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IACPE No 19, Jalan Bilal Mahmood 80100 Johor Bahru Malaysia	**SOLID WASTE TREATMENT** **CPE LEVEL TWO TRAINING MODULE**	

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INTRODUCTION

Scope

This design guideline covers the basic element of Solid Waste Treatment in sufficient detail to allow an engineer to develop and implement a solid waste treatment system.

The processes of storage, collection, transport, treatment and disposal of wastes all have the potential to pollute the environment and particularly groundwater due to uncontrolled migration of fluids (leachate) derived from the wastes. Solid waste composition, rate of generation and methods of treatment and disposal vary considerably throughout the world and largely determine the potential of waste to impair groundwater quality. Without a good management it can have a negative effect for health and the environment.

Solid waste can be managed with many process such as sanitary landfill, incineration recycle, bio-gasification, reuse, etc. Each process has advantages and disadvantages. Discussion details about each process can be considered for what the right process that should be applied in each area.

Waste can be loosely defined as any material that is considered to be of no further use to the owner and is, hence, discarded. However, most discarded waste can be reused or recycled, one of the principles of most waste management philosophies. Solid waste composition, rate of generation and methods of treatment and disposal vary considerably throughout the world and largely determine the potential of waste to impair groundwater quality.

General Design Consideration

Waste is generated universally and is a direct consequence of all human activities. Wastes are generally classified into solid, liquid and gaseous. Gaseous waste is normally vented to the atmosphere, either with or without treatment depending on composition and the specific regulations of the country involved. Liquid wastes are commonly discharged into sewers or rivers, in which many countries have legislation governing treatment before discharge. Solid waste means any garbage or refuse; sludge and other discarded material, including solid, semi-solid resulting from industrial, commercial, mining, and agricultural operations, and from community activities from a wastewater treatment plant, water supply treatment plant, or air pollution control facility.

Solid waste (i.e., trash) includes such routine wastes as office trash, un reusable packaging, lunchroom wastes, and manufacturing or processing wastes that are not otherwise classified as “hazardous” under the Resource Conservation and Recovery Act (RCRA). These wastes are normally deposited in trash cans and dumpsters and collected by a local trash hauler for disposal in a municipal landfill or treatment at a municipal incinerator.

Typical classification of solid waste as follows (Hosetti and Kumar, 1998)

1. Garbage: Putrescible wastes from food, slaughterhouses, canning and freezing industries.
2. Rubbish: non-putrescible wastes either combustible or non-combustible. These include wood, paper, rubber, leather and garden wastes as combustible wastes whereas the non-combustible wastes include glass, metal, ceramics, stones and soil.
3. Ashes: Residues of combustion, solid products after heating and cooking or incineration by the municipal, industrial, hospital and apartments areas.
4. Large wastes: Demolition and construction wastes, automobiles, furniture’s, refrigerators and other home appliances, trees, fires etc.
5. Dead animals: Households pets, birds, rodents, zoo animals, and anatomical and pathological tissues from hospitals.
6. Sewage sledges: These include screening wastes, settled solids and sledges.
7. Industrial wastes: Chemicals, paints, sand and explosives.

8. Mining wastes: Tailings, slug ropes, culm piles at mine areas
9. Agricultural wastes: Farm animal manure, crop residues and others.

Traditionally these wastes are categorized into the following five types.

1. Residential: It refers to wastes generated mainly from dwelling, apartments, and consisted of leftover food scrapes, vegetables, peeled material, plastics, wood pieces, clothes and ashes.
2. Commercial: This mainly consists of grocery materials, leftover food, glasses, and metals, ashes generated from stores, hotels, markets, shops and medical facilities.
3. Institutional: The wastes generated from schools, colleges and offices include, paper, plastics, and glasses.
4. Municipal: This includes dust, leaf litter, building debris, and treatment plant sediments. These arise from various activities like demolition, construction, street cleaning, land scraping etc.
5. Agricultural: This mainly includes spoiled food grains, vegetables, grass, litter etc., generated from fields and farms.

NTEPA classified waste into four general categories

1. Inert Waste. Inert wastes are wastes that are non-biodegradable, non-flammable, non-chemically reactive and have no potentially hazardous content once landfilled. Inert waste must not be contaminated or mixed with any other material.
2. Municipal Solid Waste. Municipal solid waste (MSW) is any non-hazardous, solid waste from a combination of domestic, commercial and industrial sources. It includes putrescible waste, garden waste and uncontaminated bio solids. All municipal solid waste should have an angle of repose of greater than five degrees (5°) and have no free liquids.
3. Listed Waste. Listed waste pose a threat or risk to public health, safety or the environment and include substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidizing and radioactive.
4. Industrial Waste. Industrial waste is that waste specific to a particular industry or industrial process. It may contain somewhat higher levels of contaminants, such as

heavy metals and human-made chemicals, than municipal solid waste and needs to be managed with environmental controls appropriate to the specific waste(s) being landfilled.

Waste composition also varies with the socio-economic status within a particular community since the income determines the life style, composition pattern and cultural behaviors. The typical composition of solid waste is showed in Table 1.

1. Important constituents are paper and decomposable organic matter.
2. Metal, glass, ceramics, textile, dust, dirt, and wood are generally present and their relative proportion depends on the local factor.
3. Average proportion of constituents reaching the disposal sites is consistent. Urban wastes are fairly constant in their composition although subject to long-term changes such as seasonal variations.

Table 1: The typical composition of solid waste

Components	*Mass%*	*Moisture %*	*Density Kg/m*
Food wastes	‘6-26	14	50-80
Paper	‘15-45	34	‘4-10
Cardboard	‘3-15	7	‘4-8
Plastics	‘2-8	5	‘1-4
Textiles	‘0-4	2	6-15
Rubber	‘0-1	0.5	‘1-4
Leather	‘0-2	0.5	‘8-12
Garden Trimmings	‘0-20	12	30-80
Wood	‘1-4	2	15-40
Misc.Org Sub.	‘0-5	2	10-60
Glass	‘4-16	8	‘1-4
Tin cans	‘2-8	6	‘2-4
Non ferrous Metals	‘0-1	1	‘2-4
Ferrous metals	‘1-4	2	‘2-6
Dirt ash bricks	‘0-10	4	‘6-12

Among the most desirable methods of waste reduction is the production of a salable substance or material, either by modification of the waste itself or by combining it with another waste material. Each significant solid waste stream should undergo characterization in order to determine the following:

- Opportunities for waste reduction
- Rate of waste generation
- Whether or not the waste is hazardous
- Suitability of the waste for landfilling
- Physical properties as they relate to suitability for landfilling
- Chemical properties as they relate to suitability for landfilling

- Estimation of leachate characteristics
- Suitability of the waste for incineration
- Estimated characteristics of stack emissions
- Estimated requirement for auxiliary fuel
- Estimated characteristics of ash
- Suitability of the waste for composting

Most adverse environmental impacts from solid waste management are rooted in inadequate or incomplete collection and recovery of recyclable or reusable wastes, as well as co-disposal of hazardous wastes. These impacts are also due to inappropriate siting, design, operation, or maintenance of dumps and landfills. Improper waste management activities can:

- Increase disease transmission or otherwise threaten public health. Waste handlers and waste pickers are especially vulnerable and may also become vectors, contracting and transmitting diseases when human or animal excreta or medical wastes are in the waste stream.
- Contaminate ground and surface water. Municipal solid waste streams can bleed toxic materials and pathogenic organisms into the leachate of dumps and landfills. If the landfill is unlined, this runoff can contaminate ground or surface water, depending on the drainage system and the composition of the underlying soils
- Create greenhouse gas emissions and other air pollutants. When organic wastes are disposed of in deep dumps or landfills, they undergo anaerobic degradation and become significant sources of methane, a gas with 21 times the effect of carbon dioxide in trapping heat in the atmosphere.
- Damage ecosystems. When solid waste is dumped into rivers or streams it can alter aquatic habitats and harm native plants and animals.
- Injure people and property. In locations where shantytowns or slums exist near open dumps or near badly designed or operated landfills, landslides or fires can destroy homes and injure or kill residents.
- Discourages tourism and other business. The unpleasant odor and unattractive appearance of piles of uncollected solid waste along streets and in fields, forests and

other natural areas, can discourage tourism and the establishment and/or maintenance of businesses.

Solid waste management in general —and in particular the final disposal of the waste— is a complex task that has became a common problem in developing countries. This is reflected in dirty public areas, waste recovery in the streets, an increase in informal activities; garbage is thrown into streams and rivers, or disposed of in open dumps; and men, women and children sort through the waste in these open dumps, under subhuman conditions, exposed to all kinds of diseases and accidents.

The poor management of MSW is a problem in most cities and small urban communities, and it is a growing problem. Among the many factors aggravating the situation in certain regions are: rapid population growth and high concentration of the population in urban areas, industrial development, changes in eating habits, and the widespread use of disposable containers and packages resulting in huge amounts of waste. Figure 1 show the integrated management of solid waste.

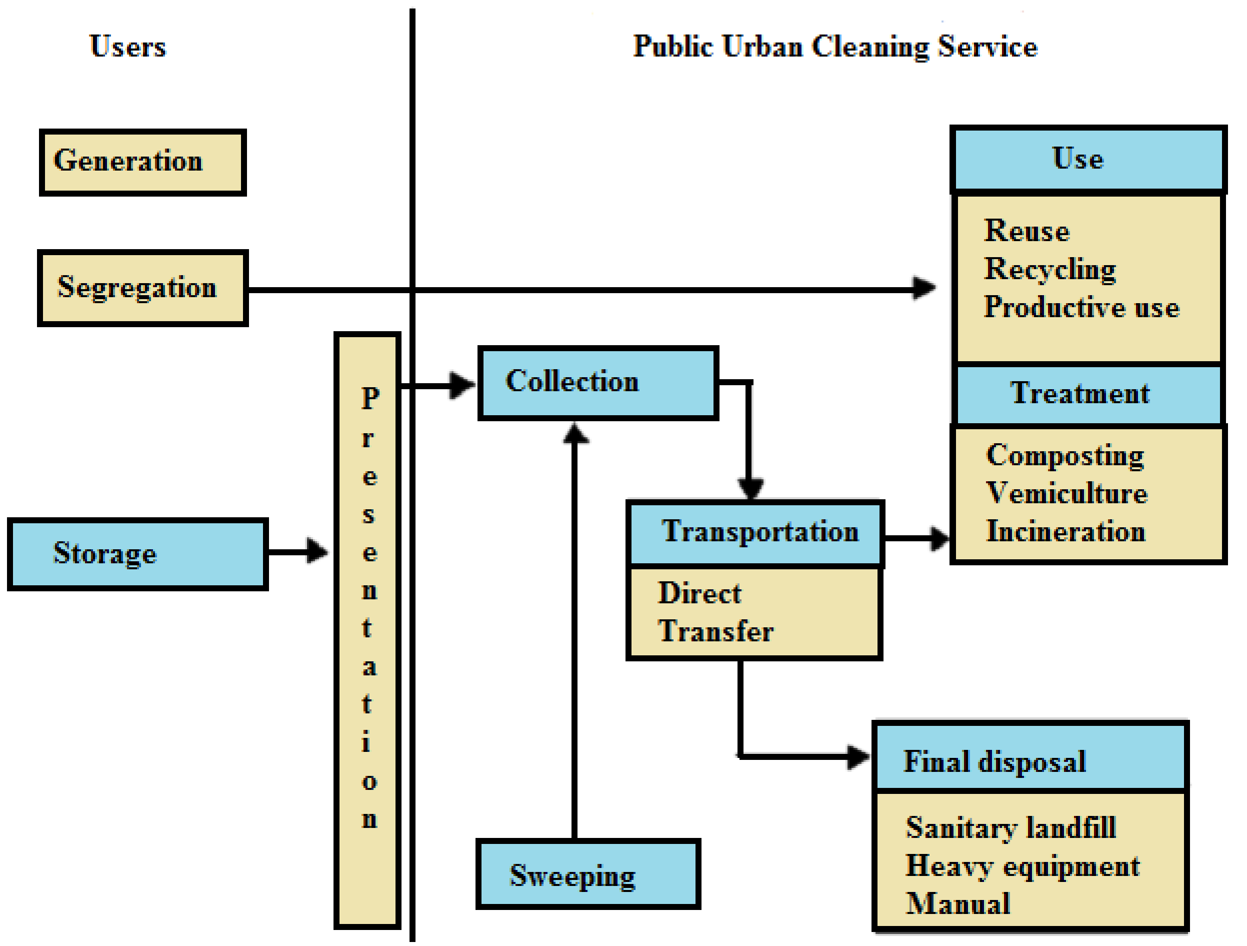

Figure 1: Integrated management of municipal solid wastes (Jaramillo, 2003)

As shown in Figure 1, generators of MSW (domestic, commercial, industrial, etc.) are users of the urban cleaning service and they are responsible for segregating their refuse, storing it in suitable containers, and depositing it in the place and at the times indicated by the operator of the service. Currently, there is a growing trend toward source segregation of MSW to facilitate recovery and recycling programs. Either the municipality or the cleaning service operator is responsible for collection, transportation, street sweeping and the cleaning of public areas, and the disposal of all MSW in a sanitary landfill. The municipality or service operator can also process the waste for reuse, or treat it in order to obtain economic and environmental benefits or to render it harmless.

Landfills (Sanitary landfills）

Landfill has been the cheapest methods of MSW disposal. Today, about 55% of MSW from the United States and 80% of Canadian MSW goes into landfills. Modern landfills have double liners with leachate collection and treatment and leak detection. Some landfills have triple liners. All landfills must be closed according to strict regulations, on reaching their useful life. Typically, an impermeable cap equipped with gas collection and erosion control means are required.

The sanitary landfill is a technique for the final disposal of solid waste in the ground that causes no nuisance or danger to public health or safety; neither does it harm the environment during its operation or after its closure. This technique uses engineering principles to confine the waste to as small an area as possible, covering it daily with layers of earth and compacting it to reduce its volume. In addition, it anticipates the problems that could be caused by the liquids and gases produced by the decomposition of organic matter.

The purpose of landfilling is to bury or alter the chemical composition of the wastes so that they do not pose any threat to the environment or public health. Landfills are not homogenous and are usually made up of cells in which a known volume of waste is kept isolated from adjacent waste cells by a suitable barrier. Barriers between the cells commonly consists of a layer of natural soil or clay, which checks the downward or later escape of the waste components or leachate.

Difficulties in developing new landfills

1. The difficulty in finding a geologically suitable site;
2. Local opposition: ‘not-in-my-backyard’;
3. Shortage of land.

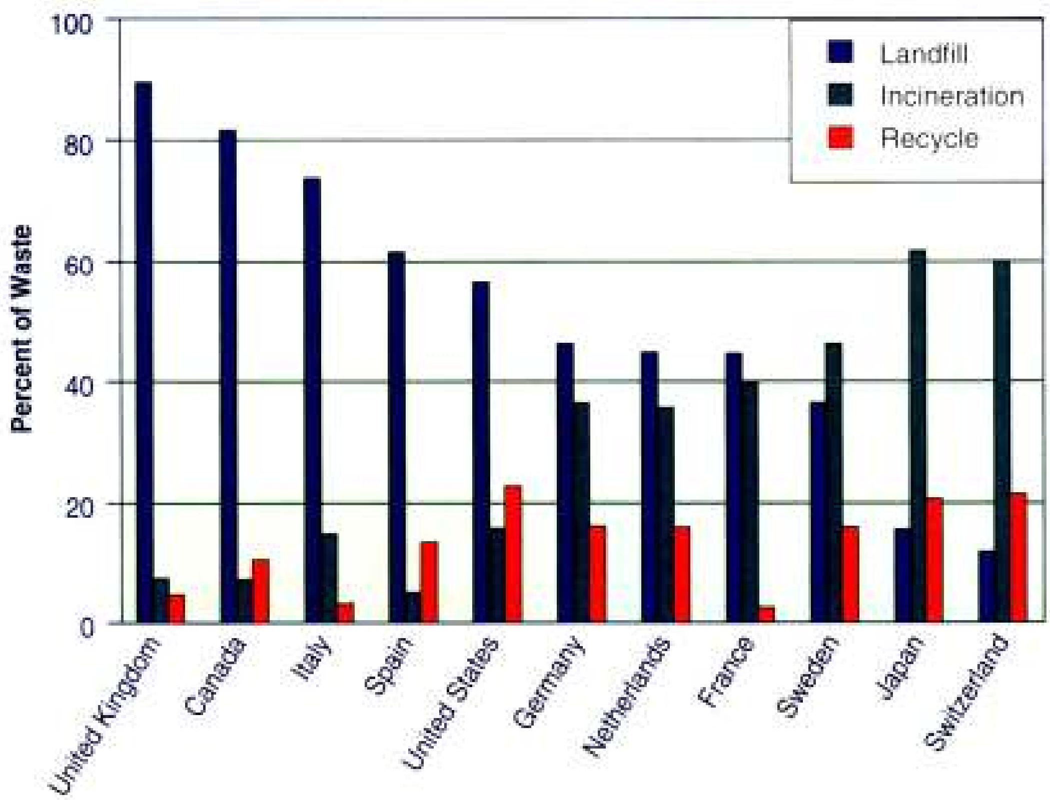

Figure 2: Disposal methods used in various countries

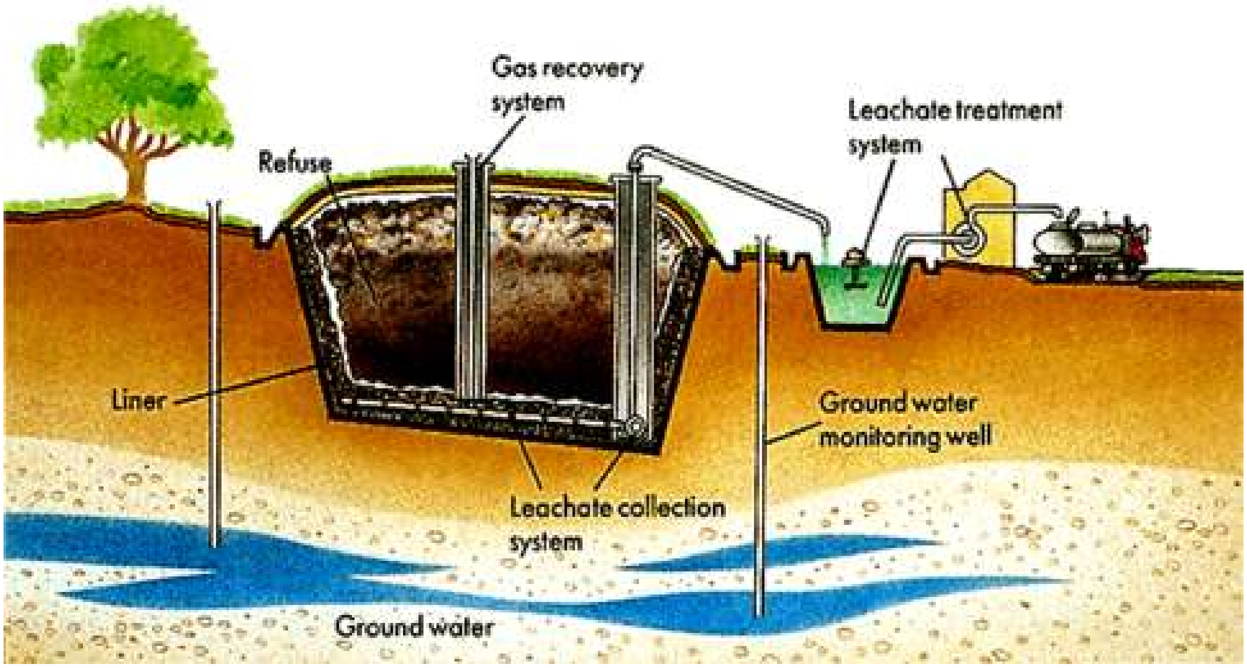

Figure 3: Sanitary Landfill (oocities.org)

Whether or not a particular solid waste is suitable for landfilling depends on its physical characteristics, chemical characteristics, and its probable leachate characteristics (i.e., whether or not there will be hazardous substances in the leachate). Physical properties that influence suitability for landfilling include those that influence structural stability. Often, water content is used to determine suitability for landfilling in the case of waste sludges. Another property is physical size.

Still another relates to the ability of landfill machinery to handle the waste at the landfill site. Chemical properties that influence suitability for landfilling, in addition to those properties that determine whether a waste is hazardous (i.e., corrosively, toxicity, ignitability, and reactivity) include foaming agents (methylene blue active substances), iron and manganese, odor and odor, generation potential, for instance, sulfate.

Incineration

Incineration is the process of burning refuse in a controlled condition. It is a chemical reaction in which carbon, hydrogen and other elements in the waste combine with oxygen in the combustion zone and generate heat. Usually excess air is supplied to the incinerator to ensure the complete mixing and combustion. Today, about 15% of MSW in the United States is incinerated; Canada incinerates about 8%; while Japan and Switzerland incinerate about 60% of their MSW. Incinerators have stack emission controls and are subject to strict regulations regarding handling and disposal of ash and residuals from stack emission controls.

Incineration converts MSW into inert material (cinder and ashes), and reduces it to 10% of its original volume. This reduction is obtained using special ovens with sufficient combustion air, turbulence, retention times, and adequate temperatures. Incomplete combustion, as in open-air burning, produces smoke, ashes, and bad odors.

The principal gas products of combustion are carbon dioxide, carbon monoxide, water, oxygen and oxides of nitrogen. Excess air also added to the incinerator to regulate operating temperature and control emissions. Excess air requirements will differ with moisture content of waste, heating values and the type of combustion technology employed. Many incinerators are designed to operate in the combustion zone of 900-1100^{o}C.

This temperature zone is selected to ensure a good combustion, complete elimination of odors and protection of the wall of the incinerator. These systems are designed to maximize the waste burnt out and heat output while minimizing the emissions by balancing the oxygen (air). The incineration process while combustion process emits air pollutants (fine particulate matter and gases) to the environment and their control is needed. The emission of combustible, carbon pollutants can be controlled by optimizing the combustion process (EPA, 1989).

Whether a waste can be destroyed by incineration (often referred to as “combustion”), and the quantity of auxiliary fuel that would be required to maintain a sufficiently high temperature in the combustion chamber to accomplish complete combustion, depends on several characteristics of the waste.

1. Water content. the demand that water places on auxiliary fuel usage and, thus, the cost of incineration.
2. Chemical composition influences the following:
   - The fraction of the total waste stream that can be converted to carbon dioxide and water
   - The characteristics of the stack emissions
   - The characteristics of the ash
   - The quantity of auxiliary fuel required

Within a total waste stream, the only elements that are converted to carbon dioxide and water are carbon and hydrogen. All other elements are converted to other substances or remain unchanged. Some elements are converted to anions of high oxidation state; for instance, sulfur is converted to sulfur dioxide or sulfur trioxide. Some elements are liberated as the free cation; for instance, mercury that has been incorporated into organic material (methyl mercury) most likely exits the stack as free Hg^+. Chunks of ferrous metals tend to remain unchanged. Sand and other inerts end up in the ash. Some heavy metals end up in the ash; a portion exit the stack.

Depending on the components the incineration process of solid waste reduces the volume of the waste by an average of 90%. The weight of the solid waste will be reduced to 70-75%. This has both ecological and economic advantages because there is less demand for final disposal to landfill, as well as reduced costs and environmental problems due to transport.

Advantages:
- The amount and volume of the MSW can be reduced significantly (up to 90% by volume and 75% by weight);

Disadvantages:
- Not all waste can be burned (There will still be landfills)
- Waste-to-energy;
- Release hundreds of toxic chemicals into the atmosphere;
- Disposal of the ash (The toxic substance are more concentrated in the ash);
- Highly related to the economic condition;

- A classic short-term solution (it destroys potentially useful (recyclable or compostable) material by turning it into toxic ash);

All incinerators (combustors) have the following characteristics in common:

- All solid waste substances must be converted to the vapor state before they can be ignited and burned.
- Two types of ash leave the system: fly ash and bottom ash. Both must be managed to prevent them from becoming environmental pollution problems. Incineration is therefore to be regarded as a treatment and volume reduction process, rather than as a disposal process.
- Solid wastes almost always have to be subjected to a conditioning process before entering the combustion chamber. Conditioning may include one or more of grinding, mixing, blending, dewatering, or other treatment.

The following points should be taken into account:

- A high initial investment is required.
- High operational costs are involved, usually beyond the reach of towns.
- Skilled technicians are needed
- Operation and maintenance procedures are complex, involving many problems.
- Insufficient flexibility for the incineration of large additional quantities of waste.
- An auxiliary fuel is required owing to the high moisture content that results in low calorific power for the MSW and this implies significantly higher treatment costs.
- Control equipment is required to prevent air pollution, since all incinerators release pollutants.

Composting

Composting is a biochemical degradation of the organic fraction of the solid wastes having humus like final products that could be primarily used as soil conditioner. Composting is the controlled biological decomposition of organic matters, such as food and yard wastes, into humus, a soil-like material. Composting is nature's way of transforming organic waste (such as kitchen vegetable scraps, soiled paper and yard trimmings) into new soil. The result of this process is known as “compost,” a product similar to humus, that acts as a soil conditioner rather than a fertilizer, and which can have a commercial value.

The composting methods can potential deal up to 25% of the MSW. The suitable (such as kitchen vegetable scraps, soiled paper and yard trimmings) materials can be turned into compost in 8 to 24 weeks. Composting facilities have extensive safeguards to protect against groundwater pollution.

Biodegradation is natural ongoing biological process that is a common occurrence in both manmade and natural environments. Grass clippings left in the lawn to decompose or food scraps rotten in the dustbins are the two examples of uncontrolled decomposition. To derive maximum benefit from this natural but slow process of decomposition it is needed to control the environmental conditions during the decomposition process. During this process in addition to compost it also produces carbon dioxide and water as by-products. Air is introduced into the waste pile through manual or mechanical turning or through blowers. The overall composting process can be explained as follows:

$$\text{Organic matter} + O_2 + \text{aerobic bacteria} \rightarrow CO_2 + NH_3 + H_2O + \text{other} + \text{energy}$$

Composting of organic materials can significantly reduce waste stream volume; it reduced the space in landfills. When compost is mixed with soil, it promotes a proper balance between air and water in the resulting mixture, helps to reduce the soil erosion and serves as a slow release fertilizer.

Composting may benefit developing countries by permitting the recovery of a high percentage of organic matter contained in MSW. Besides, composting calls for organic matter to be separated from the rest of the solid waste, which is a good opportunity to start recycling other materials. Composting can be an effective tool in managing certain waste materials, because it offers a means to generate a useful product while diverting significant amounts of organic materials away from landfills. Composting programs can be designed to handle yard wastes or the organic portion of municipal solid wastes, such as food and wood waste, or even paper.

Backyard or home composting is a common practice in rural areas and is increasing in suburban areas through promotional and instructive programs offered by waste reduction and cooperative groups. Large-scale composting programs are effective in certain areas, although civil actions against decomposition odors have repressed the development of more operations. Any consideration of new composting facilities must evaluate potential impacts to nearby residential development and the environment to avoid future lawsuits and forced closure.

In practice, composting has shown little success for the following reasons:

- Previous waste segregation is required; which increases costs, unless wastes with high organic content are collected selectively (such as wastes from restaurants, markets, etc.).
- . Flexibility does not exist for the treatment of additional large quantities.
- . The market for compost is unstable.
- . Investment costs are high.
- . Operation and maintenance costs of the composting facility are high.
- . Skilled technicians are required to operate the facility.
- . Transport expenses to rural areas are high.

Source reduction

Waste Reduction should be the highest priority in the hierarchy of solid waste management. The best way to manage solid waste is to not generate waste materials. Waste or source-reduction programs may be as broad and diverse as manufacturing earth-friendly products or encouraging selective purchasing and reuse patterns among consumers. Effective waste reduction programs result in broad-ranging benefits, such as natural resource conservation, reduced energy consumption, and reduced air, water, and land pollution.

Source reduction, also known as waste prevention or pollution prevention, is the elimination or reduction of waste before it is created. It involves the design, manufacture, purchase or use of materials and products to reduce the amount or toxicity of what is thrown away. Source reduction will promote the product reuse, and its lifetime and also reduce the probable toxicity of the material to the environment. The need of source reduction

1. Shortage of suitable landfill space; In many areas, no suitable land is available for landfills development.
2. The development of new landfill site is expensive; New landfills often resisted due to public concerns over groundwater contamination, odors, and truck traffic;
3. The number of landfill site has decreased by nearly 70%;

The practice in source reduction

1. Purchasing long-lasting goods;
2. Seeking products and packaging that are as free of toxics as possible;
3. Redesigning products to use less raw material in production, have a longer life, or be used again after its original use;
4. Reusing items is another way to stop waste at the source

Benefits of source reduction and reuse

- Saving natural resources;
- Reducing toxicity of waste;
- Reducing costs;
- Communities: More than 6,000 communities have instituted "pay-as-you-throw" programs where citizens pay for each can or bag of trash they set out for disposal;
- Business: When businesses manufacture their products with less packaging, they are buying less raw material;
- Consumers: Buying products with less packaging, or that are reusable (not single-use) frequently means a cost savings;

The effects of waste reduction can only be inferred by lower tonnages appearing in the system. At this level, an effective approach is to make the cost of waste production high, offering a carrot and stick approach. Citizens should be educated on waste reduction alternatives (Kliem, 2012):

- Encourage citizens and businesses to minimize excessive purchasing.
- Reuse materials such as clothing, furniture, building materials, industrial by-products, etc. Second-hand and thrift stores, commercial and industrial materials exchange organizations and yard sales are all examples of supporting the conservation of resources by maximizing their use.
- Implement programs to businesses and industry to provide information on proper disposition of waste materials and waste reduction strategies. Educate during waste audits.
- Provide financial incentive through variable rates application: higher rates for higher volumes / lower rates for active participation in waste reduction.
- Provide educational programs at schools, youth organizations, and volunteer organizations.
- Expand the Comprehensive Education, Information, and Promotion Program by the County, municipalities, recycling industry, and service providers; create Public/Private programs and Interdepartmental coordination to demonstrate the relationship between the environment and our impacts.
- Adopt and implement procurement policies specific to reuse and selection of materials that contain recycled products.

Recycling

Recycling is the process of separating, collecting, processing, marketing and ultimately using a material that would have been discarded. It also helps in the source reduction. It has benefits similar to other forms of source reduction. It reduces reliance on landfills and incinerators. It protects human health and the environment by removing the harmful substances from the waste stream. It also conserves natural resources by reducing the demand for raw materials. Recycling reduces the volume of the waste that has to be finally dumped, which means a reduction in pollution at the waste sites.

Recycling of solid waste should be the second highest priority for solid waste management. Source separation has been considered the most economical way of achieving higher rates, although commingling of recyclable materials and pick lines are often the most suitable means in certain areas. Recycling options include drop-off depots, buy-back centers, curbside collection programs, apartment collection programs, commercial collection programs, and composting.

Benefits of Recycling

1. Conserves resources for our children's future;
2. Prevents emissions of many greenhouse gases and water pollutants;
3. Supplies valuable raw materials to industry;
4. Creates jobs;
5. Stimulates the development of greener technologies;
6. Reduces the need for new landfills and incinerators (about 30% of the MSW is disposed through recycling);
7. Saves energy;

The non-biodegradable materials like paper, plastics, metals, glass and wood are commonly recycled in many parts of the world

1. Paper. Paper and cardboard form the second largest component of domestic solid waste and contribute more than 13% of the total (UNCHS, 1994). Paper recycling is one of the most profitable activities and is practiced extensively. It reduces the demand for wood and energy and helps to solve littering problem in the city and around dumping sites. It has acceptable working conditions and has limited health risks. Recovered paper is classified as newsprint, corrugated cardboard, junk mail, journals, magazines, high-grade paper and pulp substitutes. Paper mills are the most common end users of recovered papers. They use recovered paper for
2. Glass. Glass generally accounts for 2.5% by weight of the total solid waste generated (UNCHS, 1994). Recycling of broken glass reduces the risk of injuries caused by cuts and wounds.

3. Metals. On the average the components of metals in the solid waste stream is around 2% (UNCHS, 1994). Using recycling metal reduces considerable amount of operating cost for the industries.
4. Plastics. It constitutes an average of 8% of the total solid wastes generated. It is one of the major objectionable components of solid wastes. Unrecycled plastic when burned it contributes to green house and carcinogenic gases. Direct benefits of recycling of plastic is reduction in the cost of the raw material and energy saving.
5. Batteries and Tires. Battery recycling is more important as it contains heavy metals like lead, cadmium and mercury. Like other materials battery recycling depends largely on market conditions and requires consistent collection and processing. Battery reprocessing includes breaking the batteries, neutralizing the acids and chipping the containers for recycling.

Bio gasification

Biogas is originated from bacterial activities in the process of biodegradation of organic matter under anaerobic conditions. The natural generation of biogas is an important part of the biogeochemical cycle. Methane producing bacteria are the last link in the chain of microorganisms, which degrade organic matter and transfer the materials to the environment. In this process the biogas is generated which is a source of renewable energy. Biogas is a mixture of methane (40-70%), carbon dioxide 30-60%, and other gases 1-5%. Biogas may be used for producing heat, electricity and light. The biogas technology can substantially contribute to energy conservation and development, if the conditions are favorable (Hosetti, 2006).

Proprietary equipment with a pulping system to pulverize or machinate the infeed materials into a consistent size feedstock for the anaerobic digestion chamber or silo. One and two stage anaerobic digestion systems are available, where the solids are pressed from the liquids and processed in a separate system. Materials typically are premixed before being loaded in the silos; all curing of materials are done in a separate structure (open-sided or enclosed). At some installations, aeration is provided in the curing phase.

Advantages:

- Biogas produced provides a fuel for the generation of electricity and/or heat, displacing the use of fossil fuels. Bio gasification can be a net producer of energy. This is in contrast to composting, which requires the consumption of energy to provide aeration for microbial activity.

- Greenhouse gas emissions are reduced by the processing of waste by bio gasification, both by the displacement of fossil fuel emissions and the capture of carbon in the waste, which would otherwise have been released to the atmosphere as CO_2 (composting) or CH_4 (landfilling).

Disadvantages:

- Bio gasification is substantially more expensive than aerobic composting. Economies of scale can bring costs down for larger plant sizes, but the cost can be expected to be in a range that is comparable to incineration and advanced thermal treatment.

- Since bio gasification deals with the biodegradable portion of the waste stream (the portion that rots), odors from a bio gasification plant can be a concern

DEFINITIONS

Biodegradable - A quality of organic matter meaning that it can be metabolized by biological means.

Cell - Geometric conformation given to the MSW and to the cover material duly compacted by means of mechanical equipment or by the workers in a sanitary landfill.

Composting - The biological degradation and transformation of organic solid waste under controlled conditions designed to promote aerobic decomposition. Natural decay of organic solid waste under uncontrolled conditions is not composting.

Contaminate - The release of solid waste, leachate, or gases emitted by solid waste, such that contaminants enter the environment at concentrations that pose a threat to human health or the environment, or cause a violation of any applicable environmental regulation.

Cover material - The surface layer of earth in each cell, the purpose of which is to isolate the waste from the external environment, control infiltration, and keep harmful fauna away.

Degradable - The quality certain substances or compounds have of gradually decomposing by physical, chemical or biological means.

Disposal/Deposition - The discharge, deposit, injection, dumping, leaking, or placing of any solid waste into or on any land or water.

Domestic solid waste - The waste that by its nature, composition, quantity, and volume is generated by activities carried out in homes or in any other establishment with similar characteristics.

Drain - A structure that serves to clear soils of excess moisture.

Energy Recovery - The recovery of energy in a useable form from mass burning or refuse-derived fuel incineration, pyrolysis or any other of using the heat of combustion of solid waste that involves high temperature (above twelve hundred degrees Fahrenheit) processing.

Garbage - Animal and vegetable waste resulting from the handling, storage, sale, preparation, cooking, and serving of foods.

Incineration - Reducing the volume of solid wastes by use of an enclosed device using controlled flame combustion.

Industrial Solid Wastes - Solid waste generated from manufacturing operations, food processing, or other industrial processes.

Landfill - A disposal facility or part of a facility at which solid waste is permanently placed in or on land including facilities that use solid waste as a component of fill.

Leachate - Water or other liquid within a solid waste handling unit that has been contaminated by dissolved or suspended materials due to contact with solid waste or gases. The liquid produced mainly by rain filtering through the cover material and percolating through the layers of garbage, carrying significant concentrations of decomposing organic matter and other contaminants. Other factors that contribute to leachate generation are the moisture content typical of wastes, the water from decomposition, and the seepage of groundwater.

Municipal Solid Waste (MSW) - A subset of solid waste which includes unsegregated garbage, refuse and similar solid waste material discarded from residential, commercial, institutional and industrial sources and community activities, including residue after recyclables have been separated. Solid waste that has been segregated by source and characteristic may qualify for management as a non-MSW solid waste, at a facility designed and operated to address the waste's characteristics and potential environmental impacts.

Recyclable Materials - Those solid wastes that are separated for recycling or reuse, including, but not limited to, papers, metals, and glass, that are identified as recyclable material pursuant to a local comprehensive solid waste plan.

Recycling - Transforming or remanufacturing waste materials into usable or marketable materials for use other than landfill disposal or incineration. Recycling does not include collection, compacting, repackaging, and sorting for the purpose of transport.

Reuse - This is the return of a good or product to the economy to be used in the same way as before, with no change in its shape or nature.

Sewage Sludge - Solid, semisolid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and a material derived from sewage sludge. Sewage sludge does not include ash generated during the firing of sewage sludge in a sewage sludge incinerator or grit and screenings generated.

Solid Waste - All putrescible and non-putrescible solid and semisolid wastes including, but not limited to, garbage, rubbish, ashes, industrial wastes, swill, sewage sludge, demolition and construction wastes, abandoned vehicles or parts thereof, contaminated soils and contaminated dredged material, and recyclable materials.

Solid Waste Handling - The management, storage, collection, transportation, treatment, use, processing or final disposal of solid wastes, including the recovery and recycling of materials from solid wastes, the recovery of energy resources from such wastes or the conversion of the energy in such wastes to more useful forms or combinations thereof.

Treating - The physical, chemical, or biological processing of solid waste to make such solid wastes safer for storage or disposal, amenable for recycling or energy recovery, or reduced in volume.

NOMENCLATURES

A	Surface area of the landfill (m^2)
Ac	Area of the cell (m^2/day)
A_{SL}	Area to be filled successively (m^2)
A_t	Total area required (m^2)
cm	cover material
dw	Work days in a week
F	Factor of increase in the additional area required
hc	Height of the cell (m)
h_{SL}	Mean height or depth of the sanitary landfill (m)
hz	Depth (m)

J	Daily work day (hours/day)
K	Coefficient
L	Length of the trench (m)
P	Mean annual precipitation (mm/year)
Q	Mean flow of leachate (l/s)
R	Excavation output of the heavy equipment (m^3/hour)
Sw_{coll}	Quantity of solid waste collected (kg/day)
Sw_d	Quantity of solid waste daily (kg/day)
Sw_{md}	Mean daily quantity of solid waste in the sanitary landfill (kg/day)
Sw_p	Quantity of solid waste produced per day (kg/day)
T	Number of seconds in a year (31,536,000 s/year)
t	Time of useful life (days)
t_{exc}	Machinery time for the excavation of the trench (days)
V_{ac}	Volume of solid waste annual compacted (m^3/year)
Vc	Volume of the daily cell (m^3)
V_{dc}	Volume of solid waste daily compacted (m^3/day)
V_{sl}	Volume of the sanitary landfill (m^3/year)
Vz	Volume of the trench (m^3)
w	Width (m)
W_D	dry weight of sample
W_W	wet weight of sample

Greek Letters

ρ_A	bulk density of material A
ρ_B	bulk density of material B
ρ_{rec}	Density of solid waste recently compacted (kg/m^3)