common uses - dry cleaning baas, produce bags, food storage containers. Wide sources in household and commercial wastes.
5. **Polypropylene (PP):** Common uses - bottle caps, drinking straws. Recycling centers almost never take #5 Plastic. Wide sources in household and commercial waste.
6. **Polystyrene (PS):** Common uses - packaging pellets or "Styrofoam peanuts," cups, plastic tableware. Wide sources in household, commercial and hospital wastes.
7. **Other*:*** Common uses - certain kinds of food containers. This plastic category is any plastic other than the named 1-6 plastic types. These are often multi-layered or mixed plastics. Recycling centers cannot easily recycle #7 Plastic. Wide sources in household, commercial wastes.

Unlike many other materials, reclamation of plastics is often a distinct and separate operation from plastics manufacturing processes. As a result, plastics re-claimers tend to be merchant processors who specialize in performingat reclamation process and then sell the reclaimed resin to manufacturers [**Daniel G. Pennington, and Robert C. Frazee, October 1996 (c)**].

2-12 Recycling of glass products

Glass containers are defined as post-consumer and post-industrialsuch as defective glass bottles) glass food and beverage containers. Glass Containers are generated in households and in industrial and commercial foodservice and hospitality settings, such as cafeterias, restaurants and bars. Asmall percentage of` the glass waste also originates from construction and Demolition waste in the form of broken windows and mirrors [**Tecobanoglous, G., 1993**].

Primary end uses for glass require the glass to be separated by color. Mixed color glass cullet has a lower market value and limited demand [**Keith Jamison, Jack Eisenhower, and Julie Rash, April 2002**]. Recycling at source tends to result in less mixed color cullet, based on the separation being done by residents. Sorting glass at MRFs tend to yield a higher amount of mixed cullet because of the increase percentage of glass breakage resulting from the extra handling of the material. Because of health and safety concerns, separating glass fragments manually is more difficult.

Broken glass is considered a major contaminant in other waste products [**Keith Jamison, Jack Eisenhower, and Julie Rash, April 2002**]. Broken glass mixes into cartons, plastic containers, cans and other targeted products, which lowers the product quality and therefore the product value.

If a mixed waste stream is eventually processed at the MRF, a methodto distinguish ceramics and other opaque materials is necessary [**Rethink Education Center, 2006**].

2-13 Recycling Aluminum Products

Aluminum cans, or Used Beverage Containers (UBCS), are single-serving aluminum cans used for beverages. They are generated wherever beverages are consumed: in households, commercial and institutional settings (restaurants, cafeterias, hospitals, schools, etc.).

Other non-ferrous metals are found in household items, construction and demolition projects (copper wire, pipe and plumbing supplies). The main problem with the recycling of non-ferrous metals is their separation from other foreign material such as plastics, fabrics and rubber [**Patrick J. Dolan, Richard G. Lampo, and Jacqueline C. Dearborn, June 1999]**.

Aluminum cans are considered a highly valuable waste. If waste sorting is not planned at an MRF, then separate collection of aluminum cans at the source is worthwhile based on the ease of collection and the market value of this product [**EPA, 1993**].

Aluminum cans are separated at the MRF from other materials by hand or by a combination of magnets and eddy current separators. They are typically baled before being sold, but are sometimes crushed and sold loose. Most MRFs sell their aluminum cans through a broker. Larger private MRFs establish contracts with end markets [**Cascadia Consulting Group, Inc., 2006**].

2-14 Recycling Ferrous Metal Products

Steel in the form of cans, including aerosol, food, and dry, used paint cans are generated by households, institutions (military, hospital, and school kitchens) and private sector commercial food service establishments (restaurants and cafeterias).

Steel waste is also generated in the form of bulky items such as appliances and vehicles. Although these are collected with other waste streams are not considered as part ofthe municipal solid waste. This category of steel waste is by far the most significant [**Cascadia Consulting Group, Inc., 2006**].

White goods such as refrigerators, washing machines, dryers, stoves, air conditioners and electric ranges are currently handled without removing any of harmful parts that is considered hazardous waste. Many older white goods contain capacitors, lighting ballasts or refrigerants that can be harmful to health and the environment. In addition, refrigerants found in freezers, refrigerators and air conditioners may contain chlorofluorocarbons (CFCS),which are harmful to the ozone layer [**White Goods Commodity Profile, 1998**].

Larger wastes are typically always collected separately. Appliances are seldom collected by waste collection vehicles mainly because they would not easily fit in compactor trucks or they may actually damage the hydraulic mechanism of the truck. Vehicles and other ferrous metals are typically taken to junkyards where they can be separated into metallic and other wastes for recycling.

Ferrous metals are considered a highly valuable waste. If waste sorting is not planned at an MRF, then separate collection of ferrous metals at thesource is worthwhile based on the ease of collection and the market value of this product? Collection at the source minimizes the extent of contamination of the ferrous metals by other wastes and other metals, [**Tom L. Richard, l993**].

2-15 Recycling C&D Wastes

Construction and demolition (C&D) wastes are generally inert waste generated during construction activities or resulting from the demolition of buildings and other structures. C&D waste consists mainly of: Concrete, Bricks block works, Soil and rock, Sand and sand bags, Asphalt, Metals, Wood, Glass,Plastics, White good, furniture and other personal belongings.

The largest fraction of C&D waste typically is made of concrete, bricks, block works, and soil and rocks. These materials have the potential to be reused with limited processing [**Patrick J. Dolan, Richard G. Lampo, and Jacqueline C. Dearborn, June 1999**].

Processing of C&D waste includes separation, preferable at the source and crushing in order to reduce the size of the waste to aggregate size and separate the metals and other unwanted wastes from the material that can be reused as aggregates (concrete, bricks, blockworks, and soil and rocks).

Crushing plants are typically installed at dedicated landfills for C&Dwastes in order to process the received waste and provide a source of aggregates to be reused in construction or roadways [**Patrick J. Dolan, Richard G. Lampo, and Jacqueline C. Dearborn, June 1999**].