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**CHE 5202- SOLID WASTE MANAGEMENT SYSTEMS**

This module is an introduction to the different solid waste management systems employed by different countries and municipalities and explains Waste Management Concepts. At the end of the Module the student should be able to: Determine the conditions for a managed solid waste system; determine the components of a waste management system and design or plan a complete waste management system or be aware of the conditions for designing a solid waste management system; Identify the best system for a given scenario; Design a trial management system for a given set of conditions and criteria; Plan for the After care of a Landfill;

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## 1. INTRODUCTION

The production of solid waste by communities has reached a stage where for all countries/governments are now required by necessity to take drastic/radical steps to address the issue. These measures include the enactment of special legislations to monitor and regulate the management of solid waste. Special bodies have been set up in many developed and developing countries to implement the regulations embodied in such legislations and to ensure compliance and best practice. Different Acts of Parliament are invoked to make up the total set of rules that must be complied with in order to fully enforce the laws. Laws are related to the collection, transportation, treatment, and safe disposal of the waste.

An in-depth knowledge of solid waste management, and in particular, management systems, processes, and, treatment methods as they relate to environment policies is required by governments in order for them to make informed decisions on waste management systems that incorporate the protection of the environment.

## 2. WASTE MANAGEMENT SYSTEMS

Waste management systems are designed to ensure the most efficient and appropriate systems are employed to match the ability of the authority implementing that particular system. In developing countries it is not always possible to implement a fully integrated system due to a lack of funding and will from the government.

A thorough knowledge of the principles of solid waste management is essential for the selection of the best methods for dealing with the urgent matter of managing the handling of solid waste from collection point to the final disposal.

Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health, the environment or aesthetics. Waste management is a distinct practice from resource recovery which focuses on delaying the rate of consumption of natural resources. The management of wastes treats all materials as a single class, whether solid, liquid, gaseous or radioactive substances, and tried to reduce the harmful environmental impacts of each through different methods.

Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential/domestic and industrial producers. Management for non-hazardous waste from residential and institutional settings in metropolitan areas is usually the responsibility of local government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator.

Land filling may be organised by a single government authority or it may be separated into both government and privately owned and run activities. In both cases a set fee may be charged for the disposal of waste through the landfills. The



government should still have inspection rights to the private landfills in order to ensure that minimum standard requirements are complied with.

### 3. BEST PRACTICABLE ENVIRONMENTAL OPTIONS

The best practicable environmental option is a set of procedures with the goal of managing waste and other environmental concerns. Emphasis is placed on the protection and conservation of the environment across land, air and water. The procedure establishes for a given set of objectives, the option that provides the most benefits or the least damage to the environment, as a whole, at acceptable cost, in the long term as well as in the short term."

### 4. WASTE MANAGEMENT CONCEPTS

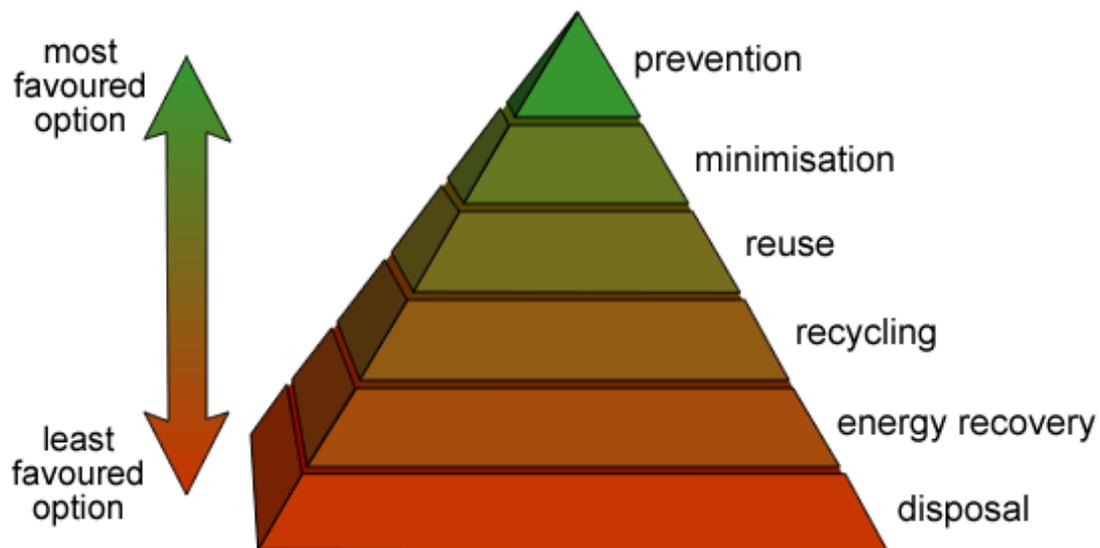


Figure 1. Diagram of the waste hierarchy.

There are a number of concepts about waste management which vary in their usage between countries or regions. Some of the most general, widely used concepts include:

- **Waste hierarchy** - The waste hierarchy refers to the "3 Rs" reduce, reuse and recycle, which classify waste management strategies according to their desirability in terms of waste minimization. The waste hierarchy remains the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.



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- **Polluter pays principle** - the Polluter Pays Principle is a principle where the polluting party pays for the impact caused to the environment. With respect to waste management, this generally refers to the requirement for a waste generator to pay for appropriate disposal of the waste.

## 5. COLLECTION

### 5.1 Waste Collection

Waste collection is the component of waste management which results in the passage of waste materials from the source of generation to either the point of treatment or final disposal. Waste collection also includes the kerbside collection of recyclable materials that technically are not waste, as part of a municipal landfill diversion program.

Waste collection methods vary widely among different countries and regions. Domestic waste collection services are often provided by local government authorities, or by private companies in the industry. Some areas, especially those in less developed countries, do not have a formal waste-collection system. Examples of waste handling systems include:

- In Europe and a few other places around the world, a few communities use a proprietary collection system known as Envac, which conveys refuse via underground conduits using a vacuum system. Other vacuum-based solutions include the MetroTaifun single-line and ring-line systems.
- In Canadian urban centres curb-side collection is the most common method of disposal, whereby the city collects waste and/or recyclables and/or organics on a scheduled basis. In rural areas people often dispose of their waste by hauling it to a transfer station. Waste collected is then transported to a regional landfill.
- In Taipei, the city government charges its households and industries for the volume of rubbish they produce. Waste will only be collected by the city council if waste is disposed in government issued rubbish bags. This policy has successfully reduced the amount of waste the city produces and increased the recycling rate.
- In Israel, the Arrow Ecology company has developed the ArrowBio system, which takes trash directly from collection trucks and separates organic and inorganic materials through gravitational settling, screening, and hydro-mechanical shredding. The system is capable of sorting huge volumes of solid waste, salvaging recyclables, and turning the rest into biogas and rich agricultural compost. The system is used in California, Australia, Greece, Mexico, the United Kingdom and in Israel. For example, an ArrowBio plant that has been operational at the Hiriya landfill site since December 2003 serves the Tel Aviv area, and processes up to 150 tons of garbage a day.

While waste transport within a given country falls under national regulations, trans-boundary movement of waste is often subject to international treaties. A major concern to many countries in the world has been hazardous waste. The Basel



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Convention, ratified by 172 countries, shall prevent movement of hazardous waste from developed to less developed countries. The provisions of the Basel convention have been integrated into the EU waste shipment regulation. Nuclear waste, although considered hazardous, does not fall under the jurisdiction of the Basel Convention.

## 5.2 Household Waste Collection

Household waste in economically developed countries will generally be left in waste containers (e.g. wheelie bins) or recycling bins prior to collection by a waste collector using a waste collection vehicle. However, in many developing countries, such as Mexico and Egypt, residents must interact with the waste collectors, or else trash is not removed (waste left in bins or bags at the side of the road cannot be expected to be removed). For example, in Mexico City residents must haul their trash to a waste collection vehicle which makes frequent stops around each neighbourhood. The waste collectors will indicate their readiness by ringing a distinctive bell and possibly shouting. Residents line up and hand their trash container to the waste collector. Depending on the neighbourhood, a tip may be expected. Additionally, private contractors waste collectors may circulate in the same neighbourhoods as many as 5 times per day, pushing a cart with a waste container, ringing a bell and shouting to announce their presence. These private contractors are not paid a salary, and survive only on the tips they receive. Later, they meet up with a waste collection vehicle to deposit their accumulated waste. The waste collection vehicle will often take the waste to a transfer station where it will be loaded up into a larger vehicle and sent either to landfill or to an alternative waste treatment facility. Similar systems operates in Sierra Leone, except that the local authorities now operate through a company called Freetown Waste management company and youths who are largely unemployed rent carts built by the company and move around the neighbourhoods to collect domestic wastes for a small fee. Ideally, household or domestic waste is collected from the residential areas on a regular basis. Sometimes for economic or management reasons, it is not possible to maintain a regular schedule so that waste can accumulate for days and potentially become a health hazard. Dogs and other scavengers rampage through the uncollected waste bins when left outside on the designated collection days.

## 5.3 Commercial or Industrial Waste Collection

Waste produced by mostly manufacturing companies is collected by the municipal authority and treated just like all other wastes. They comprise mostly of solid metal and plastic waste which are by products of their operations.

Again the type of vehicles used for this waste collection may be the same as those used for domestic waste collection. Open trucks may be used more than the closed type vehicles. Other things that are considered in Waste Collection is the positioning of the bin, type and size of bin, and how often it is to be serviced.



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There are a number of problems that can occur in Commercial Waste Collection. Overfilled bins result in rubbish falling out while being tipped. Hazardous rubbish (like empty petrol cans) lead to fires that ignite other rubbish when truck compactor is operating. Other non-paying parties can attempt to put rubbish in a bin. This behaviour is prevented by putting chains, bars and locks on the bins.

A common severe incident that occurs with many front lift garbage trucks is the pulling down of power lines. If hooks are left upright at the top of the crank, they are in prime position to pull down power lines. Truck drivers are now being trained in identifying and managing power line hazards.

#### 5.4 Hazardous Waste

Hazardous waste is produced by institutions such as hospitals and related activities and manufacturers engaged with products that involve chemicals and other additives.

### 6. TRANSPORTATION

Collection vehicles vary depending on the current practice of waste collection. Vehicles range from two wheeled bicycle type similar to a post man doing his rounds to fully articulated and automated high technology waste trucks manned by one person. In many developing countries an open back truck is used with ropes lashed around the waste to try and prevent the waste from discharging along the way to the landfill.

While waste transport within a given country falls under national regulations, trans-boundary movement of waste is often subject to international treaties. A major concern to many countries in the world has been hazardous waste. The Basel Convention, ratified by 172 countries, shall prevent movement of hazardous waste from developed to less developed countries. The provisions of the Basel convention have been integrated into the EU waste shipment regulation. Nuclear waste, although considered hazardous, does not fall under the jurisdiction of the Basel Convention.

### 7. TREATMENT

Sometimes waste may not be transported immediately to the landfills but are taken to transfer stations where they are sorted into materials that are allowed to be landfilled and those that not. This is a point also where some sorting process may occur to remove certain types and grades of waste for different subsequent processes.



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## 8. DISPOSAL

Disposal refers to any means by which solid waste is handled in a safe and proper manner to pose no harm to the human population. Leachate is collected from the landfill and is treated before it is safely disposed of in the drainage system or sewerage system.

### Methods of Disposal

Several methods are employed to treat and finally dispose of the waste in a well-managed system.

#### 8.1 Landfill

Sanitary landfills are organised facilities where the solid waste are placed and allowed to disintegrate into harmless form after a certain period of time. This will depend on the life expectancy and properties of the material of the waste components. In many developing countries, the concept of a landfill is still the operation of open dumps which are uncontrolled and exposed/subject to abuse by scavengers. This poses a health risk to everyone in the vicinity of the dumps: no clay liner means that leachate can seep through the soil to the water supply source aquifers; danger for the human scavengers from breathing toxic fumes; and, injury from sharp metal pieces, to name just a few.

Disposing of waste in a landfill involves burying the waste, and this remains a common practice in most countries. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly designed or poorly managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid leachate.

Design characteristics of a modern landfill include methods to contain leachate such as clay or plastic lining material. Deposited waste is normally compacted to increase its density and stability, and covered to prevent attracting vermin (such as mice or rats). Many landfills also have landfill gas extraction systems installed to extract the landfill gas. Gas is pumped out of the landfill using perforated pipes and flared off or burnt in a gas engine to generate electricity.

##### 8.1.1 Charges for the Landfill operations

All landfill activities must attract a fee for the convenience of the privilege to utilise the landfill. The authority that is operating the landfill set fees to be paid by either the generators or collectors of waste in some countries in the developed world.



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### 8.1.2 Landfill after care

A landfill when it finally ceases to accept any more waste will close and be buried under a top cover of soil. The landfill will continue to produce leachate and gases long after it closed. These are monitored appropriately and the soil is landscaped and may be turned into a recreation area.

### 8.2 Waste to Energy

Another common by-product of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odour problems, kill surface vegetation, and is a greenhouse gas. When properly harnessed, this gas can supply a sustainable source of Electricity via gas generators with any excess amounts being fed into the city or national grid for a nominal fee.

### 8.3 Energy recovery

The energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel. Thermal treatment ranges from using waste as a fuel source for cooking or heating and the use of the gas fuel (see above), to fuel for boilers to generate steam and electricity in a turbine.

Pyrolysis and gasification are two related forms of thermal treatment where waste materials are heated to high temperatures with limited oxygen availability. The process usually occurs in a sealed vessel under high pressure. Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other chemical products (chemical refinery). The solid residue (char) can be further refined into products such as activated carbon. Gasification and advanced Plasma arc gasification are used to convert organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam. An alternative to pyrolysis is high temperature and pressure supercritical water decomposition (hydrothermal monophasic oxidation).

### 8.4 Incineration

One way of reducing the amount of waste that is treated at the landfills is to resort to the incineration of all hazardous waste. Medical waste and biomedical waste consist of all waste materials generated at health care facilities including hospitals, clinics, offices of physicians, dentists, and veterinarians, blood banks, home health care facilities, funeral homes, medical research facilities, and laboratories. According to the Medical Waste Tracking Act of 1988, medical waste is "Any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or



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in the production or testing of biologicals." The items include blood-soaked bandages, culture dishes and other glassware, discarded surgical gloves, instruments, lancets, syringes, and needles (medical sharps), cultures, stokes, and swabs used to inoculate cultures, and removed body organs such as tonsils, appendices, etc.

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of residue of both solid waste management and solid residue from waste water management.

This process reduces the volumes of solid waste to 20 to 30 percent of the original volume. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam and ash. Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants.

Incineration is common in countries such as Japan where land availability is more scarce, as these facilities generally do not require as much area as landfills. Waste-to-energy (WtE) or energy-from-waste (EfW) are broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam or electricity. Combustion in an incinerator is not always perfect and there have been concerns about pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some very persistent organics such as dioxins, furans, PAHs which may be created and which may have serious environmental consequences.

## 8.5 Composting

This is a means of converting solid waste into useful agricultural material for fertilisation for use on farms and other crop growing activities, for example, backyard gardening. It is also a means of reducing the amount of waste that is handled by a landfill. Certain types of domestic and industrial wastes are pre-sorted so that only the fraction that is able to be decomposed fast and safely for use as agricultural products are retained for further processing.

## 9. WASTE MINIMISATION

### 9.1 Resource Recovery

Resource recovery (as opposed to waste management) uses LCA (life cycle analysis) attempts to offer alternatives to waste management. For mixed MSW (Municipal Solid Waste) a number of broad studies have indicated that administration, source



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separation and collection followed by reuse and recycling of the non-organic fraction and energy and compost/fertilizer production of the organic waste fraction via anaerobic digestion to be the favoured path.

## 9.2 Recycling

A method for reducing waste that is delivered and processed at the landfill is to separate the components of waste that can be reused.

## 9.3 Avoidance and reduction methods

An important method of waste management is the prevention of waste material being created, also known as waste reduction. Methods of avoidance include reuse of second-hand products, repairing broken items instead of buying new, designing products to be refillable or reusable (such as cotton instead of plastic shopping bags), encouraging consumers to avoid using disposable products (such as disposable cutlery), removing any food/liquid remains from cans, packaging, and designing products that use less material to achieve the same purpose (for example, light-weighting of beverage cans).

## 10. TECHNOLOGIES APPLIED IN WASTE MANAGEMENT

Traditionally the waste management industry has been slow to adopt new technologies such as RFID (Radio Frequency Identification) tags, GPS and integrated software packages which enable better quality data to be collected without the use of estimation or manual data entry.

- Technologies like RFID tags are now being used to collect data on presentation rates for curb-side pick-ups.
- Benefits of GPS tracking is particularly evident when considering the efficiency of ad hoc pick-ups (like skip bins or dumpsters) where the collection is done on a consumer request basis.
- Integrated software packages are useful in aggregating this data for use in optimisation of operations for waste collection operations.
- Rear vision cameras are commonly used for OH&S reasons and video recording devices are becoming more widely used, particularly concerning residential services.