INSTITUTE OF AERONAUTICALENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

INFORMATION TECHNOLOGY

COURSE LECTURE NOTES

Course Name	**ENERGY FROM WASTE**
Course Code	AEE551
Programme	B.Tech
Semester	VII
Course Coordinator	Mr. Ch Balakrishna, Assistant Professor
Course Faculty	Mr. B Bhavani, Assistant Professor
Lecture Numbers	1-45
Topic Covered	All

COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Understand the principles associated with effective energy management and to apply these principles in the day to day life.
II	Develop insight into the collection, transfer and transport of municipal solid waste.
III	Explain the design and operation of a municipal solid waste landfill.
IV	Evaluate the main operational challenges in operating thermal and biochemical energy from waste facilities and device key processes involved in recovering energy from wastes.

COURSE LEARNING OUTCOMES (CLOs):

Students, who complete the course, will have demonstrated the ability to do the following:

S. No	Description
AEE551.01	Apply the knowledge about the operations of Waste to Energy Plants.
AEE551.02	Understand physical and chemical analysis of municipal solid wastes and apply them for a management system that will be set up.
AEE551.03	Analyze the various aspects of Waste to Energy Management Systems.
AEE551.04	Design a compost facility, incineration facility and make site selection for a landfill.
AEE551.05	Explain the hierarchical structure in solid waste management and a requirement for an integrated solution.
AEE551.06	Use Geographical Information System for landfill site selection that takes place in Solid Waste Management Plan.

AEE551.07	Collect required data for a Solid waste management plan and edit the collected Dataset up Solid Waste Management Plan.
AEE551.08	Understand Biochemical conversion of biomass for energy application, Bio-energy systems and process integration.
AEE551.09	Discuss Thermo chemical conversion of Biomass for energy application.
AEE551.10	Understand the concept of bio mass Briquetting and its advantages.
AEE551.11	Evaluate the subject from the technical, legal and economical points by learning of all terms related to general solid waste management.
AEE551.12	Use multiple criteria decision making systems for an optimum and sustainable integrated solid waste management system based on entire data.
AEE551.13	Apply the knowledge in planning and operations of waste to Energy plants.
AEE551.14	Examine the technical points that are required to set up a solid waste management system.
AEE551.15	Apply the legal legislation related to solid waste management.
AEE551.16	Encourage students to organize recycling events and waste audit.
AEE551.17	Discuss the growth of electrical and electronics in waste to energy industry in India.
AEE551.18	Summarize government regulations on e-waste management
AEE551.19	Explain need for stringent health safeguards
AEE551.20	Understand need for stringent health safeguards and environmental protection laws of India.

SYLLABUS

UNIT-I	INTRODUCTION TO WASTE AND WASTE PROCESSING
Solid waste sources solid waste sources, types, composition, properties, global warming; Municipal solid waste: Physical, chemical and biological properties, waste collection and, transfer stations, waste minimization and recycling of municipal waste, segregation of waste, size reduction, managing waste, status of technologies for generation of energy from waste treatment and disposal aerobic composting, incineration, furnace type and design, medical waste / pharmaceutical waste treatment technologies incineration, environmental impacts, measures to mitigate environmental effects due to incineration.	
UNIT-II	**WASTE TREATMENT AND DISPOSAL**
Land fill method of solid waste disposal land fill classification, types, methods and sitting consideration; Layout and preliminary design of landfills: Composition, characteristics, generation, movement and control of landfill leachate and gases, environmental monitoring system for land fillgases.	
UNIT-III	**BIO-CHEMICAL CONVERSION**
Energy generation from waste bio-chemical conversion: Sources of energy generation, anaerobic digestion of sewage and municipal waste, direct combustion of MSW-refuse derived solid fuel.Industrial waste, agro residues and anaerobic digestion.	
UNIT-IV	**THERMO-CHEMICAL CONVERSION**
Biogas production, land fill gas generation and utilization, thermo-chemical conversion: Sources of energy generation, gasification of waste using gasifies briquetting, utilization and advantages of briquetting, environmental benefits of bio-chemical and thermo- chemical conversion.	
UNIT-V	**E-WASTE MANAGEMENT**
E-waste: E-waste in the global context: Growth of electrical and electronics industry in India, environmental concerns and health hazards; Recycling e-waste: A thriving economy of the unorganized sector, global trade in	

hazardous waste, impact of hazardous e-waste in India; Management of e-waste:
E-waste legislation, government regulations on e-waste management, international experience, need for stringent health safeguards and environmental protection laws of India.

Text Books:

1. Nicholas P Cheremisinoff, "Handbook of Solid Waste Management and Waste Minimization Technologies", An Imprint of Elsevier, New Delhi, 2003.
2. P AarneVesilind, William A Worrell and Debra R Reinhart, "Solid Waste Engineering", 2nd Edition 2002.
3. M Dutta , B P Parida, B K Guha and T R Surkrishnan, "Industrial Solid Waste Management and Landfilling practice", Reprint Edition New Delhi, 1999.
4. RajyaSabha Secretariat, "E-waste in India: Research unit‖, Reprint Edition, June, 2011.
5. AmalenduBagchi Design, "Construction and Monitoring of Landfills‖, John Wiley and Sons, New York, 1994.
6. M. L. Davis and D. A. Cornwell, "Introduction to Environmental Engineering", International Edition, 2008.
7. C. S. Rao, "Environmental Pollution Control Engineering", Wiley Eastern Ltd. New Delhi, 1995.
8. S. K. Agarwal, "Industrial Environment Assessment and Strategy", APH Publishing Corporation, New Delhi, 1996.
9. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), "Biomass Conversion Processes for Energy and Fuels", New York, Plenum Press, 1981.
10. Hagerty, D.Joseph; Pavoni, Joseph L; Heer, John E., "Solid Waste Management‖, New York, Van Nostrand, 1973.
11. George Tchobanoglous, Hilary Theisen and Samuel Vigil Prsl: Tchobanoglous, George Theisen, Hillary Vigil, Samuel, "Integrated Solid Waste management: Engineering Principles and Management issues", New York, McGraw Hill, 1993.

Reference Books:

1. C Parker and T Roberts (Ed), "Energy from Waste", An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985.
2. KL Shah, "Basics of Solid and Hazardous Waste Management Technology", Prentice Hall, Reprint Edition, 2000.
3. M Datta, "Waste Disposal in Engineered Landfills", Narosa Publishing House, 1997.
4. G Rich et.al, Hazardous, "Waste Management Technology", Podvan Publishers, 1987.
5. AD Bhide, BB Sundaresan, "Solid Waste Management in Developing Countries", INSDOC, New Delhi, 1983.

UNIT– I
INTRODUCTION TO WASTE AND WASTE PROCESSING

1.1 INTRODUCTION

Over the years, there has been a continuous migration of people from rural and semi-urban areas to towns and cities. The proportion of population residing in urban areas has increased from 10.84% in 1901 to 25.70% in 1991. The number of class I cities has increased from 212 to 300 during 1981 to 1991, while class II cities have increased from 270 to 345 during the same period. The increase in the population in class I cities is very high as compared to that in class II cities. The uncontrolled growth in urban areas has left many Indian cities deficient in infrastructural services such as water supply, sewerage and municipal solid waste management.

Most urban areas in the country are plagued by acute problems related to solid waste. Due to lack of serious efforts by town/city authorities, garbage and its management has become a tenacious problem and this notwithstanding the fact that the largest part of municipal expenditure is allotted to it. It is not uncommon to find 30-50% of staff and resources being utilized by Urban Local Bodies for these operations. Despite this, there has been a progressive decline in the standard of services with respect to collection and disposal of municipal solid waste including hospital and industrial wastes, as well as measures for ensuring adequacy of environmental sanitation and public hygiene. In many cities nearly half of solid waste generated remains unattended, giving rise to insanitary conditions especially in densely populated slums which in turn results in an increase in morbidity especially due to microbial and parasitic infections and infestations in all segments of population, with the urban slum dwellers and the waste handlers being the worst affected.

1.2 Introduction to Waste

1.2.1. Waste

Waste is any plastics, paper, glass, metal, foods, chemicals, wood, oil, soil, effluents, liquids that have been discarded. How the waste gets generated is from commercial, household and industrial sources. Sewage sludge is another source. Domestic and municipal waste is generated by the consumption of goods, manufacturing, sewage treatment, agriculture, the production & disposal of hazardous substances and construction. They are essential parts of the process of production as the emission of carbon dioxide by human is part of breathing process. From time immemorial, waste disposal has been a problem, and after industrialization the problem has only compounded. In the past, trash was carried to the outskirts of cities and discarded in the open, but now that can no longer be done. Over time, various waste disposal methods have been devised, like compost, burning, landfill, biological reprocessing, etc. However, before going to these details, we need to understand the different kinds of wastes.

Types of Wastes

There are basically three types of wastes generated and they are classified based on their chemical, biological and physical characteristics viz:

a) Solid wastes include materials like mining wastes and industrial wastes besides household garbage.

b) Liquid wastes are those in which the composition of solids is less than 1% and there is a high concentration of metals and salts.

c) Sludge contains a mixture of solid and water

1.3 DEFINITIONS AND CLASSIFICATION OF SOLID WASTES

1.3.1 Definitions

In order to plan, design and operate a solid waste management system, a thorough knowledge of the quantities generated, the composition of wastes and its characteristics are essential. As a first step, a proper definition of the terms is necessary to avoid the general confusion that is common in the usage of these terms.

There are many terms, which relate to the types and sources of wastes and these too must be defined. Based on the source, origin and type of waste a comprehensive classification is described below:

(i) Domestic/Residential Waste:

This category of waste comprises the solid wastes that originate from singleand multi-family household units. These wastes are generated as a consequence of household activities such as cooking, cleaning, repairs, hobbies, redecoration, empty containers, packaging, clothing, old books, writing/new paper, and old furnishings. Households also discard bulky wastes such as furniture and largeappliances which cannot be repaired and used.

(ii) Municipal Waste:

Municipal waste include wastes resulting from municipal activities and services such as street waste, dead animals, market waste and abandoned vehicles. However, the term is commonly applied in a wider sense to incorporate domestic wastes, institutional wastes and commercial wastes.

(iii) Commercial Waste:

Included in this category are solid wastes that originate in offices, wholesale and retail stores, restaurants, hotels, markets, warehouses and otherc ommercial establishments. Some of these wastes are further classified as garbage and others as rubbish.

(iv) Institutional Waste:

Institutional wastes are those arising from institutions such as schools, universities, hospitals and research institutes. It includes wastes which are classified as garbage and rubbish as well as wastes which are considered to be hazardous to public health and to the environment.

(v) Garbage:

Garbage is the term applied to animal and vegetable wastes resulting from the handling, storage, sale, preparation, cooking and serving of food. Such wastes contain putrescible organic matter, which produces strong odours and therefore attracts rats, flies and other vermin. It requires immediate attention in its storage, handling and disposal.

(vi) Rubbish:

Rubbish is a general term applied to solid wastes originating in households, commercial establishments and institutions, excluding garbage and ashes.

(vii) Ashes:

Ashes are the residues from the burning of wood, coal, charcoal, coke and other combustible materials, for cooking and heating in houses, institutions and small industrial establishments. When produced in large quantities at power generating plants and factories these wastes are classified as industrial wastes. Ashes consist of a fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass.

(viii) Bulky Wastes:

In this category are bulky household wastes which cannot be accommodated in the normal storage containers of households. For this reason they require special collection. In developed countries bulky wastes are large household appliances such as cookers, refrigerators and washing machines as well as furniture, crates, vehicle parts, tyres, wood, trees and branches. Metallic bulky wastes are sold as scrap metal but some portion is disposed of at sanitary landfills.

(ix) Street Sweeping:

This term applies to wastes that are collected from streets, walkways, alleys, parks and vacant lots. In the more affluent countries manual street sweeping has virtually disappeared but it still commonly takes place in developing countries, where littering of public places is a far more widespread and acute problem. Mechanised street sweeping is the dominant practice in the developed countries. Street wastes include paper, cardboard, plastic, dirt, dust, leaves and other vegetable matter.

(x) Dead Animals:

This is a term applied to dead animals that die naturally or accidentally killed. This category does not include carcass and animal parts from slaughterhouses which are regarded as industrial wastes. Dead animals are divided into two groups, large and small. Among the large animals are horses, cows, goats, sheep, hogs and the like. Small animals include dogs, cats, rabbits and rats. The reason for this differentiation is that large animals require special equipment for lifting and handling during their removal. If not collected promptly, dead animals are a threat to public health because they attract flies and other vermin as they putrefy. Their presence in public places is particularly offensive and emits foul smell from the aesthetic point of view.

(xi) Construction and Demolition Wastes:

Construction and demolition wastes are the waste materials generated by the construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. It mainly consists of earth, stones, concrete, bricks, lumber, roofing materials, plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream, but when generated in large amounts at building and demolition sites, it is generally removed by contractors for filling low lying areas and by urban local bodies for disposal at landfills.

(xii) Industrial Wastes:

In the category are the discarded solid material of manufacturing processes and industrial operations. They cover a vast range of substances which are unique to each industry. For this reason they are considered separately from municipal wastes. It should be noted, however, that solid wastes from small industrial plants and ash from power plants are frequently disposed of at municipal landfills.

(xiii) Hazardous Wastes:

Hazardous wastes may be defined as wastes of industrial, institutional or consumer origin which, because of their physical, chemical or biological characteristics are potentially dangerous to human and the environment. In some cases although the active agents may be liquid or gaseous, they are classified as solid wastes because they are confined in solid containers. Typical examples are: solvents, paints and pesticides whose spent containers are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous wastes cause explosions in incinerators and fires at landfill sites. Others, such as pathological wastes from hospitals and radioactive wastes, require special handling at all time. Good management practice should ensure that hazardous wastes are stored, collected, transported and disposed off separately, preferably after suitable treatment to render them innocuous. For details please refer to

(xiv) Sewage Wastes:

The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derive from the treatment of organic sludge from both the raw and treated sewage. The inorganic fraction of raw sewage such as grit is separated at the preliminary stage of treatment, but because it entrains putrescible organic matter which may contain pathogens, must be buried/disposed off without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but invariably its use for this purpose is uneconomical. The solid sludge therefore enters the stream of municipal wastes unless special arrangements are made for its disposal.

1.3.2 Composition and Characteristics

The composition and characteristics of municipal solid wastes vary throughout the world. Even in the same country it changes from place to place as it depends on number of factors such as social customs, standard of living, geographical location, climate etc. MSW is heterogeneous in nature and consists of a number of different materials derived from various types of activities. Even then it is worthwhile to make some general observation to obtain some useful conclusions.

- The major constituents are paper and putrescible organic matter;
- Metal, glass, ceramics, plastics, textiles, dirt and wood are generally present although not always so, the relative proportions depending on local factors;
- The average proportion of constituents reaching a disposal site(s) for a particular urban area changes in long term although there may be significant seasonal variations within a year.

For these reasons an analysis of the composition of solid waste, for rich and poor countries alike, is expressed in terms of a limited number of constituents. It is useful in illustrating the variations from one urban center to another and from country to country. Data for different degrees of national wealth (annual per-capita income) are presented in **Table 1.1.** Waste composition also varies with socio-economic status within a particular community, since income determines life-style – consumption patterns and cultural behaviour.

	Low Income Countries (1)	Middle Income Countries (2)	High Income Countries (3)
Composition : (% by weight)			
Metal	0.2 – 2.5	1 – 5	3 – 13
Glass, Ceramics	0.5 – 3.5	1 – 10	4 – 10
Food and Garden waste	40 – 65	20 – 60	20 – 50
Paper	1 – 10	15 – 40	15 – 40
Textiles	1 – 5	2 – 10	2 – 10
Plastics/Rubber	1 – 5	2 – 6	2 – 10
Misc. Combustible	1 – 8	–	–
Misc. Incombustible	–	–	–
Inert	20 – 50	1 – 30	1 – 20
Density (kg/m^3)	250 – 500	170 – 330	100 – 170
Moisture Content (% by wt)	40 – 80	40 – 60	20 – 30
Waste Generation (kg/cap/day)	0.4 – 0.6	0.5 – 0.9	0.7 – 1.8

Table.1.1: Composition and characteristics

The proportion of paper waste increases with increasing national income;

- The proportion of putrescible organic matter (food waste) is greater in countries of low income than those of high income;
- Variation in waste composition is more dependent on national income than geographical location, although the latter is also significant;
- Waste density is a function of national income, being two to three times higher in the low-income countries than in countries of high income;
- Moisture content is also higher in low-income countries; and

- The composition of waste in a given urban center varies significantly wiocio-economic status (household income).

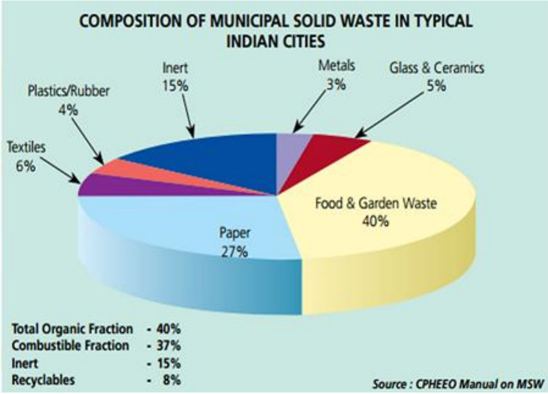


Fig 1.2 Composition of MSW

1.3.2.1 Characteristics of Municipal Solid Waste

1.3.2.1(a) Physical Characteristics

i. Density

A knowledge of the density of a waste i.e. its mass per unit volume (kg/m3) is essential for the design of all elements of the solid waste management system viz. Community storage, transportation and disposal. For example, in high income countries, considerable benefit is derived through the use of compaction vehicles on collection routes, because the waste is typically of low density. A reduction of volume of 75% is frequently achieved with normal compaction equipment, so that an initial density of 100 kg/m3 will readily be increased to 400 kg/m3. In other words, the vehicle would haul four times the weight of waste in the compacted state than when the waste is uncompacted. The situation in low-income countries is quite different: a high initial density of waste precludes the achievement of high compaction ratio. Consequently, compaction vehicles offer little or no advantage and are not cost-effective.

ii. Moisture Content

Moisture content of solid wastes is usually expressed as the weight of moisture per unit weight of wet material.

$$\text{Moisture Content (\%)} = \frac{\text{Wet weight} - \text{dry weight}}{\text{Wet weight}} \times 100$$

A typical range of moisture contents is 20 – 45% representing the extremes of wastes in an arid climate and in the wet season of a region having large precipitation. Values greater than 45% are however not uncommon. Moisture increases the weight of solid waste and therefore the cost of collection and transport. Consequently, waste should be insulated from rainfall or other extraneous water. Moisture content is a critical determinant in the economic feasibility of waste treatment and processing methods by incineration since energy (e.g. heat) must be supplied for evaporation of water and in raising the temperature of the water vapour. Climatic conditions apart, moisture content is generally higher in low income countries because of the higher proportion of food and yard waste.

iii. Calorific Value

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of 25^{O}c from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water, the combustion water remains in the liquid state. However, during combustion the temperature of the combustion gases remains above 100Oc so that the water resulting from combustion is in the vapour state. **Table 3.5** shows typical values of the residue and calorific value for the components of municipal solid waste. While evaluating incineration as a means of disposal or energy recovery, the following points should be kept in view:

- Organic material yields energy only when dry;
- The moisture contained as free water in the waste reduces the dry organic material per kilogram of waste and requires a significant amount of energy for evaporation;
- The ash content of the waste reduces the proportion of dry organic material per kilogram of waste. It also retains some heat when removed from the furnace.

1.3.2.1(b) Chemical Characteristics

A knowledge of chemical characteristics of waste is essential in determining the efficacy of any treatment process.
Chemical characteristics include (i) chemical; (ii) bio-chemical; and (iii) toxic.

Chemical: Chemical characteristics include pH, Nitrogen, Phosphorus and Potassium (N-P-K), total Carbon, C/N ratio, calorific value.

Bio-Chemical: Bio-Chemical characteristics include carbohydrates, proteins, natural fibre, and biodegradable factor.

Toxic: Toxicity characteristics include heavy metals, pesticides, insecticides, Toxicity test for Leachates (TCLP), etc. The waste may include lipids as well.

Chemical characteristics

Chemical Characteristics are very useful in assessment of potential of methane gas generation. The various chemical components normally found out in municipal solid waste are described below. The product of decomposition and heating values are two examples of the importance of chemical characteristics. Analysis identifies the compounds and the per cent dry weight of each class.

(i) Lipids:

Included in this class of compounds are fats, oils and grease. The principal sources of lipids are garbage, cooking oils and fats. Lipids have high calorific values, about 38000 kcal/kg, which makes waste with a high lipid content suitable for energy recovery processes. Since lipids in the solid state become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. They are biodegradable but because they have a low solubility in waste, the rate of biodegradation is relatively slow.

(ii) Carbohydrates:

Carbohydrates are found primarily in food and yard waste. They include sugars and polymers of sugars such as starch and cellulose and have the general formula $(CH_2O)X$. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates are particularly attractive for flies and rats and for this reason should not be left exposed for periods longer than is necessary.

(iii) Proteins:

Proteins are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH2). They are found mainly in food and garden wastes and comprise 5-10% of the dry solids in solid waste. Proteins decompose to form amino acids but partial decomposition can result in the production of amines, which have intensely unpleasant odours.

(iv) Natural Fibres:

This class includes the natural compounds, cellulose and lignin, both of which are resistant to biodegradation. They are found in paper and paper products and in food and yard waste. Cellulose is a larger polymer of glucose while lignin is composed of a group of monomers of which benzene is the primary member. Paper, cotton and wood products are 100%, 95% and 40% cellulose respectively.

Since they are highly combustible, solid waste having a high proportion of paper and wood products, are suitable for incineration. The calorific values of ovendried paper products are in the range 12000 – 18000 kcal/kg and of wood about 20000 kcal/kg, which compare with 44200 kcal/kg for fuel oil.

(v) Synthetic Organic Materials (Plastic):

In recent years, plastics have become a significant component of solid waste accounting for 5-7%. Plastic being non-bio-degradable, its decomposition does not take place at disposal site. Besides, plastic causes choking of drains and environmental pollution when burnt under uncontrolled condition. Recycling of plastics is receiving more attention, which will reduce the proportion of this waste component at disposal sites.

(vi) Non-combustibles:

Materials in this class are glass, ceramic, metals, dust, dirt, ashes and construction. Non-combustibles account for 30-50% of the dry solids.

To find the content of ash, fixed carbon, moisture content, volatiles and cellulose , glucose content in waste following analysis is to be carried out

Proximate analysis-Moisture content, volatiles, ash and fixed carbon can be found by this analysis.

Ultimate analysis-Carbon, nitrogen, hydrogen and oxygen can be found using this method of analysis. Firstly, this compounds are converted into oxides and then passed to combustion chamber where the temperature is around 990 deg. The output of the combustion unit is flue gases which are then passed through tubes of copper granules and the after the process of mixing and separation then components are detected by detection units.

Fusing point of ash-Fusion agglomerization

Lignocellulosic composition-To find the compounds like cellulose, hemi cellulose and lignin in corn stoves, Dry grass and baggase

1.3.2.1(C) BIOLOGICAL CHARACTERISTICS:

(i) **Biodegradability of organic waste:**

The most important biological characteristic of the organic fraction of MSW is that almost all the organic components can be converted biologically to gases and relatively inert organic and inorganic solids. ′ The production of odours and the generation of flies are also related to the putrescible nature of the organic materials. These will be discussed when talking about landfill processes. Biodegradability of MSW Biodegradability of MSW ′ Volatile solids (VS), determined by ignition at 550^{o}C, is often used as a measure of the biodegradability of the organic fraction of MSW. Some of the organic constituents of MSW are highly volatile but low in biodegradability (e.g. Newsprint) due to lignin content.The rate at which the various components can be degraded varies markedly. For practical purposes, the principal organic waste components in MSW are often classified as rapidly and slowly decomposable.

(ii) Odour:

Odors are developed when solid wastes are stored for long periods of time on-site between collections, in transfer stations, and in landfills. It is more significant in warm climates. The formation of odors results from the anaerobic decomposition of the readily decomposable organic components found in MSW.

(iii) Breeding of flies:

Flies can breed in soil soaked with water used to clean garbage cans and dumpsters. Check these areas regularly and scrape up any maggots along with the soil, and dispose of the material in a sealed plastic bag. This food waste will attract many different kinds of flies.

1.4. INTRODUCTION TO WASTE COLLECTION

Primary collection of waste is the second essential step of Solid Waste Management activity. Primary collection system is necessary to ensure that waste stored at source is collected regularly and it is not disposed of on the streets, drains, water bodies, etc. However, step has to synchronize well with the first step i.e. Storage of Waste at source.

In India, the system of primary collection of waste is practically non- existent, as the system of storage of waste at source is yet to be developed.

Doorstep collection of waste from households, shops and establishments is insignificant and wherever it is introduced through private sweepers or departmentally, the system does not synchronize further with the facility of Waste Storage Depots and Transportation of Waste. The waste so stored is deposited on the streets or on the ground outside the dustbin. Thus streets are generally treated as receptacles of waste and the primary collection of waste is done, by and large, through street sweeping.

An appropriate system of primary collection of waste is to be so designed by the urban local bodies that it synchronizes with storage of waste at source as well as waste storage depots facility ensuring that the waste once collected reaches the processing or disposal site through a containerized system.

1.4.1 MEASURES NECESSARY TO IMPROVE THE SERVICE

Local bodies should provide daily waste collection service to all households, shops and establishments for the collection of putrescible organic waste from the doorstep because of the hot climatic conditions in the country. This service must be regular and reliable. Recyclable material can be collected at longer regular intervals as may be convenient to the waste producer and the waste collector, as this waste does not normally decay and need not be collected daily. Domestic hazardous waste is produced occasionally. Such waste need not be collected from the doorstep. People could be advised or directed to deposit such waste in special bins kept in the city for disposal.

STEPS TO BE TAKEN

1. Urban local bodies may arrange for the collection of domestic, trade and institutional food/ biodegradable waste from the doorstep or from the community bin on a daily basis.

2. Local bodies may also arrange through NGOs collection of recyclable waste material/non bio-degradable waste other than toxic and hazardous waste from the source of waste generation at the frequency and in the manner, notified by local bodies from time to time in consultation with the NGOs/Resident Associations, etc.

3. Domestic hazardous/ toxic waste material deposited by the waste producers in special bins (provided by the local body at various places in the city) may be collected at regular intervals after ascertaining the quantities of such waste deposited in special bins.

1.4.2 WASTE COLLECTION VEHICLES

Collection vehicles Almost all collections are based on collector and collection crew, which move through the collection service area with a vehicle for collecting the waste material. The collection vehicle selected must be appropriate to the terrain, type and density of waste generation points, the way it travels and type and kind of material (UNEP, 1996). It also depends upon strength, stature and capability of the crew that will work with it. The collection vehicle may be small and simple two-wheeled cart pulled by an individual) or large, complex and energy intensive (e.g., rear loading compactor truck). The most commonly used collection vehicle is the dump truck fitted with a hydraulic lifting mechanism.

A description of some vehicle types follows:

Small-scale collection and muscle-powered vehicles: These are common vehicles used for waste collection in many countries and are generally used in rural hilly areas. As Figure 1.2 illustrates, these can be small rickshaws, carts or wagons pulled by people or animals, and are less expensive, easier to build and maintain compared to other vehicles

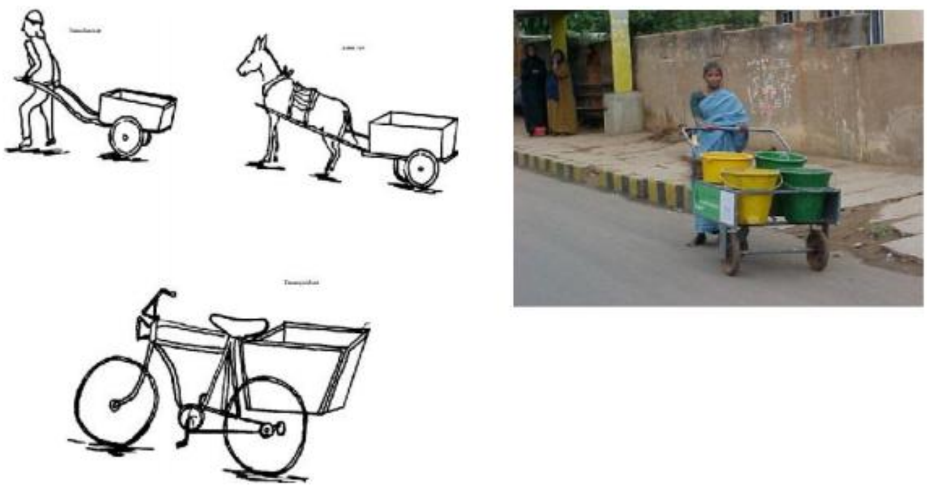


Fig.1.2 Small-scale Collection Vehicles/Primary collection Vehicles

They are suitable for densely populated areas with narrow lanes, and squatter settlements, where there is relatively low volume of waste generated. Some drawbacks of these collection vehicles include limited travel range of the vehicles and weather exposure that affect humans and animals.

Non-compactor trucks: Non-compactor trucks are efficient and cost effective in small cities and in areas where wastes tend to be very dense and have little potential for compaction.

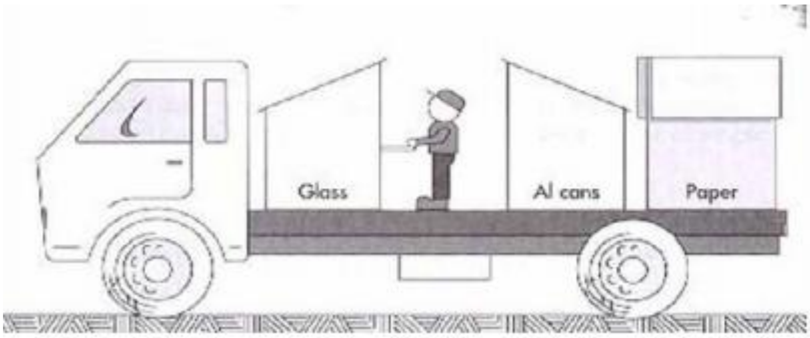
Figure 1.3: illustrates a non- compactor truck

When these trucks are used for waste collection, they need a dumping system to easily discharge the waste. It is generally required to cover the trucks in order to prevent residue flying off. Trucks with capacities of 10 – 12 m^3 are effective, if the distance between the disposal site and the collection area is less than 15 km. If the distance is longer, a potential transfer station closer than 10 km from the collection area is required. Non-compactor trucks are generally used, when labour cost is high. Controlling and operating cost is a deciding factor, when collection routes are long and relatively sparsely populated.

Compactor truck: Compaction vehicles are more common these days, generally having capacities of 12 – 15 ^{3} due to limitations imposed by narrow roads. Although the capacity of a compaction vehicle, illustrated in Figure 1.4, is similar to that of a dump truck, the weight of solid wastes two-wheeled cart pulled by an individual) or large, complex and energy intensive (e.g., rear loading compactor truck). The most commonly used collection vehicle is the dump truck fitted with a hydraulic lifting mechanism.

Fig.1.4 Compactor Truck.

. As Figure 1.4 illustrates, these can be small rickshaws, carts or wagons pulled collected per trip is 2 to 2.5 times larger since the wastes are hydraulically compacted.



The success of waste management depends on the level of segregation at source. One of the examples for best collection method is illustrated in the figure below A compactor truck allows waste containers to be emptied into the vehicle from the rear, front or sides and inhibits vectors (of disease) from reaching the waste during collection and transport. It works poorly when waste stream is very dense, wet, collected materials are gritty or abrasive, or when the roads are dusty.

SUMMURY OF WASTE COLLECTION

Waste collection is of two types. They are primary waste collection vehicles and secondary waste collection vehicle. In primary collection vehicles the waste generated at local municipalities is collected e.g. Bins ,small rickshaws, trolleys and non-compactor vehicles and this waste collected in primary vehicle sis transfer to secondary collection vehicle in place known as transfer station. Where, secondary vehicles are compactor trucks, large trucks. Let us discuss briefly about transfer station in Next section.

1.5. TRANSFER STATION

Transfer station is a centralised facility, where waste is unloaded from smaller collection vehicles and re-loaded into large vehicles for transport to a disposal or processing site. This transfer of waste is frequently accompanied by removal, separation or handling of waste. In areas, where wastes are not already dense, they may be compacted at a transfer station. The technical limitations of smaller collection vehicles and the low hauling cost of solid waste, using larger vehicles, make a transfer station viable. Also, the use of transfer station proves reasonable, when there is a need for vehicles servicing a collection route to travel shorter distances, unload and return quickly to their primary task of collecting the waste. Limitations in hauling solid wastes are the main factors to be considered, while evaluating the use of transfer stations. These include the additional capital costs of purchasing trailers, building transfer stations and the extra time, labour and energy required for transferring wastes from collection truck to transfer trailer. The main problem in the establishment of a transfer station, however, is securing a suitable site. Stored solid wastes and recyclable materials, if not properly handled, will attract flies and other insect vectors. Odours from the transferred solid wastes will also be a nuisance, if not properly controlled. In addition, the traffic and noise due to small and large collection vehicles, collectors, drivers, etc., invite the resentment of the communities living in the vicinity of transfer stations.

Depending on the size, transfer stations can be either of the following two types:

Small to medium transfer stations: These are direct-discharge stations that provide no intermediate waste storage area. The capacities are generally small (less than 100 tonnes/day) and medium (100 to 500 tonnes/day). Depending on weather, site aesthetics and environmental concerns, transfer operations of this size may be located either indoor or outdoor. More complex small transfer stations are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, it includes a recyclable material separation and processing centre. The required overall station capacity (i.e., the number and size of containers) depends on the size and population density of the area served and the frequency of collection.

Large transfer stations: These are designed for heavy commercial use by private and municipal collection vehicles. The typical operational procedure for a larger station is as follows: Several different designs for larger transfer operations are common, depending on the transfer distance and vehicle type. Most designs, however, fall into one of the following three categories:

Direct-discharge non-compaction station: In these stations, waste is dumped directly from collection vehicle into waiting transfer trailers and is generally designed with two main operating floors. In the transfer operation, wastes are dumped directly from collection vehicles (on the top floor) through a hopper and into open top trailers on the lower floor. The trailers are often positioned on scales so that dumping can be stopped when the maximum payload is reached. A stationary crane with a bucket is often used to distribute the waste in the trailer. After loading, a cover or tarpaulin is placed over the trailer top. Howe ver, some provision for waste storage during peak time or system interruptions should be developed. Because of the use of little hydraulic equipment, a shutdown is unlikely and this station minimises handling of waste.

Platform/pit non-compaction station: In this arrangement, the collection vehicles dump their wastes onto a platform or into a pit using waste handling equipment, where wastes can be temporarily stored, and if desired, picked through for recyclables or unacceptable materials. The Like direct discharge stations, platform stations have two levels. If a pit is used, however, the station has three levels. A major advantage of these stations is that they provide temporary storage, which allows peak inflow of wastes to be levelled out over a longer period. Construction costs for this type of facility are usually higher because of the increased floor space. This station provides convenient and efficient storage area and due to simplicity of operation and equipment, the potential for station shutdown is less.

Compaction station: In this type of station, the mechanical equipment is used to increase the density of wastes before they are transferred. The most common type of compaction station uses a hydraulically powered compactor to compress wastes. Wastes are fed into the compactor through a chute, either directly from collection trucks or after intermediate use of a pit

1.4.2. ADVANTAGES OF WASTE TRANSFER STATIONS IN WASTE MANAGEMENT

In addition to cost savings, waste transfer stations offer a range of benefits including the following:

- Provide an opportunity to increase waste density. In areas where compacting vehicles are not available, waste transfer stations may be used to compact the waste so greater quantities can be carried at once to the final disposal sites.
- Minimize illegal waste dumping. particularly in developing countries where the human and animal powered plus small motorized vehicles are used for the collection of waste but unsuitable for travelling long distances.
- Can serve as a controlled place for sorting and processing the waste. Particularly in many low-income countries where a thriving informal economy exits in recycling of waste, these waste transfer stations can minimize health hazards and may limit the amount of waste picking that is done in the streets, which will reduce the amount of waste that is scattered around communal bins and waste accumulation points.
- Reduce maintenance cost of collection vehicles. These vehicles stay on well paved roads and are not travelling on rough roads, particularly in landfill sites.
- Improved waste dumping efficiency at final disposal site, reducing the number of vehicles at the disposal site.

1.4.3. PROBLEMS

The main problems associated with waste transfer stations are:

- Increased traffic volume, noise and air pollution in the surrounding areas, and
- unless they are properly maintained there is potential for environmental damage in the surrounding area.

However, if the waste transfer stations are properly constructed and maintained, some of the above problems can be minimised. for example, some large, modern transfer stations are enclosed and made with materials that can be easily maintained.

1.5. WASTE MINIMIZATION

Waste minimisation or reduction at source is the most desirable activity, because the community does not incur expenditure for waste handling, recycling and disposal of waste that is never created and delivered to the waste management system. However, it is an unfamiliar activity as it has not been included in earlier waste management systems.

To reduce the amount of waste generated at the source, the most practical and promising methods appear to be (i) the adoption of industry standards for product manufacturing and packaging that use less material, (ii) the passing of laws that minimise the use of virgin materials in consumer products, and (iii) the levying (by communities) of cess/fees for waste management services that penalise generators in case of increase in waste quantities. Modifications in product packaging standards can result in reduction of waste packaging material or use of recyclable materials. Minimisation of use of virgin raw materials by the manufacturing industry promotes substitution by recycled materials. Sorting at source, recycling at source and processing at source (e.g. yard composting) help in waste minimisation. One waste management strategy used in some communities in developed countries is to charge a variable rate per can (or ton) of waste, which gives generators a financial incentive to reduce the amount of waste set out for collection. Issues related to the use of variable rates include the ability to generate the revenues required to pay the costs of facilities, the administration of a complex monitoring and reporting network for service, and the extent to which wastes are being put in another place by the generator and not reduced at source.

1.5.1 INTEGRATED SOLID WASTE MANAGEMENT

A. WASTE REDUCTION AT SOURCE

- Proper manufacturing and packaging
- phasing out toxic material and use of naturally available materials
- selective reuse
- Packaging back to the manufacturer

B. RESOURCE RECOVERY THROUGH MATERIAL RECYCLING AND SEPARATION

Material recycling can occur through sorting of waste into different streams at the source or at a centralised facility. Sorting at source is more economical than sorting at a centralised facility.

Sorting at Source : Sorting at source (home sorting) is driven by the existing markets for recyclable materials and the link between the house holder and the waste collector. The desirable home sorting streams are:

- Dry recyclable materials e.g. glass, paper, plastics, cans etc.,
- Bio-waste and garden waste,
- Bulky waste,
- Hazardous material in household waste,
- Construction and Demolition waste, and
- Commingled MSW (mixed waste).

Centralised Sorting: Centralised sorting is needed wherever recyclable materials are collected in a commingled (mixed) state. Hand sorting from a raised picking belt is extensively adopted in several countries. Mechanised sorting facilities using magnetic and electric field separation, density separation, pneumatic separation, size separation and other techniques are used in some developed countries. Such facilities are usually prohibitively expensive in comparison to hand sorting.

In India, centralised sorting is not adopted. There is a need to formalise this intermediate sorting system or develop a centralised sorting facility to minimise recyclable materials reaching a waste processing facility or a landfill.

C.RESOURCE RECOVERY THROUGH WASTE PROCESSING

Biological or thermal treatment of waste can result in recovery of useful products such as compost or energy.

Biological Processes/Treatment: Biological treatment involves using micro-organisms to decompose the biodegradable components of waste. Two types of processes are used, namely:

- Aerobic processes: Windrow composting, aerated static pile composting and in-vessel composting; vermi-culture etc.
- Anaerobic processes: Low-solids anaerobic digestion (wet process), highsolids anaerobic digestion (dry process) and combined processes.

In the aerobic process the utilisable product is compost. In the anaerobic process the utilisable product is methane gas (for energy recovery). Both processes have been used for waste processing in different countries – a majority of the biological treatment process adopted world-wide are aerobic composting; the use of anaerobic treatment has been more limited. In India, aerobic composting plants have been used to process up to 500 tons per day of waste.

Thermal Processes/Treatment: Thermal treatment involves conversion of waste into gaseous, liquid and solid conversion products with concurrent or subsequent release of heat energy. Three types of systems can be adopted, namely:

- Combustion systems (Incinerators): Thermal processing with excess amounts of air.
- Pyrolysis systems: Thermal processing in complete absence of oxygen (low temperature).
- Gasification systems: Thermal processing with less amount of air (high temperature).

Combustion system is the most widely adopted thermal treatment process world-wide for MSW. Though pyrolysis is a widely used industrial process, the pyrolysis of municipal solid waste has not been very successful. Similarly, successful results with mass fired gasifiers have not been achieved. However both pyrolysis and gasification can emerge as viable alternatives in the future.

Other Processes : New biological and chemical processes which are being developed for resource recovery from MSW are

- Fluidised bed bio-reactors for cellulose production and ethanol production.
- Hydrolysis processes to recover organic acids.
- Chemical processes to recover oil, gas and cellulose.
- Physical process/treatment: Physical treatment generally refers to air-stripping and filtration of waste and the material is used for manufacturing construction and can also be used in paving of roads.

D. WASTE TRANSFORMATION (WITHOUT RESOURCE RECOVERY) PRIOR TO DISPOSAL

At the end of all sorting processes, biological processes and thermal processes, the non-utilisable waste has to be disposed off on land. Prior to this disposal, waste may need to be subjected to transformation by mechanical treatment, thermal treatment or other methods to make it suitable for landfilling.

Mechanical Transformation

- Sorting of waste may be undertaken to remove bulky items from the waste.
- Shredding of waste may be undertaken for size reduction to enable better compaction of waste.

Thermal Transformation

In regions where land space is very scarce (e.g. islands), waste with low calorific value may be subjected to combustion without heat recovery to reduce the volume of waste requiring disposal on land.

Other Methods:

To reduce toxicity of wastes e.g. hazardous wastes or biomedical wastes, special detoxification transformations may be undertaken. Some methods used are

- Autoclaving,
- Hydroclaving,
- Microwaving,

- Chemical fixation,
- Encapsulation and solidification.

E. WASTE DISPOSAL ON LAND

Waste is disposed off on land in units called landfills which are designed to minimise the impact of the waste on the environment by containment of the waste. Usually three types of landfills are adopted. Landfills in which municipal waste is placed are designated as "MSW Landfills" or "Sanitary Landfills". Landfills in which hazardous waste is placed are designated as "Hazardous Waste landfills". Landfills in which a single type of waste is placed (e.g. only construction waste) are designated as "Monofills".

1.6. RECYCLING AND REUSE

The use of these materials basically depends on their separation and condition of the separated material. A majority of these materials are durable and therefore, have a high potential of reuse. It would, however, be desirable to have quality standards for the recycled materials. Construction and demolition waste can be used in the following manner:

- Reuse (at site) of bricks, stone slabs, timber, conduits, piping railings etc. to the extent possible and depending upon their condition.
- Sale / auction of material which cannot be used at the site due to design constraint or change in design.
- Plastics, broken glass, scrap metal etc. can be used by recycling industries.
- Rubble, brick bats, broken plaster/concrete pieces etc. can be used for building activity, such as, leveling, under coat of lanes where the traffic does not constitute of heavy moving loads.
- Larger unusable pieces can be sent for filling up low-lying areas.
- Fine material, such as, sand, dust etc. can be used as cover material over sanitary landfill. Metropolitan and mega cities usually generate huge quantities of wastes because of large-scale building and other developmental activities. They may identify suitable sites where such waste can be temporarily stored and some physical treatment can be carried out. These sites may have the following features:
- Compared to the general waste treatment/disposal/landfill site such sites may be suitably located near the municipal boundaries, because the inert waste do not cause odour or pollution, provided adequate steps are taken to reduce dust and noise during handling. Since these wastes are heavy, their transportation cost can also be reduced to some extent if the distance to be carried is less.
- At this site, different kinds of waste should be kept in separate heaps.
- Arrangement for size grading can also be planned so that reuse is facilitated. This can be simply done by erecting sturdy metallic screens of different sizes at an angle and putting the waste over them with the help of a front-end loader.
- The graded material should be kept in separate heaps with appropriate label and direction.
- Sale or auction of these materials can also be planned from time to time.

1.7. Waste Segregation

Many wastes are mixtures of hazardous and non-hazardous wastes. Much of their contents may even be water. By segregating key toxic constituents, isolating liquid fraction, keeping hazardous streams away from non-hazardous wastes, generator can save substantial amounts of money on disposal or find new opportunities for recycling and reuse of wastes.

1.7. STATUS OF TECHNOLOGIES FOR GENERATION OF ENERGY FROM WASTE TREATMENT AND DISPOSAL OF AEROBIC COMPOSTING:

The increasing industrialization, urbanization and changes in the pattern of life, which accompany the process of economic growth, give rise to generation of increasing quantities of wastes leading to increased threats to the environment. In recent years, technologies have been developed that not only help in generating substantial quantity of decentralized energy but also in reducing the quantity of waste for its safe disposal.

The Ministry is promoting all the Technology Options available for setting up projects for recovery of energy from urban wastes. In developed countries, environmental concerns rather than energy recovery is the prime motivator for waste-to-energy facilities, which help in treating and disposing of wastes. Waste to energy is term that is used to describe various technologies that convert non-recyclable waste to usable forms of energy such as heat, fuel and electricity.

Energy in the form of biogas, heat or power is seen as a bonus, which improves the viability of such projects. While incineration and biomethanation are the most common technologies, pyrolysis and gasification are also emerging as preferred options. A common feature in most developed countries is that the entire waste management system is being handled as a profitable venture by private industry or non-government organizations with tipping fee for treatment of waste being one of the major revenue streams. The major Advantages for adopting technologies for recovery of energy from urban wastes is to reduce the quantity of waste and net reduction in environmental pollution, besides generation of substantial quantity of energy.

1.8. WASTE INCINERATION PROCESS

Incineration of waste is not a new process, but the rules and regulations regarding emission of the resultant pollutants to the atmosphere have been tightened and upgraded. This is due to the fumes produced containing dioxin particulates and heavy metals, both of which are dangers to public health.

The following sections examine the incineration of municipal solid waste incorporating a waste heat boiler to recover some of the energy from waste (EfW). The first section gives a brief overview of waste management techniques and strategies.

Waste Management – an Overview

Waste management plays an important role in the disposal of our waste in an environmentally efficient, safe manner.
There are a number of basic means of disposing of our waste.

- Recycling
  Here materials such as paper, glass, plastic, aluminum, and tin cans are sorted by the householder and collected from the curbside outside their property. Vegetation, grass and hedge clippings are collected for composting; the remaining waste is sent to a landfill or an incineration plant.

- Incineration (after sorting)
  Here the recyclable materials are removed before incineration as per the above method.

- Incineration (non-sorted)
  In this method all the municipal waste is incinerated without segregation of recyclable materials, with the ferrous metals being extracted from furnace bottom ash by magnets.

- Landfill
  Land-fill usage is either banned or being phased out in major countries of the Western World. EU legislation has made this method of disposal very expensive through the introduction of a levy per ton for disposal. At the same time, old disused landfill sites produce a gas that can be processed to run gas turbine/engines driving electric generators providing power to the local grid.

- Gasification
  The MSW is fed into large steel digesters that are free from oxygen and light and heat are applied. The organic waste breaks down through time producing a gas that can be used to run a gas turbine/engine driving an electric generator.

- Incineration – Energy from Waste (EfW)
  All new plants are required by law to incorporate some form of EfW system through using the heat produced to run a waste heat boiler or a district/community heating system.
  The next section examines one such method for the incineration of municipal solid waste using a waste heat boiler as a means of recovering energy from its combustion.

Characteristics of Waste Incineration Plants

Municipal solid waste incineration is basically a waste treatment process that involves the combustion of waste as an alternative method to using the scarce number of remaining landfill sites.

Some facilities practice recycling techniques where the recyclable materials are sorted (mostly still by hand) from the incoming waste before being segregated, bagged, and transported to one of the various recycling plants. The remaining waste is tipped into a storage pit from where it is loaded into a hopper on the side of the furnace by an overhead gantry crane.

The furnace consists of a rectangular steel box lined with fire-brick on the inside and insulated on the outer shell. Oil/gas burners/registers of normal boiler furnace design are fitted, and these project the flames towards the floor of the furnace. Running along the floor of the furnace is a steel-link fire grate that is mechanically driven, picking up the waste at one end from under the loading hopper and, through providing a combustion bed, burning the waste as it moves along the floor. At the end of the grate, the waste that has by now turned to ash falls off the grate into a quench tank. From here it passes under a magnet to remove any ferrous metals before passing into a storage hopper.

This residue is known as bottom ash. Along with fly-ash, it contains a large portion of the heavy metals such as lead and cadmium. The ash is sent to a landfill or, better, used as aggregate in the road construction industry.Combustion air is provided from a forced draft fan that supplies the air to the grate, helping to break-up and mix the waste. This along with the air supplied to the furnace burners ensures complete combustion of the waste, albeit in excess air. Complete combustion takes place at around a temperature of 550°C. Along with this, recent EU directives call for temperature of 850°C to be maintained for 2 seconds per new load, eliminating any bacteria/viruses contained in the new charge of waste. Water-tubes that form part of a normal waste heat boiler system are fitted inside the furnace in the path of the hot combustion fumes. A superheater is also positioned in this pathway, before the combustion fumes exit from the roof of the furnace.

The fumes are now subjected to fume treatment that consists of components in the following order:

1. **Gas Cooler** – The gases are still at a high temperature; exiting the furnace after the waste heat boiler at around 200°C. So, before passing to the treatment plant proper they are cooled using a normal water tube cooler.

2. **Particulate Filtration** – These minute particulates being assigned a PM10 category are particularly dangerous to us humans as they clog up the respiratory and vascular systems, especially that of the elderly and babies.

   There are several methods of removing/reducing them from the gas-flow.

   - **Bag-house Filters**
     These fabric-mix filter bags are installed in the bag-house, being open at one end to allow the fumes to enter. As the fumes pass through the bags, the particles and fine dust are trapped; falling down into a storage hopper in the base of the housing. These are very efficient filters capable of removing up to 95% of PM10's and fine dust from the fumes. The fume treatment had not worked for a long time due to lack of spares and the indifference of the workforce to the fumes that were emitted from high brick chimneys. Sulfur was extracted from the fumes through processing in an acid plant, but the particulates and other heavy metals went straight up the chimney-dropping from the resultant plume to land on the local townships and shanty towns. Today's filter bags are very robust, being manufactured from durable fine woven fabric materials that can promote a large reduction in particulate and dust emissions.The bag-house also has an automatic self-purging/cleaning operation using compressed air to ensure efficient operation.

   - **Electro Static Precipitator (ESP)**
     This component utilizes the properties of a negative and positive DC current to collect the particulates on steel plates. Once the plates are full, a hammer head strikes the plates releasing the particulates/dust to fall into a hopper at the base of the unit.

3. Scrubbers

A wet scrubber consists of a vertical steel tower with the fumes entering at the bottom and passing upwards. A solution of lime and water is sprayed into the path of the fumes removing the sulfur oxide and some of the dioxins (produced from combustion of plastics). These all fall to the bottom of the scrubber forming a slurry of calcium sulfate – (gypsum). This is the material used for producing wall boards, and it is sold off to the building industry.

4. Gas Drier / De-activated Carbon Unit

The fumes leave the wet scrubber and enter a drier to remove the moisture before passing through an activated carbon unit/dry scrubber that extracts more heavy metals from the fumes.

5. Fume Extraction Fan/Chimney

The fumes are drawn through the activated carbon unit by a centrifugal fume extraction fan that forces them into the chimney. (Some systems incorporate fine, high-pressure water sprays inside the chimney).

From here the fumes, still containing various pollutants, are propelled high into the atmosphere where they form a plume before dispersing and falling to the ground.

The layout of key components of a Municipal Solid Waste Incinerator is shown below.

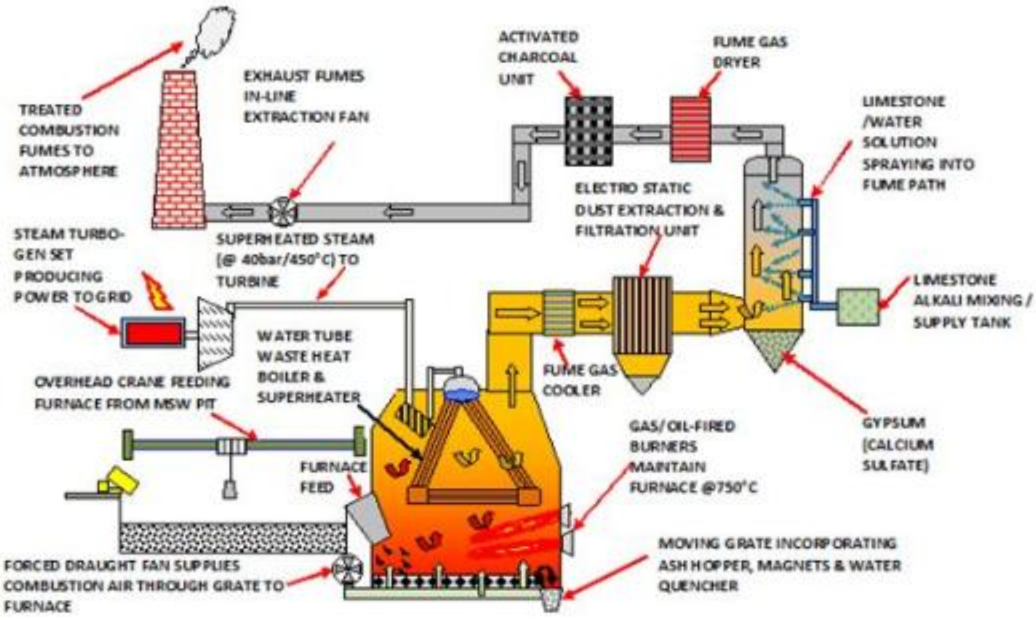


Fig.1.4 Typical layout of waste incineration plant(EFW Conversion Technology)

1.9. FURNACE TYPE AND DESIGN

Furnace: A furnace is essentially a thermal enclosure and is employed to process raw materials at high temperatures both in solid state and liquid state. Several industries like iron and steel making, non ferrous metals production, glass making, manufacturing, ceramic processing, calcination in cement production etc. employ furnace.

The principle objectives are

a. To utilize heat efficiently so that losses are minimum, and
b. To handle the different phases (solid, liquid or gaseous) moving at different velocities for different times and temperatures such that erosion and corrosion of the refractory are minimum.

PRINCIPLE COMPONENTS

The principle components are
i. Source of energy

a. Fossil fuel: For fossil fuel one requires burner for efficient mixing of fuel and air. Arrangement of burner is important.
b. Electric energy: Resistance heating, induction heating or arc heating.
c. Chemical energy: Exothermic reactions

1.10. PROCESSING OF MSW:

PHYSICAL PROCESSING

Unit process	Purpose	Energy source	Temperature in °C	Type of furnace
Carbonization	Conversion of coal to coke	Indirect heating by burning fuel	≈ 1000 to 1200	Coke oven
Calcination	Removal of CO_2 from $CaCO_3$ for cement production Production of anhydrous alumina for electrolysis	Fossil fuel Fossil fuel	≈ 1200 ≈ 1300	Rotary kiln Rotary kiln
Roasting	To convert sulphide into oxide partially or completely	Chemical + Fossil fuel	≈ 900	Multiple hearth furnace, Fluid bed roaster, etc
Heating	To eliminate segregation To perform hot working To perform heat treatment	Mostly oil and gas fired	Below the melting points of materials	Batch type or continuous type
Sintering	To produce compacts of particles	Fossil or electric	Below the melting point	Sintering furnaces

CHEMICAL PROCESSING

Unit process	Purpose	Energy source	Temperature in °C	Type of furnace
Electrolysis of molten salt	To produce Al,Mg and Na	Electric energy	700 to 900	Hall-Heroult cell,
Refining	To produce steel	Chemical and electric	1600	LD Converter Electric furnace
Melting	To produce castings of metals and alloys	Electric and fossil fuel	Above the melting points of respective metal and alloy	Induction furnace, reverberatory furnace and melting furnace
Matte smelting	To produce matte	Chemical and fossil fuel	≈1200	Flash smelter, Reverberatory smelter

Above mentioned are various types of furnace used in physical and chemical processing. In general furnace are classified into

- Under fired type,
- Over-fired type,
- Side fired,
- Direct fired and
- Muffle type

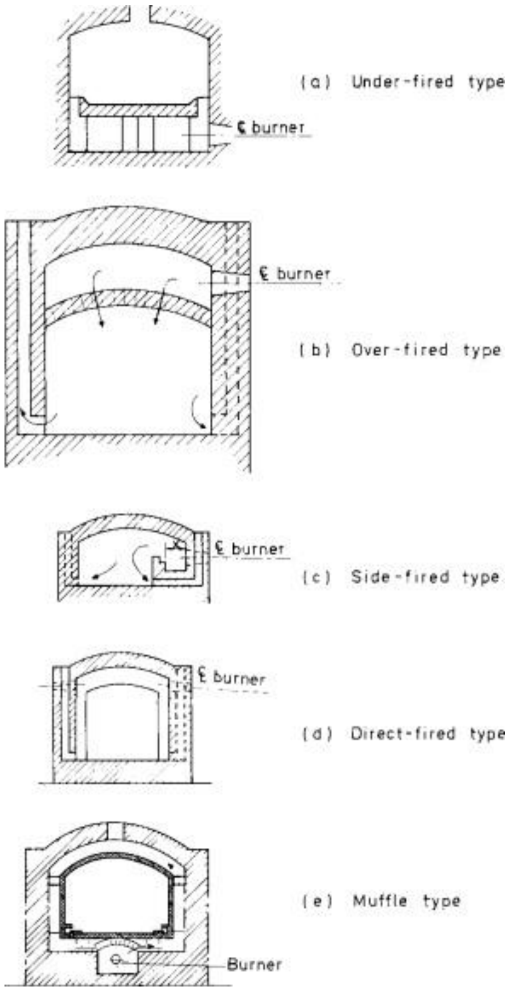


Fig.1.5 Various types of furnace

1.11. MEDICAL WASTE/PHARMACEUTICAL WASTE TREATMENT TECHNOLOGIES

MEDICAL WASTE:

Medical waste is defined as: potentially infectious waste materials generated at health care facilities, such as hospitals, clinics, physician's offices, dental practices, blood banks, and veterinary hospitals/clinics, as well as medical research facilities and laboratories.

Various medical wastes are:

- Blood-soaked bandages
- Culture dishes and other glassware
- Discarded surgical gloves
- Discarded surgical instruments
- Discarded needles used to give shots or draw blood (e.g., medical sharps)
- Cultures, stocks, swabs used to inoculate cultures
- Removed body organs (e.g., tonsils, appendices, limbs)
- Discarded lancets

Many hospitals and laboratories have the resources to implement internal waste treatment processes to both reduce the volume of the medical waste in general and decontaminate certain infectious waste so that it can be disposed of as non-infectious. This bio-medical waste are termed to be hazardous.

Hazardous waste: Hazardous wastes refer to wastes that may, or tend to, cause adverse health effects on the ecosystem and human beings. These wastes pose present or potential risks to human health or living organisms, due to the fact that they:

- are non-degradable or persistent in nature; can be biologically magnified;
- are highly toxic and even lethal at very low concentrations.

1.12. CHARACTERISTICS OF HAZARDOUS WASTE

Characteristics such as ignitibility, corrosivity, reactivity and toxicity of the substance.

Ignitability:
A waste is an ignitable hazardous waste, if it has a flash point of less than 60 C; readily catches fire and burns so vigorously as to create a hazard; or is an ignitable compressed gas or an oxidiser. A simple method of determining the flash point of a waste is to review the material safety data sheet, which can be obtained from the manufacturer or distributor of the material. Naphtha, lacquer thinner, epoxy resins, adhesives and oil based paints are all examples of ignitable hazardous wastes.

Corrosivity:
A liquid waste which has a pH of less than or equal to 2 or greater than or equal to 12.5 is considered to be a corrosive hazardous waste. Sodium hydroxide, a caustic solution with a high pH, is often used by many industries to clean or degrease metal parts. Hydrochloric acid, a solution with a low pH, is used by many industries to clean metal parts prior to painting. When these caustic or acid solutions are disposed of, the waste is a corrosive hazardous waste.

Reactivity:
A material is considered a reactive hazardous waste, if it is unstable, reacts violently with water, generates toxic gases when exposed to water or corrosive materials, or if it is capable of detonation or explosion when exposed to heat or a flame. Examples of reactive wastes would be waste gunpowder, sodium metal or wastes containing cyanides or sulphides.

Toxicity:
To determine if a waste is a toxic hazardous waste, a representative sample of the material must be subjected to a test conducted in a certified laboratory. The toxic characteristic identifies wastes that are likely to leach dangerous concentrations of toxic chemicals into ground water.

Waste Category	Sources
Radioactive substances	Biomedical research facilities, colleges and university laboratories, offices, hospitals, nuclear power plants, etc.
Toxic chemicals	Agricultural chemical companies, battery shops, car washes, chemical shops, college and university laboratories, construction companies, electric utilities, hospitals and clinics, industrial cooling towers, newspaper and photographic solutions, nuclear power plants, pest control agencies, photographic processing facilities, plating shops, service stations, etc.
Biological wastes	Biomedical research facilities, drug companies, hospitals, medical clinics, etc.
Flammable wastes	Dry cleaners, petroleum reclamation plants, petroleum refining and processing facilities, service stations, tanker truck cleaning stations, etc.
Explosives	Construction companies, dry cleaners, ammunition production facilities, etc.

Table.1.5. Hazardous waste

1.13 VARIOUS WASTE TREATMENT TECHNOLOGIES OF BIO-MEDICAL WASTE

1.13.1. On-Site Medical Waste Treatment

Autoclaving

- Thermal treatment is typically used for sharps and certain other types of infectious waste. An autoclave is in essence a large pressure cooker that uses high temperatures and steam to deeply penetrate all materials and kill any microorganisms. Depending on the type and amount of waste you will need to sterilize, you can purchase an appropriately-sized autoclave for your facility. These appliances range from 100 liters to 4,000+ liters in volume for bulk waste treatment.
- Modern autoclaves are also automated to minimize human involvement and therefore reduce needle-stick injuries and contamination. Decontaminated sharps and other medical waste that's been autoclaved can then be handed over to your Maryland medical waste removal vendor to be disposed of as non-infectious waste. However, keep in mind that such medical wastes as chemical waste, including chemotherapy waste, as well as pharmaceutical waste can't be decontaminated in an autoclave.

1.13.2. Chemical Treatment

- Often used to deactivate liquid waste, chemical treatment is designed to decontaminate or deactivate certain wastes on site rather than packaging and sending them to a separate facility. Since liquids are highly susceptible to spills, it's typically best to have them treated as close to the generation site as possible. Chemical treatment can also be applied to some non-liquid infectious wastes, but they would typically need to be shredded first to ensure that all portions of the waste are exposed to the chemicals.
- Depending on the type of waste, chemicals like chlorine, sodium hydroxide or calcium oxide can be used. However, these chemicals may often produce undesirable byproducts, as well as

off-gas dangerous VOCs when applied. Chemical treatment has to be executed carefully and by knowledgeable staff. If you are not comfortable with on-site chemical treatment, an alternative is to use solidifying agents to turn liquids into solids and direct them to your medical waste removal vendor for disposal.

1.13.3. Microwave Treatment

- A microwave treatment system, similar to an autoclave, also uses heat to decontaminate medical waste. These systems work best for waste that is not 100% dry or solid, as the moisture allows the heat to penetrate deeper, and the steam sterilizes. Therefore, before microwaving, most types of medical waste need to be shredded and mixed with water to achieve the desired effect. The bonus is that shredding reduces the volume of the waste, so it can later be land-filled.

1.13.4. Off-Site Medical Waste Disposal

- **Incineration**

- Incineration is typically used (and often required by the state) for pathological and pharmaceutical waste. Incineration of medical waste should be preformed in a controlled facility to ensure complete combustion and minimize any negative effects for the environment. The great thing about incineration is that it kills 99% of microorganisms and leaves very minimal waste, if any.

1.13.5. Land Disposal

- Land disposal is typically used for shredded, treated and decontaminated waste. In certain cases, it can also be used for hazardous waste or other untreated waste that can not be decontaminated by other means. Specialized sanitary landfill sites exit to reduce the risk of soil and water contamination and provide a safe space for medical waste disposal.

1.14 IMPACTS OF BIO-MEDICAL WASTES ON ENVIRONMENT

Wildlife and Pharmaceuticals

Biohazard waste that is not disposed of properly can end up in lakes, parks, and other wildlife refuges where birds and fauna live. Wildlife are very curious about pharmaceuticals. It is thought they are attracted to the scent or color of pills and liquid medicine. This curiosity results in digestion of medication, which can injure or even kill the animal.

Groundwater Contamination

Much thought and effort has been taken to ensure landfills are built to protect the earth around them. Most are built with a special lining so nearby soil and groundwater cannot become contaminated. Mishandled biohazard waste can compromise even the best landfill design. Syringes and other sharp objects can easily rip the lining. As rain falls, contaminants in the landfill can seep out to the exterior soil, and the groundwater become toxic.

Radioactive Pollution

In order to accurately diagnose patients, doctors must sometimes use radioactive tools. When disposed of improperly, radioactivity can enter landfills and other areas. These substances emit particles that are dangerous to people. Excessive exposure to radioactivity can result in serious diseases.

Airborne Pollutants

Certain medical waste can be destroyed by incineration. But, if not ignited properly, pollutants can move through the air. Airborne pollutants can be worse than land-based types because they can spread far and wide and quickly.

1.15. MEASURES TO MITIGATE ENVIRONMENTAL EFFECTS DUE TO INCINERATION

(Pollution Prevention By Waste Minimization)

Pollution prevention is the use of materials, processes, or practices that reduce or eliminate the generation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous and non-hazardous materials, energy, water or other resources as well as those that protect natural resources through conservation or more efficient use. Pollution prevention is the maximum feasible reduction of all wastes generated at production sites. It involves the judicious use of resources through source reduction, energy efficiency, reuse of input materials and reduces water consumption.

Waste minimization means the feasible reduction of hazardous waste that is generated prior to treatment, storage and disposal. It is defined as any source reduction or recycling activity that results in the reduction of the total volume of hazardous waste, or toxicity of hazardous waste, or both. Practices that are considered in waste minimization include recycling, source separation, product substitution, manufacturing process changes and the use of less toxic raw materials.

Waste audits:

A programme of waste audits at the departmental level will provide a systematic and periodic survey of the industries designed to identify areas of potential waste reduction. The audit programme includes the identification of hazardous wastes and their sources, prioritization of various waste reduction actions to be undertaken, evaluation of some technically, economically and ecologically feasible approaches to waste minimization and pollution prevention, development of an economic comparison of waste minimization and pollution prevention options and evaluation of their results.

Good operating practices:

These practices involve the procedural or organizational aspects of industry, research or teaching activities and, in some areas, changes in operating practices, in order to reduce the amount of waste generated. These practices would include, at a minimum, material handling improvements, scheduling improvements, spill and leak prevention, preventive maintenance, corrective maintenance, material/waste tracking or inventory control and waste stream segregation, according to the toxicity, type of contaminant and physical state.

Material substitution practices: The purpose of these practices is to find substitute materials, which are less hazardous than those currently utilized and which result in the generation of waste in smaller quantities and/or of less toxicity.

Technological modification practices:

These practices should be oriented towards process and equipment modifications to reduce waste generation. These can range from changes that can be implemented in a matter of days at low cost to the replacement of process equipment involving large capital expenditures.

Recycling options:
These options are characterized as use/reuse and resource recovery techniques. Use and reuse practices involve the return of a waste material either to the originating process or to another process as a substitute for an input material. Reclamation practices tender a waste to another company.

Surplus chemical waste exchange options:
Inter- and intra-department chemical exchange is to be implemented and encouraged by employers/employees. Material exchanges not only reduce wastes but also save money – both are important considerations, during times of fiscal crisis.

UNIT – II
WASTE TREATMENT AND DISPOSAL

INTRODUCTION

Let us first get one thing very clear: there is no option but to dispose of wastes. Disposal is the final element in the SWM system. It is the ultimate fate of all solid wastes, be they residential wastes collected and transported directly to a landfill site, semisolid waste (sludge) from municipal and industrial treatment plants, incinerator residue, compost or other substances from various solid waste processing plants that are of no further use to society. It is, therefore, imperative to have a proper plan in place for safe disposal of solid wastes, which involves appropriate handling of residual matter after solid wastes have been processed and the recovery of conversion products/energy has been achieved. It follows that an efficient SWM system must provide an environmentally sound disposal option for waste that cannot be reduced, recycled, composted, combusted, or processed further.

LAND FILL

Land fill is an engineered method of solid waste disposal/hazardous in a manner that protects the environment. within the land fill biologigal, chemical and physical processes occur tgat promote degradation of wastes and result in production of leachate. Leachate is a polluted water emanating from the base of land fill and gases.

2.2 LAND FILL CLASSIFICATION

- Sanitary land fill and
- Modern engineered land fill

Sanitary land fill: It is a method of land fill where spread of deseases , odour, breeding of flies, birds can be reduced .

Modern land fill: It is the method where emission of leachate gas and formation of leachate can be removed and used for production of energy.

The term landfill generally refers to an engineered deposit of wastes either in pits/trenches or on the surface. And, a sanitary landfill is essentially a landfill, where proper mechanisms are available to control the environmental risks associated with the disposal of wastes and to make available the land, subsequent to disposal, for other purposes. However, you must note that a landfill need not necessarily be an engineered site, when the waste is largely inert at final disposal, as in rural areas, where wastes contain a large proportion of soil and dirt. This practice is generally designated as non-engineered disposal method. When compared to uncontrolled dumping, engineered landfills are more likely to have pre-planned installations, environmental monitoring, and organised and trained workforce. Sanitary landfill implementation, therefore, requires careful site selection, preparation and management.

The four minimum requirements you need to consider for a sanitary landfill are:

(i) full or partial hydrological isolation;
(ii) formal engineering preparation;
(iii) permanent control;
(iv) planned waste emplacement and covering.

2.2 PRINCIPLES, PROCESSES AND OPERATION OF SANITARY LANDFILLS.

2.2.1. PRINCIPLE

The purpose of land filling 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 homogeneous and are usually made up of cells in which a discrete volume of waste is kept isolated from adjacent waste cells by a suitable barrier. The barriers between cells generally consist of a layer of natural soil (i.e., clay), which restricts downward or lateral escape of the waste constituents or leachate.

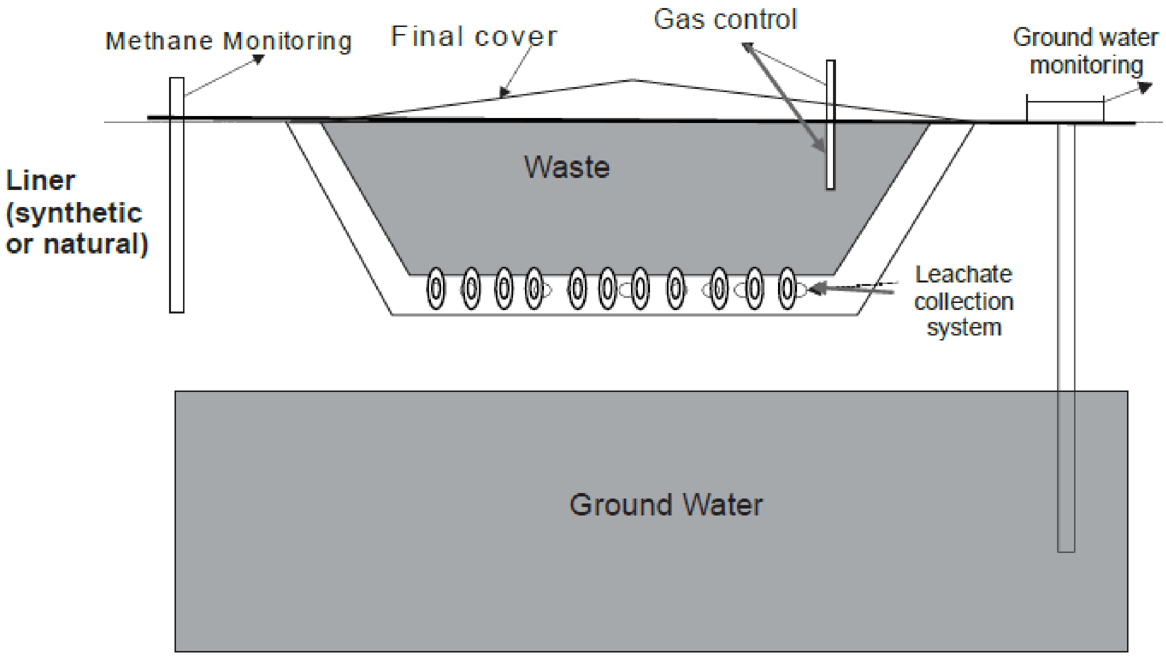


Fig. 2.1. Schematic layout of sanitary landfill

Phases in the life cycle of a landfill, and these are:

Planning phase: This typically involves preliminary hydro-geological and geo-technical site investigations as a basis for actual design.

Construction phase: This involves earthworks, road and facility construction and preparation (liners and drains) of the fill area.

Operation phase (5 – 20 years): This phase has a high intensity of traffic, work at the front of the fill, operation of environmental installations and completion of finished sections.

Completed phase (20 – 100 years): This phase involves the termination of the actual filling to the time when the environmental installations need no longer be operated. The emissions may have by then decreased to a level where they do not need any further treatment and can be discharged freely into the surroundings.

Final storage phase: In this phase, the landfill is integrated into the surroundings for other purposes, and no longer needs special attention.

2.2.2. LANDFILL PROCESSES

The feasibility of land disposal of solid wastes depends on factors such as the type, quantity and characteristics of wastes, the prevailing laws and regulations, and soil and site characteristics. Let us now explain some of these processes.

(i) **Site selection process and considerations:** This requires the development of a working plan – a plan, or a series of plans, outlining the development and descriptions of site location, operation, engineering and site restoration. Considerations for site include public opinion, traffic patterns and congestion, climate, zoning requirements, availability of cover material and liner as well, high trees or buffer in the site perimeter, historic buildings, and endangered species, wetlands, and site land environmental factors, speed limits, underpass limitations, load limits on roadways, bridge capacities, and proximity of major roadways, haul distance, hydrology and detours.

(ii) **Settling process:** The waste body of a landfill undergoes different stages of settling or deformation.

Settling Processes in Landfill

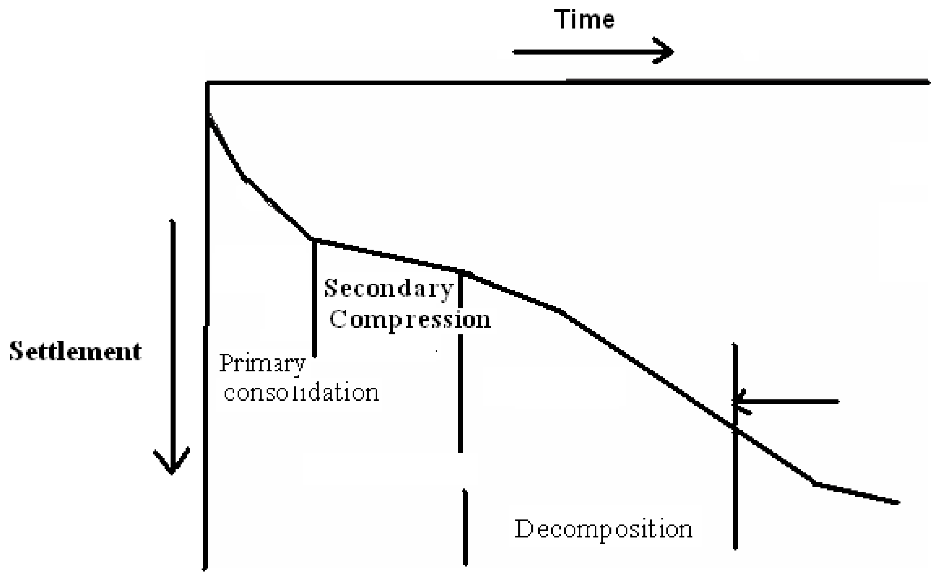


Fig.2.3.Stages of land fill

The three stages shown in the figure above are described below:

Primary consolidation: During this stage, a substantial amount of settling occurs. This settlement is caused by the weight of the waste layers. The movement of trucks, bulldozers or mechanical compactors will also enhance this process. After this primary consolidation, or short-term deformation stage, aerobic degradation processes occur.

Secondary compression: During this stage, the rate of settling is much lower than that in the primary consolidation stage, as the settling occurs through compression, which cannot be enhanced.

Decomposition: During the degradation processes, organic material is converted into gas and leachate. The settling rate during this stage increases compared to the secondary compression stage, and continues until all decomposable organic matter is degraded. The settling rate, however, gradually decreases with the passage of time.

To appropriately design protective liners, and gas and leachate collection systems, it is, therefore, necessary to have a proper knowledge of the settling process of wastes.

Microbial degradation process: The microbial degradation process is the most important biological process occurring in a landfill. These processes induce changes in the chemical and physical environment within the waste body, which determine the quality of leachate and both the quality and quantity of landfill gas.Assuming that landfills mostly receive organic wastes, microbial processes will dominate the stabilisation of the waste and therefore govern landfill gas generation and leachate composition. Soon after disposal, the predominant part of the wastes becomes anaerobic, and the bacteria will start degrading the solid organic carbon, eventually to produce carbon dioxide and methane. The anaerobic degradation process undergoes the following stages:

- Solid and complex dissolved organic compounds are hydrolysed and fermented by the fermenters primarily to volatile fatty acids, alcohols, hydrogen and carbon dioxide.

- An acidogenic group of bacteria converts the products of the first stage to acetic acid, hydrogen and carbon dioxide.

- Methanogenic bacteria convert acetic acid to methane and carbon dioxide and hydrogenophilic bacteria convert hydrogen and carbon dioxide to methane.

The biotic factors that affect methane formation in the landfill are pH, alkalinity, nutrients, temperature, oxygen and moisture content.

Enhancement of degradation:
Enhancement of the degradation processes in landfills will result in a faster stabilisation of the waste in the landfill, which enhances gas production, and we can achieve this by:
Adding partly composted waste: As the readily degradable organic matter has already been decomposed aerobically, the rapid acid production phase is overcome, and the balance of acid and methane production bacteria can develop earlier and the consequent dilution effect lowers the organic acid concentration.

Recirculating leachate: This may have positive effects since a slow increase in moisture will cause a long period of gas production. During warmer periods, recirculated leachate will evaporate, resulting in lower amounts of excess leachate.

2.3. LANDFILL GAS AND LEACHATE

Leachate and landfill gas comprise the major hazards associated with a landfill. While leachate may contaminate the surrounding land and water, landfill gas can be toxic and lead to global warming and explosion leading to human catastrophe (Phelps, 1995). (Note that global warming, also known as greenhouse effect, refers to the warming of the earth's atmosphere by the accumulation of gases (e.g., methane, carbon dioxide and chlorofluorocarbons) that absorbs reflected solar radiation.)
The factors, which affect the production of leachate and landfill gas, are the following:

Nature of waste: The deposition of waste containing biodegradable matter invariably leads to the production of gas and leachate, and the amount depends on the content of biodegradable material in the waste.

Moisture content: Most micro-organisms require a minimum of approximately 12% (by weight) moisture for growth, and thus the moisture content of landfill waste is an important factor in determining the amount and extent of leachate and gas production.

pH: The methanogenic bacteria within a landfill produce methane gas, which will grow only at low pH range around neutrality.

Particle size and density: The size of waste particle affects the density that can be achieved upon compaction and affects the surface area and hence volume. Both affect moisture absorption and therefore are potential for biological degradation.

Temperature: An increase in temperature tends to increase gas production. The temperature affects the microbial activity to the extent that it is possible to segregate bacteria, according to their optimum temperature operating conditions.

Carbohydrates comprise a large percentage of biodegradable matter within municipal waste, the overall breakdown of which can be represented by the following equation:
(Bacteria)

$$C_6H_{12}O_6 + CH_4 + CO_2 + \text{Biomass} + \text{Heat}$$

(Carbohydrate) (Methane) (Carbon dioxide)

Let us now discuss landfill leachate and gas emission in detail along with their composition and adverse effects.

2.4. LANDFILL GAS EMISSION

Landfill gas contains a high percentage of methane due to the anaerobic decomposition of organic matter, which can be utilised as a source of energy.

COMPOSITION AND PROPERTIES

We can predict the amount and composition of the gas generated for different substrates, depending on the general anaerobic decomposition of wastes added. Climatic and environmental conditions also influence gas composition. Due to the heterogeneous nature of the landfill, some acid-phase anaerobic decomposition occurs along with the methanogenic decomposition. Since aerobic and acid-phase degradation give rise to carbon dioxide and not methane, there may be a higher carbon dioxide content in the gas generated than what would otherwise be expected. Furthermore, depending on the moisture distribution, some carbon dioxide goes into solution. This may appear to increase (artificially) the methane content of the gas measured in the landfill. A typical landfill gas contains a number of components such as the following, which tend to occur within a characteristic range:

Methane: This is a colourless, odourless and flammable gas with a density lighter than air, typically making up 50 – 60% of the landfill gas.

Carbon dioxide: This is a colourless, odourless and non-inflammable gas that is denser than air, typically accounting for 30 – 40%.

Oxygen: The flammability of methane depends on the percentage of oxygen. It is, therefore, important to control oxygen levels, where gas abstraction is undertaken.

Nitrogen: This is essentially inert and will have little effect, except to modify the explosive range of methane.

2.5 CONTROL AND HAZARDS

HAZARDS

Landfill gas consists of a mixture of flammable, asphyxiating and noxious gases and may be hazardous to health and safety, and hence the need for precautions. Some of the major hazards are listed below:

Explosion and fire: Methane is flammable in air within the range of 5 – 15% by volume, while hydrogen is flammable within the range of 4.1 – 7.5% (in the presence of oxygen) and potentially explosive. Fire, occurring within the waste, can be difficult to extinguish and can lead to unpredictable and uncontrolled subsidence as well as production of smoke and toxic fumes.

Trace components: These comprise mostly alkanes and alkenes, and their oxidation products such as aldehydes, alcohols and esters. Many of them are recognised as toxicants, when present in air at concentrations above occupational exposure standards.

Global warming: Known also as greenhouse effect, it is the warming of the earth's atmosphere by the accumulation of gases (methane, carbon dioxide and chlorofluorocarbons) that absorbs reflected solar radiation.

Migration

During landfill development, most of the gas produced is vented to the atmosphere, provided the permeable intermediate cover has been used. While biological and chemical processes affect gas composition through methane oxidation, which converts methane to carbon dioxide, physical factors affect gas migration. The physical factors that affect gas migration include:

Environmental conditions: These affect the rate of degradation and gas pressure build up.

Geophysical conditions: These affect migration pathways. In the presence of fractured geological strata or a mineshaft, the gas may travel large distances, unless restricted by the water table.

Climatic conditions: Falling atmospheric pressure, rainfall and water infiltration rate affect landfill gas migration.

CONTROL

To control gas emission, it is necessary to control the following:

- Waste inputs (i.e., restrict the amount of organic waste).
- Processes within the waste (i.e., minimise moisture content to limit gas production).
- Migration process (i.e., provide physical barriers or vents to remove the gas from the site and reduce gas pressure). Note that since gas migration cannot be easily prevented, removal is often the preferred option. This is done by using vents (extraction wells) within the waste or stone filled vents, which are often placed around the periphery of the landfill site. Some of the gas collection systems include impermeable cap, granular material, collection pipes and treatment systems.

2.6. LEACHATE FORMATION

Leachate can pollute both groundwater and surface water supplies. The degree of pollution will depend on local geology and hydrogeology, nature of waste and the proximity of susceptible receptors. Once groundwater is contaminated, it is very costly to clean it up. Landfills, therefore, undergo siting, design and construction procedures that control leachate migration.

2.6.1. COMPOSITION AND PROPERTIES

Leachate comprises soluble components of waste and its degradation products enter water, as it percolates through the landfill. The amount of leachate generated depends on:

- Water availability;
- Landfill surface condition;
- Refuse state;
- Condition of surrounding strata.

The major factor, i.e., water availability, is affected by precipitation, surface runoff, waste decomposition and liquid waste disposal. The water balance equation for landfill requires negative or zero (“Lo”) so that no excess leachate is produced. This is calculated using the following formula:

$$Lo = I - E - aW$$

$$\text{i.e. } I - E < aW$$

where, Lo = free leachate retained at site (equivalent to leachate production minus leachate leaving the site); I = total liquid input;
E = evapotranspiration losses; a = absorption capacity of waste;
W = weight of waste disposed.
Common toxic components in leachate are ammonia and heavy metals, which can be hazardous even at low levels, if they accumulate in the food chain. Leachate composition varies with time and location.

Typical leachate properties and composition at various stages of waste decomposition:

Components	Fresh wastes	Aged wastes	Wastes with high moisture
pH	6.2	7.5	8.0
COD	23800	1160	1500
BOD	11900	260	500
TOC	8000	465	450
Volatile acid (as C)	5688	5	12
NH_3-N	790	370	1000
NO_3-N	3	1	1.0
Ortho-P	0.73	1.4	1.0
Cl	1315	2080	1390
Na	9601	300	1900
Mg	252	185	186
K	780	590	570
Ca	1820	250	158
Mn	27	2.1	0.05
[illegible]	[illegible]	[illegible]	[illegible]

Table.2.1. Properties and composition of leachate

Leachate migration

It is generally difficult to predict the movement of escaped leachate accurately. The main controlling factors are the surrounding geology and hydrogeology. Escape to surface water may be relatively easy to control, but if it escapes to groundwater sources, it can be very difficult both to control and clean up. The degree of groundwater contamination is affected by physical, chemical and biological actions. The relative importance of each process may change, however, if the leachate moves from the landfill to the sub-surface region.

Control

The best way to control leachate is through prevention, which should be integral to the site design. In most cases, it is necessary to control liquid access, collection and treatment, all of which can be done using the following landfill liners:

Natural liners: These refer to compacted clay or shale, bitumen or soil sealants, etc., and are generally less permeable, resistant to chemical attack and have good sorption properties. They generally do not act as true containment barriers, because sometimes leachate migrates through them.

Synthetic (geo-membrane) liners: These are typically made up of high or medium density polyethylene and are generally less permeable, easy to install, relatively strong and have good deformation characteristics. They sometimes expand or shrink according to temperature and age.

Note that natural and geo-membrane liners are often combined to enhance the overall efficiency of the containment system. Some of the leachate collection systems include impermeable liner, granular material, collection piping, leachate storage tank; leachate is trucked to a wastewater treatment facility.

2.7. LINER SYSTEMS

Landfill liners are designed to create a barrier between the waste and the environment, and to drain the leachate to collection and treatment facilities. Liners may be single, composite, or double. Selection of liner is based on chemical compatibility, stress-strain characteristics, survivability and permeability.

I. Single liner Single liners consist of a clay liner, a geosynthetic clay liner or a geomembrane. Single liners are sometimes used in landfills containing construction debris. Clay liner is easily available and is durable. Synthetic geo-membranes are composed of polymers such as: Thermoplastics (PVC); crystalline thermoplastics (HDPE, LDPE); thermoplastic elastomers (chlorinated polyethylene, chlorylsulphonated polyethylene); elastomers (neoprene, ethylene propene diene monomer).

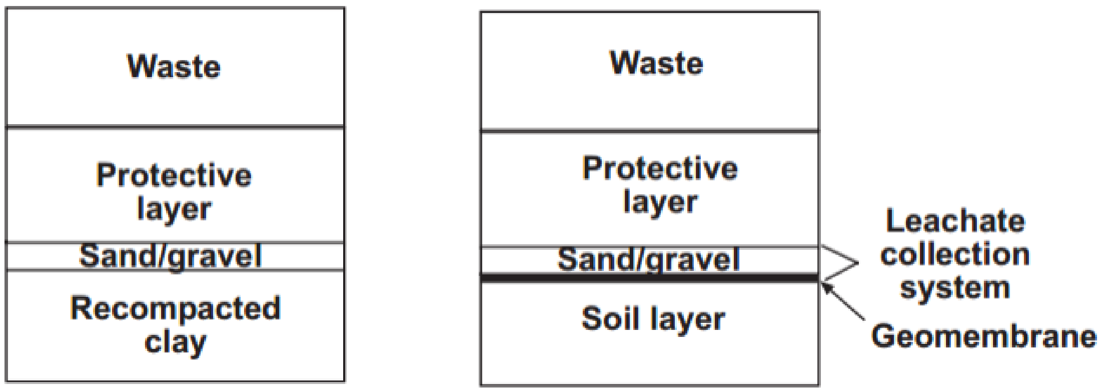


Fig. 2. 6 Single liner system

II. Composite liner A composite liner consists of a geomembrane in combination with a clay liner. These are more effective at limiting leachate migration into the subsoil.

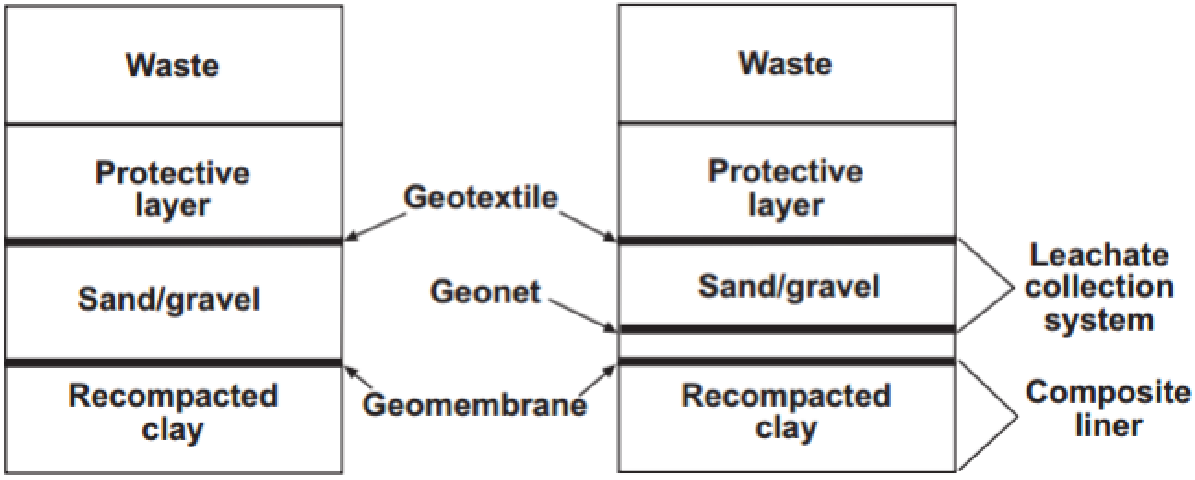


Fig.2.7. Composite liner system

III. Double liner A double liner consists of either two single liners, two composite liners, or a single and a composite liner. The upper (primary) liner collects the leachate, while the lower (secondary) liner acts as a leak detection system. Double liners are to be used in MSW landfills, and especially in hazardous waste landfills. A double liner is more resistant to stress cracking and increased strain due to tensile yield.

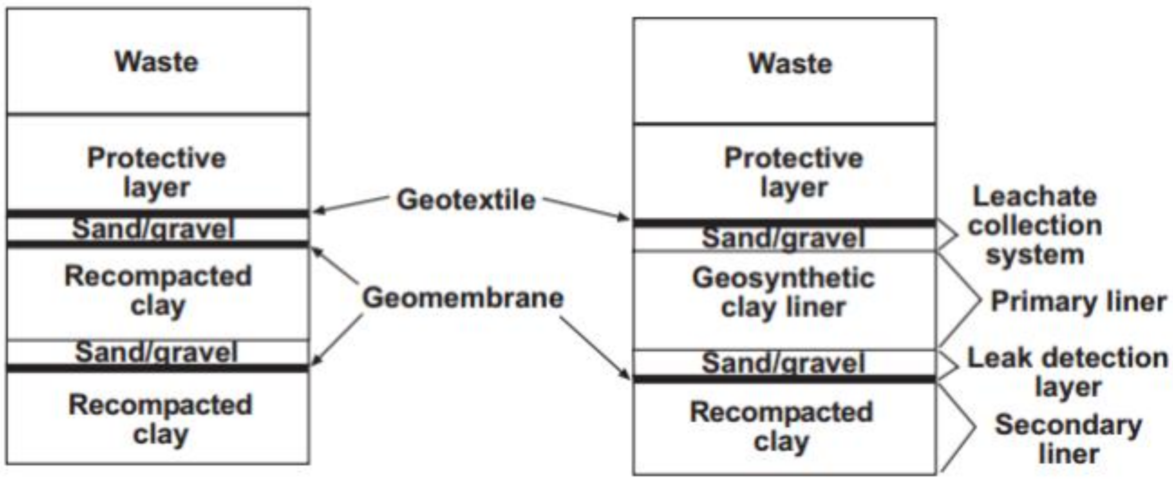


Fig.2.7. Double liner system

Basic Definitions:

Geotextile:
A permeable fabric made of plastic threads that separates the base of the landfill from the underlying soil. It allows water to pass through it but prevents soil from coming into the base.

Geomembrane:
A synthetic membrane with very low permeability that controls the movement of fluid in any engineering structure or system.

Landfill cover:
A daily cover of compacted soil or earth is applied on top of the waste deposited in a landfill. This cover minimizes the interaction between waste and the surrounding environment. It also reduces odours.

Treatment
Concentrations of various substances occurring in leachate are too high to be discharged to surface water or into a sewer system. These concentrations, therefore, have to be reduced by removal, treatment or both. The various treatments of leachate include:

Leachate recirculation: It is one of the simplest forms of treatment. Recirculation of leachate reduces the hazardous nature of leachate and helps wet the waste, increasing its potential for biological degradation.

Biological treatment: This removes BOD, ammonia and suspended solids. Leachate from land filled waste can be readily degraded by biological means, due to high content of volatile fatty acids (VFAs). The common methods are aerated lagoons (i.e., special devices which enhance the aerobic processes of degradation of organic substances over the entire depth of the tank) and activated sludge process, which differs from aerated lagoons in that discharged sludge is recirculated and is often used for BOD and ammonia removal. While under conditions of low COD, rotating biological contactors (i.e., biomass is brought into contact with circular blades fixed to a common axle which is rotated) are very effective in removing ammonia. In an anaerobic treatment system, complex organic molecules are fermented in filter. The common types are anaerobic filters, anaerobic lagoon and digesters.

Physicochemical treatment: After biological degradation, effluents still contain significant concentrations of different substances. Physicochemical treatment processes could be installed to improve the leachate effluent quality. Some of these processes are flocculation-precipitation. (Note that addition of chemicals to the water attracts the metal by floc formation). Separation of the floc from water takes place by sedimentation, adsorption and reverse osmosis.

2.8. ENVIRONMENTAL EFFECTS OF LANDFILL

The environmental effects of a landfill include wind-blown litter and dust, noise, obnoxious odour, vermin and insects attracted by the waste, surface runoff and inaesthetic conditions. Gas and leachate problems also arise during the operation phase and require significant environmental controls. In what follows, we will describe some of the major environmental effects below:

Wind-blown litter and dust are continuous problems of the ongoing landfill operation and a nuisance to the neighbourhood. Covering the waste cells with soil and spraying water on dirt roads and waste in dry periods, in combination with fencing and movable screens, may minimise the problem of wind-blown litter and dust. However, note that the problem will remain at the tipping front of the landfill.

Movement of waste collection vehicles, emptying of wastes from them, compactors, earthmoving equipment, etc., produce noise. Improving the technical capability of the equipment, surrounding the fill area with soil embankments and plantations, limiting the working hours and appropriately training the workforce will help minimise noise pollution.

Birds (e.g., scavengers), vermin, insects and animals are attracted to the landfill for feeding and breeding. Since many of these may act as disease vectors, their presence is a potential health problem.

Surface run-off, which has been in contact with the land filled waste, may be a problem in areas of intense rainfall. If not controlled, heavily polluted run-off may enter directly into creeks and streams. Careful design and maintenance of surface drains and ditches, together with a final soil cover on completed landfill.

An operating landfill, where equipment and waste are exposed, appears inaesthetic. This problem may be reduced by careful design of screening soil embankments, plantings, rapid covering and re-vegetation of filled sections.

Gas released, as a result of degradation or volatilisation of waste components, causes odour, flammability, health problems and damage of the vegetation (due to oxygen depletion in the root zone). The measures to control this include liners, soil covers, passive venting or active extraction of gas for treatment before discharge into the atmosphere.

Polluted leachate appears shortly after disposal of the waste. This may cause groundwater pollution and pollution of streams through sub-surface migration. Liners, drainage collection, treatment of leachate, and groundwater and downstream water quality monitoring are necessary to control this problem.

UNIT – III
BIO-CHEMICAL CONVERSION

3.1 BIOCHEMICAL CONVERSION OF BIOMASS

Biochemical conversion of biomass involves use of bacteria, microorganisms and enzymes to breakdown biomass into gaseous or liquid fuels, such as biogas or bioethanol. The most popular biochemical technologies are anaerobic digestion (or biomethanation) and fermentation. Anaerobic digestion is a series of chemical reactions during which organic material is decomposed through the metabolic pathways of naturally occurring microorganisms in an oxygen depleted environment. Biomass wastes can also yield liquid fuels, such as cellulosic ethanol, which can be used to replace petroleum-based fuels.

3.2. ANAEROBIC DIGESTION

Anaerobic digestion is the natural biological process which stabilizes organic waste in the absence of air and transforms it into biofertilizer and biogas. Anaerobic digestion is a reliable technology for the treatment of wet, organic waste. Organic waste from various sources is biochemically degraded in highly controlled, oxygen-free conditions circumstances resulting in the production of biogas which can be used to produce both electricity and heat. Almost any organic material can be processed with anaerobic digestion. This includes biodegradable waste materials such as municipal solid waste, animal manure, poultry litter, food wastes, sewage and industrial wastes.

An anaerobic digestion plant produces two outputs, biogas and digestate, both can be further processed or utilized to produce secondary outputs. Biogas can be used for producing electricity and heat, as a natural gas substitute and also a transportation fuel. A combined heat and power plant system (CHP) not only generates power but also produces heat for in-house requirements to maintain desired temperature level in the digester during cold season. In Sweden, the compressed biogas is used as a transportation fuel for cars and buses. Biogas can also be upgraded and used in gas supply networks.Digestate can be further processed to produce liquor and a fibrous material. The fiber, which can be processed into compost, is a bulky material with low levels of nutrients and can be used as a soil conditioner or a low level fertilizer. A high proportion of the nutrients remain in the liquor, which can be used as a liquid fertilizer.

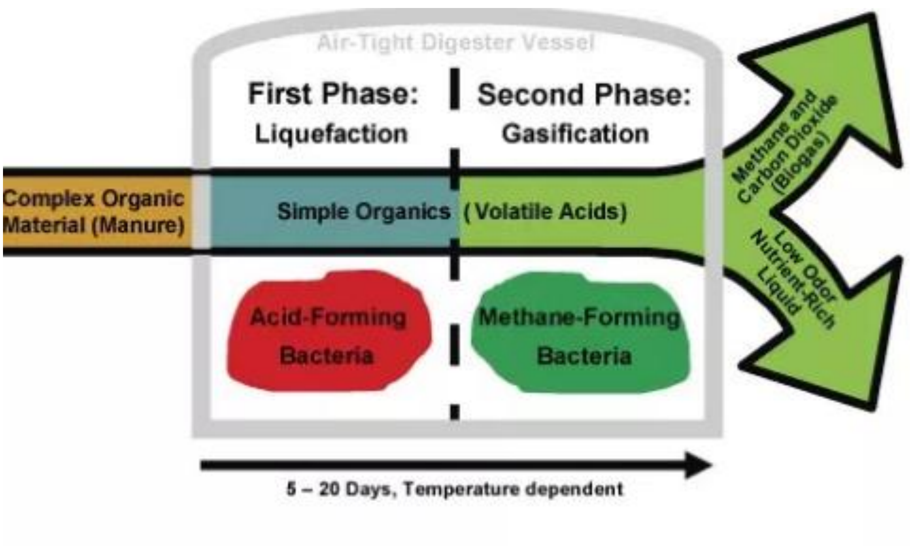


Fig.3.1. Working of anaerobic digestion

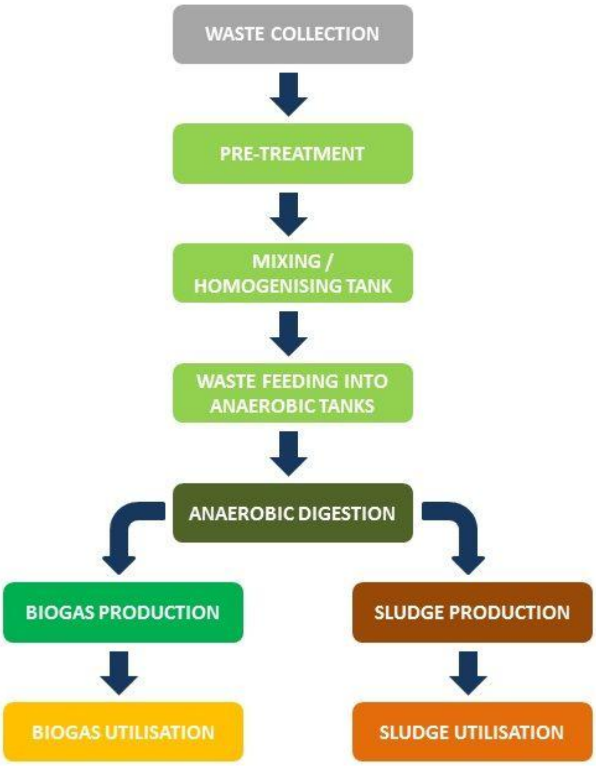


Fig.3.2. Block diagram of biomass conversion

3.3. BIOFUEL PRODUCTION

A variety of fuels can be produced from waste resources including liquid fuels, such as ethanol, methanol, biodiesel, Fischer-Tropsch diesel, and gaseous fuels, such as hydrogen and methane. The resource base for biofuel production is composed of a wide variety of forestry and agricultural resources, industrial processing residues, and municipal solid and urban wood residues. Globally, biofuels are most commonly used to power vehicles, heat homes, and for cooking.

The largest potential feedstock for ethanol is lignocellulosic biomass wastes, which includes materials such as agricultural residues (corn stover, crop straws and bagasse), herbaceous crops (alfalfa, switchgrass), short rotation woody crops, forestry residues, waste paper and other wastes (municipal and industrial). Bioethanol production from these feedstocks could be an attractive alternative for disposal of these residues. Importantly, lignocellulosic feedstocks do not interfere with food security.

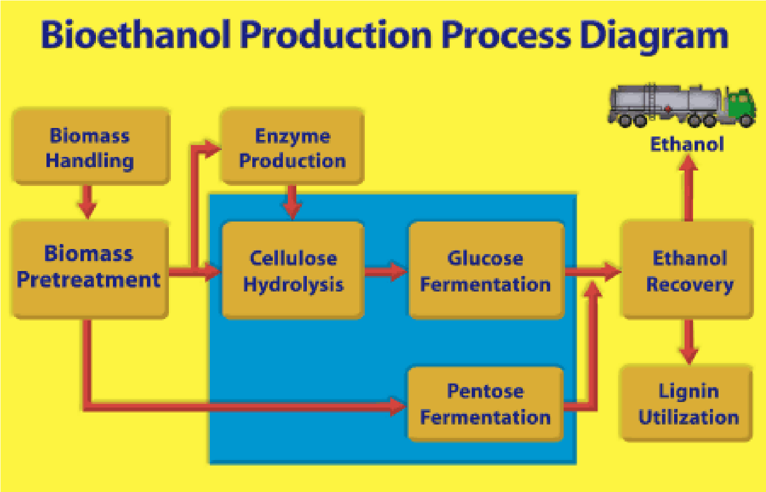


Fig.3.3. Bioethanol production process diagarm

Ethanol from lignocellulosic biomass is produced mainly via biochemical routes. The three major steps involved are pretreatment, enzymatic hydrolysis, and fermentation. Biomass is pretreated to improve the accessibility of enzymes. After pretreatment, biomass undergoes enzymatic hydrolysis for conversion of polysaccharides into monomer sugars, such as glucose and xylose. Subsequently, sugars are fermented to ethanol by the use of different microorganisms.

3.4. BIOMASS GASIFICATION PROCESS

Biomass gasification involves burning of biomass in a limited supply of air to give a combustible gas consisting of carbon monoxide, carbon dioxide, hydrogen, methane, water, nitrogen, along with contaminants like small char particles, ash and tars. The gas is cleaned to make it suitable for use in boilers, engines and turbines to produce heat and power (CHP). Biomass gasification provides a means of deriving more diverse forms of energy from the thermochemical conversion of biomass than conventional combustion. The basic gasification process involves devolatization, combustion and reduction.

During devolatization, methane and other hydrocarbons are produced from the biomass by the action of heat which leaves a reactive char.During combustion, the volatiles and char are partially burned in air or oxygen to generate heat and carbon dioxide. In the reduction phase, carbon dioxide absorbs heat and reacts with the remaining char to produce carbon monoxide (producer gas). The presence of water vapour in a gasifier results in the production of hydrogen as a secondary fuel component.

There are two main types of gasifier that can be used to carry out this conversion, fixed bed gasifiers and fluidized bed gasifiers. The conversion of biomass into a combustible gas involves a two-stage process. The first, which is called pyrolysis, takes place below 600°C, when volatile components contained within the biomass are released. These may include organic compounds, hydrogen, carbon monoxide, tars and water vapour. Pyrolysis leaves a solid residue called char. In the second stage of the gasification process, this char is reacted with steam or burnt in a restricted quantity of air or oxygen to produce further combustible gas. Depending on the precise design of gasifier chosen, the product gas may have a heating value of 6 – 19 MJ/Nm^3.

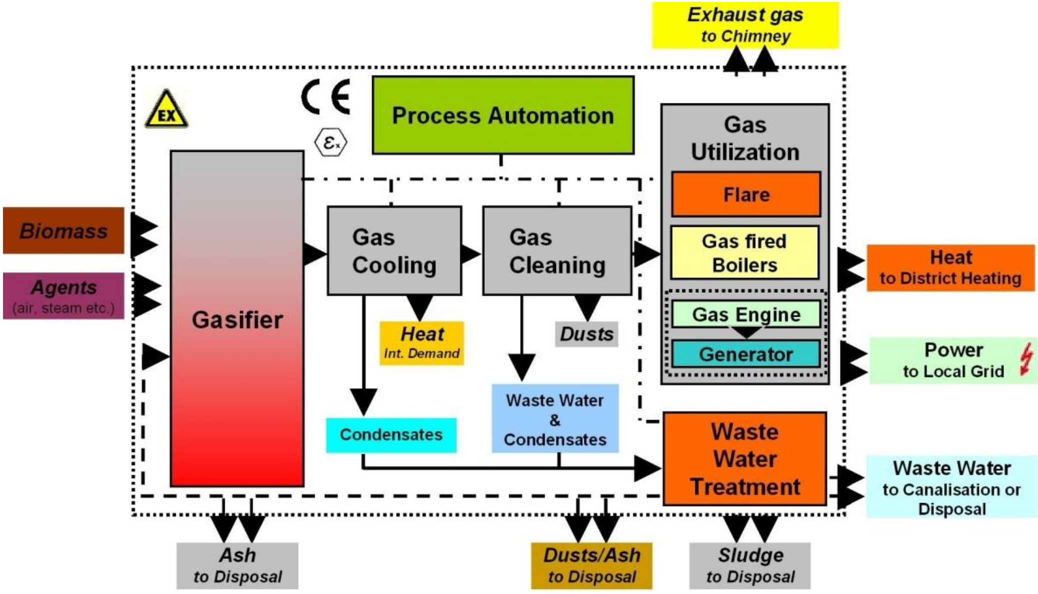


Fig.3.4. Layout of a Typical Biomass Gasification Plant

The products of gasification are a mixture of carbon monoxide, carbon dioxide, methane, hydrogen and various hydrocarbons, which can then be used directly in gas turbines, and boilers, or used as precursors for synthesising a wide range of other chemicals.

In addition there are a number of methods that can be used to produce higher quality product gases, including indirect heating, oxygen blowing, and pressurisation. After appropriate treatment, the resulting gases can be burned directly for cooking or heat supply, or used in secondary conversion devices, such as internal combustion engines or gas turbines, for producing electricity or shaft power (where it also has the potential for CHP applications).

3.5. BIOMASS PYROLYSIS PROCESS

Pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. It is the fundamental chemical reaction that is the precursor of both the combustion and gasification processes and occurs naturally in the first two seconds. The products of biomass pyrolysis include biochar, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide.

Depending on the thermal environment and the final temperature, pyrolysis will yield mainly biochar at low temperatures, less than 450 ^{0}C, when the heating rate is quite slow, and mainly gases at high temperatures, greater than 800 ^{0}C, with rapid heating rates. At an intermediate temperature and under relatively high heating rates, the main product is bio-oil.

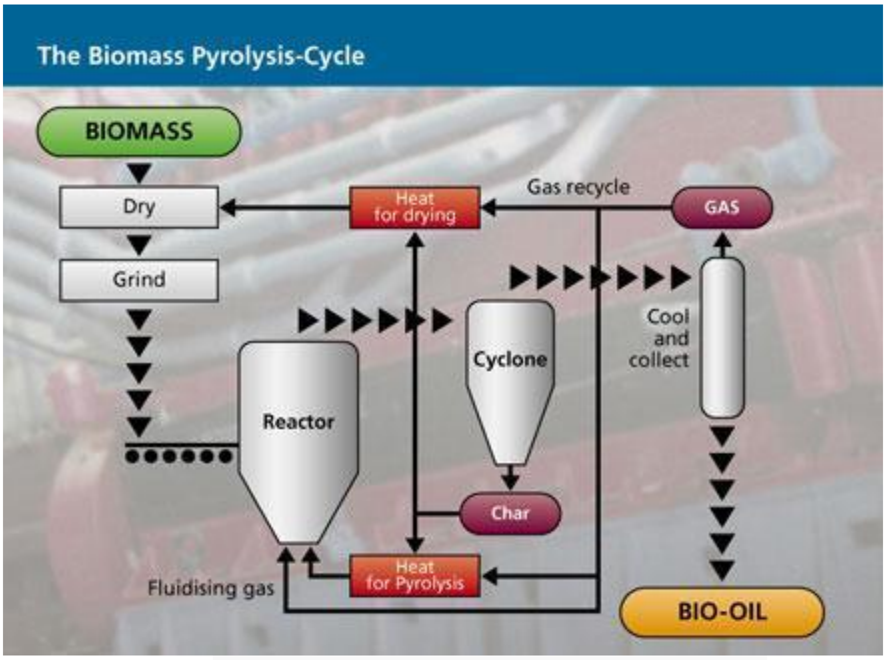


Fig.3.5. Layout of a Typical Biomass Pyrolysis Process

Pyrolysis can be performed at relatively small scale and at remote locations which enhance energy density of the biomass resource and reduce transport and handling costs. Pyrolysis offers a flexible and attractive way of converting solid biomass into an easily stored and transported liquid, which can be successfully used for the production of heat, power and chemicals.

A wide range of biomass feedstocks can be used in pyrolysis processes. The pyrolysis process is very dependent on the moisture content of the feedstock, which should be around 10%. At higher moisture contents, high levels of water are produced and at lower levels there is a risk that the process only produces dust instead of oil. High-moisture waste streams, such as sludge and meat processing wastes, require drying before subjecting to pyrolysis.

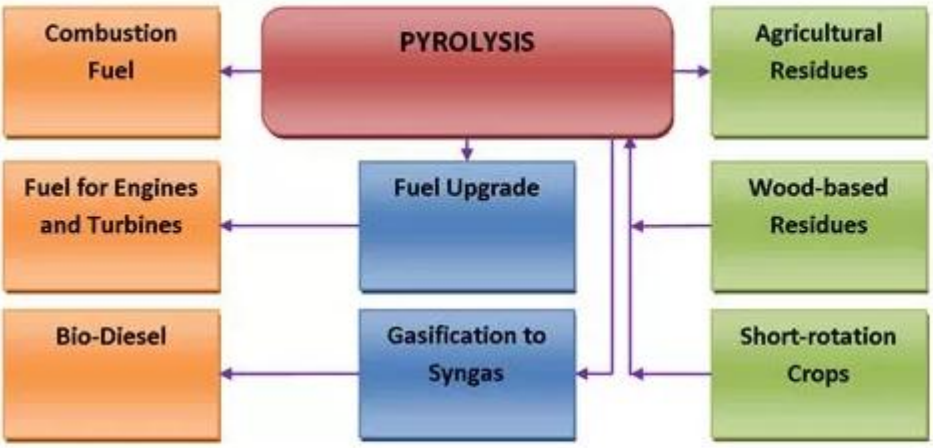


Fig.3.6. Block Diagram of pyrolysis process

The efficiency and nature of the pyrolysis process is dependent on the particle size of feedstocks. Most of the pyrolysis technologies can only process small particles to a maximum of 2 mm keeping in view the need for rapid heat transfer through the particle. The demand for small particle size means that the feedstock has to be size-reduced before being used for pyrolysis.

Pyrolysis processes can be categorized as slow pyrolysis or fast pyrolysis. Fast pyrolysis is currently the most widely used pyrolysis system. Slow pyrolysis takes several hours to complete and results in biochar as the main product. On the other hand, fast pyrolysis yields 60% bio-oil and takes seconds for complete pyrolysis. In addition, it gives 20% biochar and 20% syngas.

3.5.1 PYROLYSIS OF MUNICIPAL WASTES

Pyrolysis process consists of both simultaneous and successive reactions when carbon-rich organic material is heated in a non-reactive atmosphere. Simply speaking, pyrolysis is the thermal degradation of organic materials in the absence of oxygen. Thermal decomposition of organic components in the waste stream starts at 350°C–550°C and goes up to 700°C–800°C in the absence of air/oxygen.

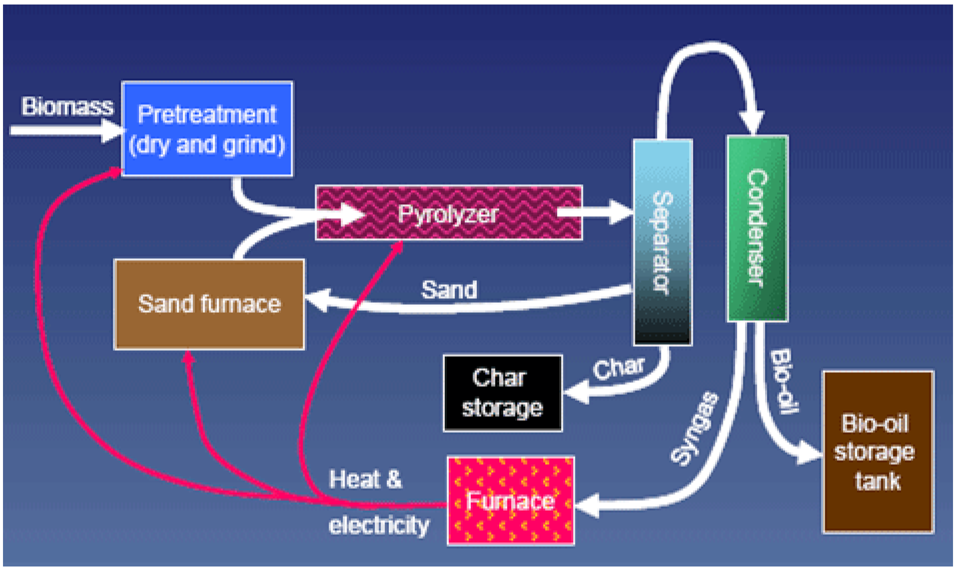


Fig.3.7. Block Diagram of pyrolysis process of municipal waste

Pyrolysis of municipal wastes begins with mechanical preparation and separation of glass, metals and inert materials prior to processing the remaining waste in a pyrolysis reactor. The commonly used pyrolysis reactors are rotary kilns, rotary hearth furnaces, and fluidized bed furnaces. The process requires an external heat source to maintain the high temperature required. Pyrolysis can be performed at relatively small-scale which may help in reducing transport and handling costs. In pyrolysis of MSW, heat transfer is a critical area as the process is endothermic and sufficient heat transfer surface has to be provided to meet process heat requirements.

The main products obtained from pyrolysis of municipal wastes are a high calorific value gas (synthesis gas or syngas), a biofuel (bio oil or pyrolysis oil) and a solid residue (char). Depending on the final temperature, MSW pyrolysis will yield mainly solid residues at low temperatures, less than 4500C, when the heating rate is quite slow, and mainly gases at high temperatures, greater than 8000C, with rapid heating rates. At an intermediate temperature and under relatively high heating rates, the main product is a liquid fuel popularly known as bio oil.

3.5.2.WIDE RANGE OF PRODUCTS

Bio oil is a dark brown liquid and can be upgraded to either engine fuel or through gasification processes to a syngas and then biodiesel. Pyrolysis oil may also be used as liquid fuel for diesel engines and gas turbines to generate electricity Bio oil is particularly attractive for co-firing because it can be relatively easy to handle and burn than solid fuel and is cheaper to transport and store. In addition, bio oil is also a vital source for a wide range of organic compounds and specialty chemicals.

Syngas is a mixture of energy-rich gases (combustible constituents include carbon monoxide, hydrogen, methane and a broad range of other VOCs). The net calorific value (NCV) of syngas is between 10 and 20MJ/Nm^3. Syngas is cleaned to remove particulates, hydrocarbons, and soluble matter, and then combusted to generate electricity. Diesel engines, gas turbines, steam turbines and boilers can be used directly to generate electricity and heat in CHP systems using syngas and pyrolysis oil. Syngas may also be used as a basic chemical in petrochemical and refining industries.

The solid residue from MSW pyrolysis, called char, is a combination of non-combustible materials and carbon. Char is almost pure carbon and can be used in the manufacture of activated carbonfiltration media (for water treatment applications) or as an agricultural soil amendment.

3.5.2. OVERVIEW OF BIOMASS PYROLYSIS

The pyrolysis process consists of both simultaneous and successive reactions when organic material is heated in a non-reactive atmosphere. Thermal decomposition of organic components in biomass starts at 350 °C–550 °C and goes up to 700 °C–800 °C in the absence of air/oxygen. The long chains of carbon, hydrogen and oxygen compounds in biomass break down into smaller molecules in the form of gases, condensable vapours (tars and oils) and solid charcoal under pyrolysis conditions. Rate and extent of decomposition of each of these components depends on the process parameters of the reactor temperature, biomass heating rate, pressure, reactor configuration, feedstock etc

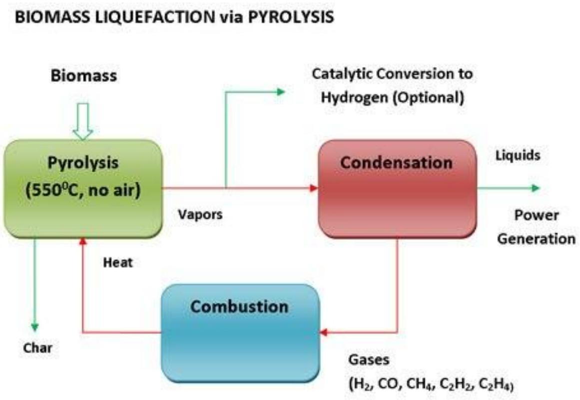


Fig.3.7. Biomass liquefaction via Pyrolysis

Depending on the thermal environment and the final temperature, pyrolysis will yield mainly biochar at low temperatures, less than 450 0C, when the heating rate is quite slow, and mainly gases at high temperatures, greater than 800 0C, with rapid heating rates. At an intermediate temperature and under relatively high heating rates, the main product is bio-oil.

Biomass pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. It is the fundamental chemical reaction that is the precursor of both the combustion and gasification processes and occurs naturally in the first two seconds. The products of biomass pyrolysis include biochar, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide.

3.5.3. SLOW AND FAST PYROLYSIS

Pyrolysis processes can be categorized as slow or fast. Slow pyrolysis takes several hours to complete and results in biochar as the main product. On the other hand, fast pyrolysis yields 60% bio-oil and takes seconds for complete pyrolysis. In addition, it gives 20% biochar and 20% syngas. Fast pyrolysis is currently the most widely used pyrolysis system.

- The essential features of a fast pyrolysis process are:
- Very high heating and heat transfer rates, which require a finely ground feed.
- Carefully controlled reaction temperature of around 500oC in the vapour phase
- Residence time of pyrolysis vapours in the reactor less than 1 sec
- Quenching (rapid cooling) of the pyrolysis vapours to give the bio-oil product.

3.5.4. ADVANTAGES OF BIOMASS PYROLYSIS

Pyrolysis can be performed at relatively small scale and at remote locations which enhance energy density of the biomass resource and reduce transport and handling costs. Heat transfer is a critical area in pyrolysis as the pyrolysis process is endothermic and sufficient heat transfer surface has to be provided to meet process heat needs. Biomass pyrolysis offers a flexible and attractive way of converting organic matter into energy products which can be successfully used for the production of heat, power and chemicals.

A wide range of biomass feedstocks can be used in pyrolysis processes. The pyrolysis process is very dependent on the moisture content of the feedstock, which should be around 10%. At higher moisture contents, high levels of water are produced and at lower levels there is a risk that the process only produces dust instead of oil. High-moisture waste streams, such as sludge and meat processing wastes, require drying before subjecting to pyrolysis.

Furthermore, the bio-char produced can be used on the farm as an excellent soil amender as it is highly absorbent and therefore increases the soil’s ability to retain water, nutrients and agricultural chemicals, preventing water contamination and soil erosion. Soil application of bio-char may enhance both soil quality and be an effective means of sequestering large amounts of carbon, thereby helping to mitigate global climate change through carbon sequestration. Use of bio-char as a soil amendment will offset many of the problems associated with removing crop residues from the land.

Biomass pyrolysis has been garnering much attention due to its high efficiency and good environmental performance characteristics. It also provides an opportunity for the processing of agricultural residues, wood wastes and municipal solid waste into clean energy. In addition, biochar sequestration could make a big difference in the fossil fuel emissions worldwide and act as a major player in the global carbon market with its robust, clean and simple production technology.

3.6. BIO-OIL

Bio-oil is a dark brown liquid and has a similar composition to biomass. It has a much higher density than woody materials which reduces storage and transport costs. Bio-oil is not suitable for direct use in standard internal combustion engines. Alternatively, the oil can be upgraded to either a special engine fuel or through gasification processes to a syngas and then bio-diesel. Bio-oil is particularly attractive for co-firing because it can be more readily handled and burned than solid fuel and is cheaper to transport and store.

Bio-oil can offer major advantages over solid biomass and gasification due to the ease of handling, storage and combustion in an existing power station when special start-up procedures are not necessary. In addition, bio-oil is also a vital source for a wide range of organic compounds and speciality chemicals.

3.7. REFUSE-DERIVED FUEL

RDF is the product of processing municipal solid waste to separate the noncombustible from the combustible portion, and preparing the combustible portion into a form that can be effectively fired in an existing or new boiler.

3.7.1. ENERGY RECOVERY FROM THE COMBUSTION OF MUNICIPAL SOLID WASTE (MSW)

Energy recovery from waste is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion and landfill gas recovery. This process is often called waste to energy.Energy recovery from the combustion of municipal solid waste is a key part of the non-hazardous waste management hierarchy, which ranks various management strategies from most to least environmentally preferred. Energy recovery ranks below source reduction and recycling/reuse but above treatment and disposal. Confined and controlled burning, known as combustion, can not only decrease the volume of solid waste destined for landfills, but can also recover energy from the waste burning process. This generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills.

3.7.2. THE MASS BURN PROCESS

At an MSW combustion facility, MSW is unloaded from collection trucks and placed in a trash storage bunker. An overhead crane sorts the waste and then lifts it into a combustion chamber to be burned. The heat released from burning converts water to steam, which is then sent to a turbine generator to produce electricity.

The remaining ash is collected and taken to a landfill where a high-efficiency baghouse filtering system captures particulates. As the gas stream travels through these filters, more than 99 percent of particulate matter is removed. Captured fly ash particles fall into hoppers (funnel-shaped receptacles) and are transported by an enclosed conveyor system to the ash discharger. They are then wetted to prevent dust and mixed with the bottom ash from the grate. The facility transports the ash residue to an enclosed building where it is loaded into covered, leak-proof trucks and taken to a landfill designed to protect against groundwater contamination. Ash residue from the furnace can be processed for removal of recyclable scrap metals.

3.7.3. COMBUSTION TECHNOLOGIES

Common technologies for the combustion of MSW include

- Mass burn facilities,
- Modular systems and
- Refuse derived fuel systems.

3.7.3.1. MASS BURN FACILITIES

Mass burn facilities are the most common type of combustion facility in the United States. The waste used to fuel the mass burn facility may or may not be sorted before it enters the combustion chamber. Many advanced municipalities separate the waste on the front end to save recyclable products.

Mass burn units burn MSW in a single combustion chamber under conditions of excess air. In combustion systems, excess air promotes mixing and turbulence to ensure that air can reach all parts of the waste. This is necessary because of the inconsistent nature of solid waste. Most mass-burn facilities burn MSW on a sloping, moving grate that vibrates or otherwise moves to agitate the waste and mix it with air.

3.7.3.2. MODULAR SYSTEMS

Modular Systems burn unprocessed, mixed MSW. They differ from mass burn facilities in that they are much smaller and are portable. They can be moved from site to site.

3.7.3.3. REFUSE DERIVED FUEL SYSTEMS

Refuse derived fuel systems use mechanical methods to shred incoming MSW, separate out non-combustible materials, and produce a combustible mixture that is suitable as a fuel in a dedicated furnace or as a supplemental fuel in a conventional boiler system.

3.8. SUSTAINABLE MATERIALS MANAGEMENT

The hierarchy places emphasis on reducing, reusing, and recycling as key to sustainable materials management.

Fig.3.7. Non-Hazardous Materials and Waste Management Hierarchy

- Source Reduction and Reuse
- Recycling and Composting
- Energy Recovery
- Treatment and Disposal

3.8.1. SOURCE REDUCTION AND REUSE

Source reduction, also known as waste prevention, means reducing waste at the source, and is the most environmentally preferred strategy. It can take many different forms, including reusing or donating items, buying in bulk, reducing packaging, redesigning products, and reducing toxicity. Source reduction also is important in manufacturing. Lightweighting of packaging, reuse, and remanufacturing are all becoming more popular business trends. Purchasing products that incorporate these features supports source reduction.

- Source reduction can:
- Save natural resources,
- Conserve energy,
- Reduce pollution,
- Reduce the toxicity of our waste, and
- Save money for consumers and businesses alike.

3.8.2. RECYCLING AND COMPOSTING

Recycling is a series of activities that includes collecting used, reused, or unused items that would otherwise be considered waste; sorting and processing the recyclable products into raw materials; and remanufacturing the recycled raw materials into new products. Consumers provide the last link in recycling by purchasing products made from recycled content. Recycling also can include composting of food scraps, yard trimmings, and other organic materials.

Benefits of recycling include:

- Preventing the emission of many greenhouse gases and water pollutants;
- Saving energy;
- Supplying valuable raw materials to industry;
- Creating jobs;
- Stimulating the development of greener technologies;
- Conserving resources for our children's future; and
- Reducing the need for new landfills and combustors.

3.8.3. ENERGY RECOVERY

Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy (WTE). Converting non-recyclable waste materials into electricity and heat generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills. After energy is recovered, approximately ten percent of the volume remains as ash, which is generally sent to a landfill.

3.8.4.TREATMENT AND DISPOSAL

Prior to disposal, treatment can help reduce the volume and toxicity of waste. Treatments can be physical (e.g., shredding), chemical (e.g., incineration), and biological (e.g., anaerobic digestor). Landfills are the most common form of waste disposal and are an important component of an integrated waste management system. Modern landfills are well-engineered facilities located, designed, operated, and monitored to ensure compliance with state and federal regulations. Landfills that accept municipal solid waste are primarily regulated by state, tribal, and local governments. EPA, however, established national standards that these landfills must meet in order to stay open. The federal landfill regulations eliminated the open dumps (disposal facilities that do not meet federal and state criteria) of the past. Today's landfills must meet stringent design, operation, and closure requirements. Methane gas, a byproduct of decomposing waste, can be collected and used as fuel to generate electricity. After a landfill is capped, the land may be used for recreation sites such as parks, golf courses, and ski slopes.

3.9. DIGESTION

Digestion techniques are the most unique feature of the various composting processes and may vary from the backyard composting process to the highly controlled mechanical digester. Composting systems fall into the following two categories:

(i) windrow composting in open windrows;

(ii) mechanical composting in enclosed digestion chambers.

CURING

Organic materials, remaining after the first (rapid) phase of composting, decompose slowly, despite ideal environmental conditions. The second phase, which is usually carried out in windrows, typically takes from a few weeks to six months, depending on the outdoor temperatures, intensity of management and market specifications for maturity. With some system configurations, a screening step may precede the curing operation. During curing, the compost becomes biologically stable, with microbial activity occurring at a slower rate than that during actual composting. Curing piles may be either force-aerated or passive . Compost and Biogas aerated with occasional turning. As the pile cures, the microorganisms generate less heat and the pile begins to cool. Note that the cooling of piles does not always mean that the curing is complete. Cooling is merely a sign of reduced microbial activity, which can result from lack of moisture, inadequate oxygen within the pile, nutrient imbalance or the completion of the composting process. Curing may take from a few days to several months to complete. The cured compost is then marketed.

SCREENING OR FINISHING

Compost is screened or finished to meet the market specifications. Sometimes, this processing is done before the compost is cured. One or two screening steps and additional grindings are used to prepare the compost for markets. During the composting operation, the compostable fraction separated from the noncompostable fraction, through screens, undergoes a significant size reduction. The non-compostable fraction retained on the coarse screen is sent to the landfill, while the compostable materials retained on finer screens may be returned to the beginning of the composting process to allow further composting. The screened compost may contain inert particles such as glass or plastic that may have passed through the screen. The amount of such inert materials depends on feedstock processing before composting and the composting technology used. To successfully remove the foreign matter and recover the maximum compost by screening, the moisture content should be below 50%. Drying should be allowed only after the compost has sufficiently cured. If screening takes place before curing is complete, moisture addition may be necessary to cure the compost. The screen size used is determined by market specifications of particle size.

STORAGE OR DISPOSAL

In the final analysis, regardless of the efficiency of the composting process, the success or failure of the operation depends upon the method of disposal. Even when a good market for compost exists, provision must be still made for storage. Storage is necessary because the use of composting is seasonal, with greatest demand during spring and winter. Therefore, a composting plant must have a 6- month storage area. For a 300 tonne per day plant, this will require about 6 hectares of storage area. Many composting operations combine their curing period with the storage period. The price at which compost can be sold depends on the benefit to be obtained from its use and the customers who are willing to make use of such benefits. Compost may be sold in bulk, finished or unfinished, as well as fortified with chemical fertilisers.

BIOGASIFICATION

Biogas is a mixture of gases composed of methane (CH_4) 40 – 70 vol.%, carbon dioxide (CO_2) 30 – 60 vol.%, other gases 1 – 5 vol.% including, hydrogen (H2) 0 – 1 vol.% and hydrogen sulphide (H2S) 0 – 3 vol.%. It originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biogeochemical carbon cycle.

Methanogens (methane producing bacteria) are the last link in a chain of microorganisms, which degrade organic material and return the decomposition products to the environment. In this process, biogas is generated, which is a source of renewable energy. As is the case with any pure gas, the characteristic properties of biogas are pressure and temperature dependency. It is also affected by moisture content.

Well-functioning biogas systems can yield a whole range of benefits for their users, the society and the environment in general. Some of the important benefits are as follows: production of energy (heat, light, electricity); transformation of organic waste into high quality fertiliser; improvement of hygienic conditions through reduction of pathogens, worm eggs and flies; reduction of workload in firewood collection and cooking; environmental advantages through protection of soil, water, air and woody vegetation; micro-economical benefits through energy and fertiliser substitution, additional income generation and increasing yields of animal husbandry and agriculture; macro-economic benefits through decentralised energy generation, import substitution and environmental protection.

What we can deduce from the list above, is that biogas technology can substantially contribute to energy conservation and development, if the economic viability and social acceptance of biogas technology are favourable. Biogasification or Biomethanation is the process of conversion of organic matter in the waste (liquid or solid) to BioMethane (sometimes referred to as "Biogas" with high energy density) and manure (bio compost) by microbial action in the absence of air, known as "anaerobic processing or digestion."

Anaerobic processing Anaerobic processing of organic material is a two-stage process, where large organic polymers are fermented into short-chain volatile fatty acids. These acids are then converted into methane and carbon dioxide. The metabolic stages in biogasification are illustrated in figure below.

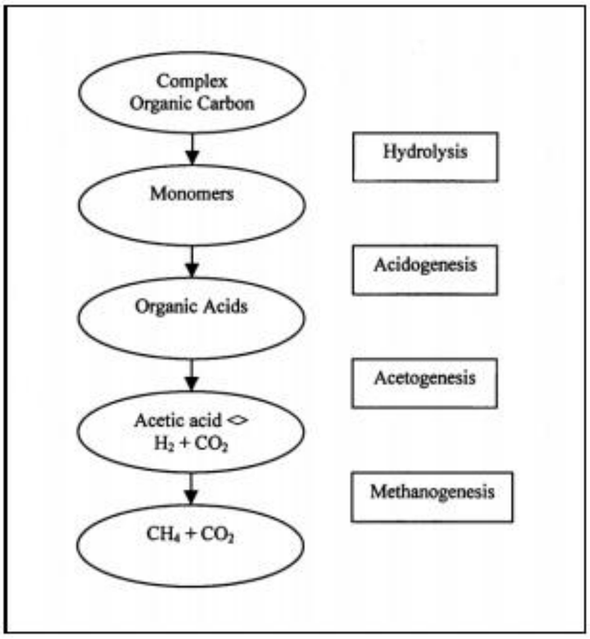


Fig.1. Metabolic stages in biogasification process

Note that both the organic polymers fermentation process and acid conversion occur at the same time, in a single-phase system. And, the separation of the acid-producing (acidogenic) bacteria from the methane producing (methanogenic) bacteria results in a two-phase system.

The main feature of anaerobic treatment is the concurrent waste stabilisation and production of methane gas, which is an energy source. The retention time for solid material in an anaerobic process can range from a few days to several weeks, depending upon the chemical characteristics of solid material and the design of the biogasification system (e.g., single stage, two stage, multi- stage, wet or dry, temperature and pH control). In the absence of oxygen, anaerobic bacteria decompose organic matter as follows:

Organic matter + anaerobic bacteria $CH_4 + CO_2 + H_2S + NH_4$ + other end products + energy

The conditions for biogasification need to be anaerobic, for which a totally enclosed process vessel is required. Although this necessitates a higher level of technology than compared to composting, it allows a greater control over the process itself and the emission of noxious odours. Greater process control, especially of temperature, allows a reduction in treatment time, when compared to composting. Since a biogas plant is usually vertical, it also requires less area than a composting plant. Biogasification is particularly suitable for wet substrates, such as sludges or food waste, which present difficulties in composting, as the lack of structural material restricts air circulation.

The anaerobic process is used sometimes to digest sewage sludge, and this has been extended to fractions of household solid waste. In contrast to aerobic processes (i.e., composting), biogasification is mildly exothermic. Thus, the heat needs to be supplied to maintain the process temperature, especially for thermophilic processes.

The advantage of high temperature is that the reaction will occur at a faster rate, and so a shorter residence time is required in the reactor vessel. According to the solid content of the material digested and the temperature at which the process operates, the various biogasification processes can be classified as under: Dry anaerobic digestion: In dry anaerobic digestion, semi-solid wastes are digested to produce biogas in a single stage, either as a batch process or a continuous process.

It takes place at a total solid concentration of over 25%, and below this level of solid, the process is described as wet digestion. With regard to temperature, the processes are either described as mesophilic (operating between 30 and 40 C) or thermophilic (operating between 50 and 65 C), and anaerobic microorganisms have optimum growth rates within these temperature ranges.

The dry fermentation process means that only little process water has to be added or heated, which favours thermophilic operation. No mixing equipment is necessary, and crust formation is not possible due to the relatively solid nature of the digester contents. This anaerobic process usually takes between 12 and 18 days, followed by several days in post-digestion for residue stabilisation and maturation.

Wet anaerobic digestion: In its simplest form, this process consists of a single stage in a completely mixed mesophilic digester, operating at a total solid content of around 3 – 8%. To produce this level of dilution, a considerable amount of water has to be added and heated, and then removed after the digestion process. This method is routinely used to digest sewage sludge, and animal and household wastes.

The single-stage wet process can suffer from several practical problems such as the formation of a hard scum layer in the digester and difficulty in keeping the content completely mixed. The major problem with the single-stage process is that the different reactions in the process cannot be separately optimised. The acidogenic microorganisms grow fast and lower the pH of the reaction mixture, whereas the methanogens, which grow slowly, have a pH optimum around 7.0. The development of the two-stage digestion process solves this problem as hydrolysis and acidification occur in the first reactor vessel, kept at a pH of around 6.0 and methanogenesis occurs in the second vessel, operated at a pH of 7.5 – 8.2.

Maturing or refining The residues of both wet and dry biogasification processes require extensive maturing under aerobic conditions. However, we can considerably reduce this period through effective aeration. The maturation processes facilitate the release of entrapped methane, elimination of phytotoxins (i.e., substances that are harmful for plant growth, such as volatile organic acids) and reduce the moisture content to an acceptable level.

These residues contain a high level of water – even the dry process residue contains around 65% water. 314 Filtering or pressing can reduce excess water, and further drying can be achieved using waste heat from the gas engine, if the biogas is burnt onsite to produce electricity. The digested residue, initially anaerobic, will also contain many volatile organic acids and reduced organic materials.

These need to be matured aerobically to oxidise and stabilise the compounds, in the process similar to the maturation of aerobic compost, prior to sale as compost or disposal as residue. Odour production is measured as the total amount of volatile organics produced per tonne of bio-waste during composting and the final aerobic maturation after anaerobic digestion. Factors affecting biogasification As with composting, a number of environmental factors influence biogasification, some of which are listed below:

Temperature: A temperature range of about 25 – 40 C (mesophilic) is generally optimal. It can be achieved without additional heating, thus being very economical. In some cases, additional energy input is provided to increase temperature to 50 – 60 C (thermophilic range) for greater gas production. Often digesters are constructed below ground to conserve heat. pH and alkalinity: pH close to neutral, i.e., 7, is optimum. At lower pH values (below 5.5), some bacteria carrying out the process are inhibited. Excess loading and presence of toxic materials will lower pH levels to below 6.5 and can cause difficulties. When pH levels are too low, stopping the loading of the digester and/or use of time is recommended. The presence of alkalinity between 2500 and 5000 mg/L will provide good buffering against excessive pH changes.

Nutrient concentration: An ideal C: N ratio of 25:1 is to be maintained in any digester. It is an important parameter, as anaerobic bacteria need nitrogen compound to grow and multiply. Too much nitrogen, however, can inhibit methanogenic activity. If the C: N ratio is high, then gas production can be enhanced by adding nitrogen, and if the C: N ratio is low, it can be increased by adding carbon, i.e., adding chicken manure, etc., which reduces

Effect of toxins: The main cause of biogas plants receiving flak is the presence of toxic substance. Chlorinated hydrocarbons, such as chloroforms and other organic solvents, are particularly toxic to biogas digestion. If the digester has been badly poisoned, it may be difficult to remove the toxins 316 without removing most of the bacteria. In that case, the digester must be emptied, cleaned with plenty of water and refilled with fresh slurry. 7.2.2 Types of digesters

In the anaerobic digestion process, the organic matter in mixtures of sludges is converted biologically, under anaerobic conditions, to a variety of products including methane (CH4) and carbon dioxide (CO2). The process is carried out in an airtight reactor, where wastes in the form of sludges are introduced continuously or intermittently and retained in the reactor for varying periods. The microbiology of anaerobic digestion and the optimum environmental considerations for the microorganisms can be achieved by selecting the proper type of digester. Against this background, we explain below the operation and physical facilities for anaerobic digestion in single-stage digester (standard rate and high rate) and two-stage digester , which generally operate in a mesophilic range, i.e., between 30 and 38 C

3.9.2. STANDARD RATE SINGLE-STAGE DIGESTER:

In a single stage digester, the untreated waste sludge is directly added to the zone, where the sludge is actively digested and the gas is being released. The sludge is heated by means of an external heat exchanger. As the gas rises to the surface, it lifts sludge particles and other minerals such as grease oil and fats, ultimately giving rise to the formation of scum layer. As a result of digestion, the sludges stratify by forming a supernatant layer above the digesting sludge and become more mineralised, i.e., the percentage of fixed solid increases. Due to stratification and lack of mixing, the standard rate process is used principally for small installations. Detention time for standard rate processes vary from 30 to 60 days.

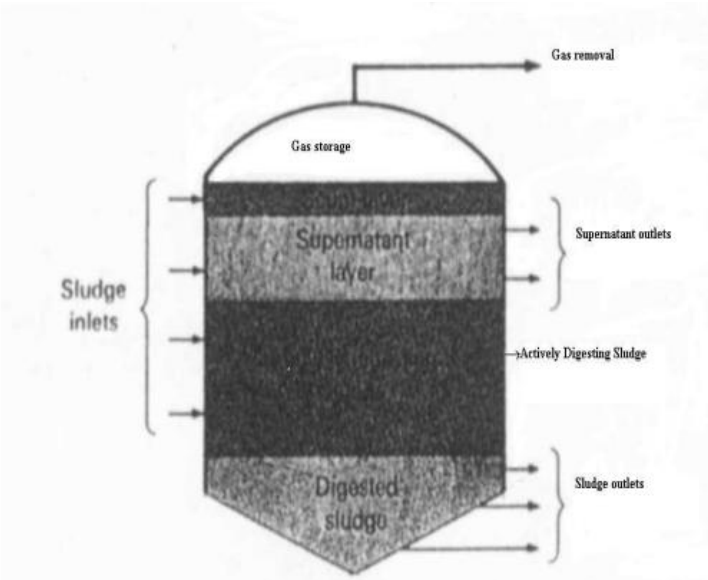


Fig.2. Standard Rate Single-Stage Digester

3.9.3. HIGH RATE SINGLE-STAGE DIGESTER:

The single-stage high rate digester differs from the single-stage standard rate digester in that the solid-loading rate is much greater. The sludge is mixed intimately by gas recirculation, mechanical mixing, pumping or draft tube mixer and heated to achieve optimum digestion rates. With the exception of higher loading rates and improved mixing, there are only a few differences between standard rate and high rate digester. The mixing equipment should have a greater capacity and should reach the bottom of the tank, which should be deeper to aid the mixing process.

Digestion tank may have fixed roof or floating covers along with gasholder facility, which provide extra gas storage capacity. The required detention time for a high rate digestion is typically 15 days or less.

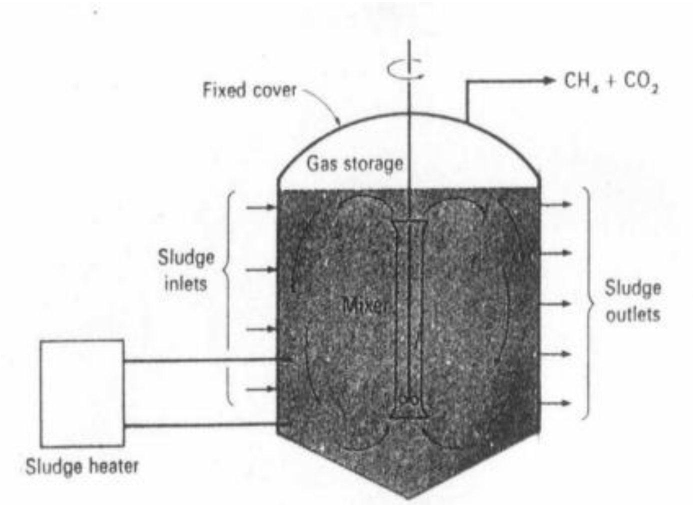


Fig.3.High rate single-stage digester

3.9.3. TWO-STAGE DIGESTER:

The combination of the two digesters, mentioned above, is known as a two-stage digester. The first stage digester is a high rate complete mix digester used for digestion, mixing and heating of waste sludge, while the primary function of a second stage is to separate the digested solid from the supernatant liquor, and in the process, additional digestion and gas production may occur. The tanks are made identical, in which case either one may be the primary digester. They may have fixed roofs or floating covers along with gasholder facility.

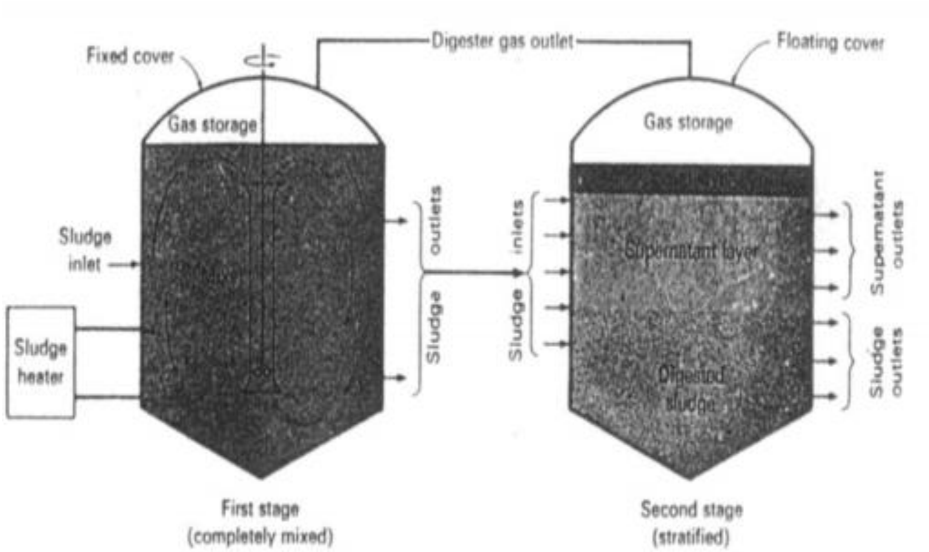


Fig.4.Two -stage digester

3.10. INDUSTRIAL WASTE, AGRO RESIDUES AND ANAEROBIC DIGESTION.

3.10.1 BIOGAS FROM AGRICULTURAL WASTES THROUGH ANAEROBIC DIGESTION.

The main problem with anaerobic digestion of agricultural wastes is that most of the agricultural residues are lignocellulosic with low nitrogen content. To obtain biogas from agricultural wastes, pre-treatment methods like size reduction, electron irradiation, heat treatment, enzymatic action etc are necessary. For optimizing the C/N ratio of agricultural residues, co-digestion with sewage sludge, animal manure or poultry litter is recommended.

3.10.2. TYPES OF AGRICULTURAL WASTES

Several organic wastes from plants and animals have been exploited for biogas production as reported in the literature. Plant materials include agricultural crops such as sugar cane, cassava, corn etc, agricultural residues like rice straw, cassava rhizome, corn cobs etc, wood and wood residues (saw dust, pulp wastes, and paper mill waste)

Fig.3.8. Agricultural waste

Others include molasses and bagasse from sugar refineries, waste streams such as rice husk from rice mills and residues from palm oil extraction and municipal solid wastes, etc. However, plant materials such as crop residues are more difficult to digest than animal wastes (manures) because of difficulty in achieving hydrolysis of cellulosic and lignocellulosic constituents.

3.10.3. CODIGESTION OF CROP WASTES

Crop residues can be digested either alone or in co-digestion with other materials, employing either wet or dry processes. In the agricultural sector one possible solution to processing crop biomass is co-digested together with animal manures, the largest agricultural waste stream.

In addition to the production of renewable energy, controlled anaerobic digestion of animal manures reduces emissions of greenhouse gases, nitrogen and odour from manure management, and intensifies the recycling of nutrients within agriculture.

In co-digestion of plant material and manures, manures provide buffering capacity and a wide range of nutrients, while the addition of plant material with high carbon content balances the carbon to nitrogen (C/N) ratio of the feedstock, thereby decreasing the risk of ammonia inhibition.

The gas production per digester volume can be increased by operating the digesters at a higher solids concentration. Batch high solids reactors, characterized by lower investment costs than those of continuously fed processes, but with comparable operational costs, are currently applied in the agricultural sector to a limited extent.

Codigestion offers good opportunity to farmers to treat their own waste together with other organic substrates. As a result, farmers can treat their own residues properly and also generate additional revenues by treating and managing organic waste from other sources and by selling and/or using the products viz heat, electrical power and stabilised biofertiliser.

3.11. BIOMASS STORAGE METHODS

Sufficient storage for biomass is necessary to accommodate seasonality of production and ensure regular supply to the biomass utilization plant. The type of storage will depend on the properties of the biomass, especially moisture content. For high moisture biomass intended to be used wet, such as in fermentation and anaerobic digestion systems, wet storage systems can be used, with storage times closely controlled to avoid excessive degradation of feedstock. Storage systems typically used with dry agricultural residues should be protected against spontaneous combustion and excess decomposition, and the maximum storage moisture depends on the type of storage employed.

Moisture limits must be observed to avoid spontaneous combustion and the emission of regulated compounds. Cost of storage is important to the overall feasibility of the biomass enterprise. In some cases, the storage can be on the same site as the source of the feedstock. In others, necessary volumes can only be achieved by combining the feedstock from a number of relatively close sources. Typically, delivery within about 50 miles is economic, but longer range transport is sometimes acceptable, especially when disposal fees can be reduced.

Agricultural residues such as wheat straw, rice husk, rice straw and corn stover are usually spread or windrowed behind the grain harvesters for later baling. Typically these residues are left in the field to air dry to moisture levels below about 14% preferred for bales in stacks or large piles of loose material. After collection, biomass may be stored in the open or protected from the elements by tarps or various structures. Pelletizing may be employed to increase bulk density and reduce storage and transport volume and cost.

3.11.1. BIOMASS STORAGE OPTIONS

Feedstock is hauled directly to the plant with no storage at the production site.Feedstock is stored at the production site and then transported to the plant as needed.Feedstock is stored at a collective storage facility and then transported to the plant from the intermediate storage location.

3.11.2. BIOMASS STORAGE SYSTEMS

The type of biomass storage system used at the production site, intermediate site, or plant can greatly affect the cost and the quality of the fuel. The most expensive storage systems, no doubt, are the most efficient in terms of maintaining the high fuel quality. Typical storage systems, ranked from highest cost to lowest cost, include:

- Enclosed structure with crushed rock floor
- Open structure with crushed rock floor
- Reusable tarp on crushed rock
- Outside unprotected on crushed rock
- Outside unprotected on ground
- Subterranean

The storage of biomass is often necessary due to its seasonal production versus the need to produce energy all year round. Therefore to provide a constant and regular supply of fuel for the plant requires either storage or multi-feedstock's to be used, both of which tend to add cost to the system.

Reducing the cost of handling and stable storage of biomass feedstock's are both critical to developing a sustainable infrastructure capable of supplying large quantities of biomass to biomass processing plants. Storage and handling of biomass fuels is expensive and increases with capacity. The most suitable type of fuel store for solid biomass fuel depends on space available and the physical characteristics of the fuel.

UNIT – IV
THERMO-CHEMICAL CONVERSION

4.1. INTRODUCTION TO THERMOCHEMICAL CONVERSION PROCESSES

Thermo chemical biomass conversion includes a number of possible roots to produce from the initial biorenewable feedstock useful fuels and chemicals. Biorenewable feedstocks can be used as a solid fuel, or converted into liquid or gaseous forms for the production of electric power, heat, chemicals, or gaseous and liquid fuels. Thermo chemical conversion processes include three subcategories: pyrolysis, gasification, and liquefaction.

Figure 4.1 shows biomass thermal conversion processes. A variety of biomass resources can be used to convert to liquid, solid, and gaseous fuels with the help of some physical, thermo chemical, biochemical, and biological conversion processes. Main biomass conversion processes are direct liquefaction, indirect liquefaction, physical extraction, thermo chemical conversion, biochemical conversion, and electrochemical conversion.

Figure 4.2 shows the types and classification of biomass conversion processes. The conversion of biomass materials has the precise objective to transform a carbonaceous solid material, which is originally difficult to handle, bulky and of low energy concentration, into fuels having physico-chemical characteristics that permit economic storage and transferability through pumping systems.

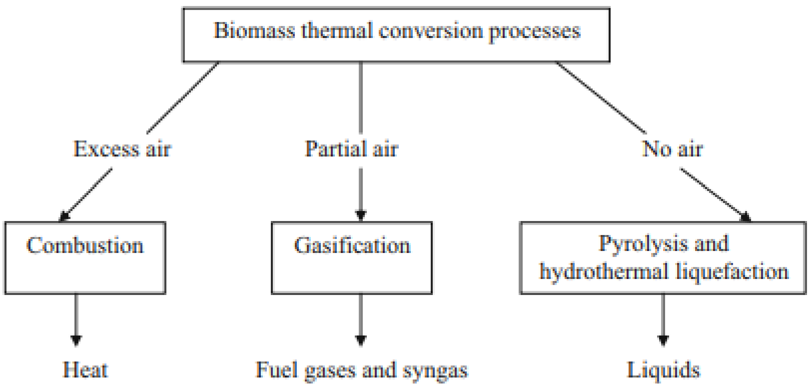


Fig.4.1.Biomass thermal conversion processes

Gasification of biomass for use in internal combustion engines for power generation provides an important alternate renewable energy resource. Gasification is partial combustion of biomass to produce gas and char at the first stage and subsequent reduction of the product gases, chiefly CO_2 and H_2O, by the charcoal into CO and H_2.

The process also generates some methane and other higher hydrocarbons depending on the design and operating conditions of the reactor. Pyrolysis is the fundamental chemical reaction process that is the precursor of both gasification and combustion of solid fuels, and is simply defined as the chemical changes occurring when heat is applied to a material in the absence of oxygen.

Flash pyrolysis of biomass is the thermochemical process that converts small dried biomass particles into a liquid fuel (biocrude) with a yield of almost 75%, and char and non-condensable gases by heating the biomass to 775 K in the absence of oxygen.

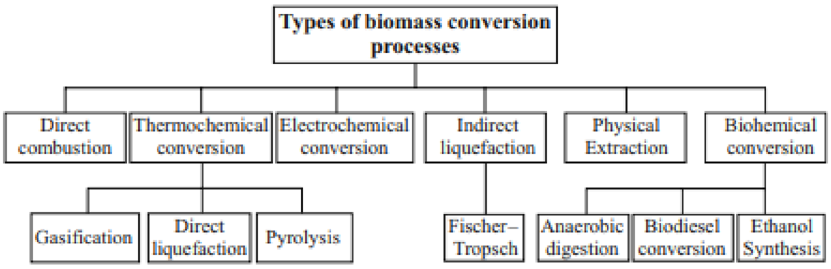


Fig.4.2. Classification of biomass conversion processes

There are several types of thermochemical processes that will be discussed in this lesson, they include:

- Gasification
- Combustion
- Pyrolysis
- Liquefaction
- Hydrothermal Upgrading Process (HTU)
- the Fischer-Tropsch Process

GASIFICATION

Gasification is a special combustion process, occurring between 1100 and 1800 degrees Fahrenheit. At this temperature, biomass solids are turned directly into biogas. More specifically, complex hydrocarbons of wood are broken down to hydrogen, carbon monoxide, and carbon dioxide. Products of gasification cannot easily be stored. As a result, the system is often integrated with other conversion processes in an effort to utilize the outputs. In addition to biogas, the gasification process produces ash, char, tars, methane, and other hydrocarbons. Studies have shown that gasification systems are as much as 20 percent more efficient than direct combustion systems.

COMBUSTION

Almost anything organic will burn, however biomass having low moisture content is best suited for combustion. Most of today's biomass-powered plants are direct-fired systems, similar to fossil fuel-powered plants. The feedstock is burned in a boiler to produce high-pressure steam that is then pumped into a turbine, over a series of blades that rotate, powering an electric generator. The most economic near-term solution is co-firing boilers with both fossil and biomass feedstocks. Much of the existing conventional power plant infrastructure can be used with little to no major modifications.

PYROLYSIS

- Is the burning of biomass in the absence of oxygen
- Produces energy, liquids, gases, and char
- Small particles, less than a quarter inch in size, are delivered to a high-heat reactor where essentially no combustion occurs
- Generates pyrolytic bio-oils, a combustible mixture of oxygenated hydrocarbons, and char.

LIQUEFACTION

Thermochemical liquefaction is a process similar to what occurs in nature. Only, it occurs in minutes rather than millions of years. Hydrocarbon oils and products to produce bio-fuels are the result of subjecting intense heat and pressure to organic material. Direct liquefaction, or thermal depolymerization, has been successful in producing liquid oil, while the newer indirect liquefaction has been successful in producing syngas, ethanol, and methanol.

HYDROTHERMAL UPGRADING PROCESS (HTU)

- Converts a large variety of biomass feedstocks into a liquid fuel that can be upgraded to a high quality diesel fuel.
- Creates the feedstock in water to 570-660 degrees fahrenheit at 100-180 bars pressure for 5 to 20 minutes.
- Creates biocrude that readily separates from water and can be separated into light and heavy crude through extraction.

The resulting light crude is mineral-free and can be used for high-efficiency electricity production. For large-scale applications, the light crude is upgraded to produce premium gas oil that has excellent ignition properties and can be blended directly with conventional diesel. There are no adaptations needed in engines to use this fuel. Heavy crude is formed as a coal-like solid that can be co-combusted for power production.

FISCHER-TROPSCH PROCESS

- Is an established technology, first used in Germany in the 1920s, that converts carbon monoxide and hydrogen into oils or fuels that can be substituted for petroleum products
- Uses a catalyst based on iron or cobalt and is fueled by the partial oxidation of coal or wood-based fuels such as ethanol, methanol, or syngas, typically coming from an adjacent gasifier
- Shows a promising route to producing economically efficient, renewable transportation fuels .
- By carefully controlling the temperature and oxygen content, resulting products can range from pure syngas to “green diesel”.
- Increases the hydrogen byproduct that can be used for the production of ammonia or for fuel cells.

4.4. LAND FILL GAS GENERATION AND UTILIZATION

Gases found in landfills include ammonia (NH3), carbon dioxide (CO2), carbon monoxide (CO), hydrogen (H2), hydrogen sulfide (H2S), methane (CH4), nitrogen (N2), and oxygen (O2). methane and carbon dioxide are the principal gases produced from the anaerobic decomposition of the biodegradable organic waste components in MSW. In addition, a number of trace gases will also be found in landfill gas. The type and concentration of the trace gases will depend to a large extent on the past history of the landfill. Issues related to the generation, control of migration, and utilization of landfill gas are considered in the following discussion.

Generation of the Principal Landfill Gases The generation of principal landfill gases is thought to occur in five more or less sequential phases, as illustrated in Figure 4.3. Each of these phases is described briefly here.

PHASE I: Initial adjustment. Phase I is the initial adjustment phase, in which the organic biodegradable components in municipal solid waste begin to undergo bacterial decomposition soon after they are placed in a landfill. In phase I, biological decomposition occurs under aerobic conditions because a certain amount of air is trapped within the landfill.

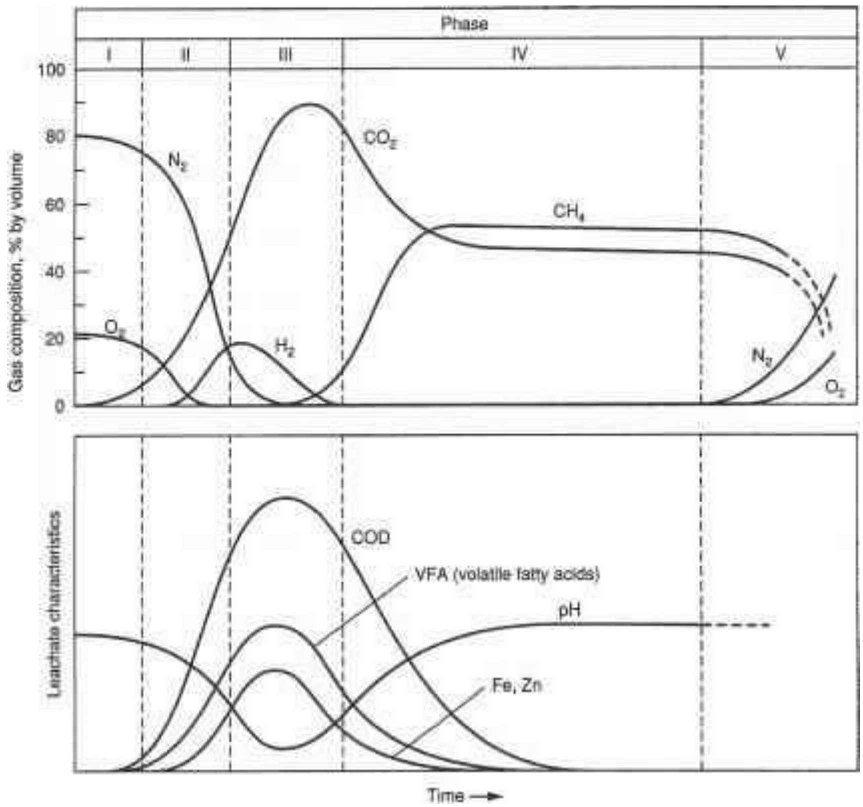


Figure 4.3. Generalized phases in generation of landfill gases

(I—initial adjustment, II—transition phase; III—acid phase; IV—methane fermentation; V—maturation phase)

PHASE II: Transition phase. In phase II, identified as the transition phase, oxygen is depleted and anaerobic conditions begin to develop.

PHASE III: Acid phase. In phase III, the bacterial activity initiated in phase II is accelerated with the production of significant amounts of organic acids and lesser amounts of hydrogen gas. The first step in the three-step process involves the enzyme-mediated transformation (hydrolysis) of higher molecular mass compounds (e.g., lipids, organic polymers, and proteins) into compounds suitable for use by microorganisms as a source of energy and cell carbon. The second step in the process (acidogenesis) involves the bacterial conversion of the compounds resulting from the first step into lower molecular weight intermediate compounds, as typified by acetic acid (CH3COOH) and small concentrations of fulvic and other more complex organic acids. Carbon dioxide (CO2) is the principal gas generated during phase III.

PHASE IV: Methane fermentation phase. In phase IV, a second group of microorganisms that convert the acetic acid and hydrogen gas formed by the acid formers in the acid phase to methane (CH4) and CO2 becomes more predominant. Because the acids and the hydrogen gas produced by the acid formers have been converted to CH4 and CO2 in phase IV, the pH within the landfill will rise to more neutral values in the range of 6.8 to 8.

PHASE V: Maturation phase. Phase V occurs after the readily available biodegradable organic material has been converted to CH4 and CO2 in phase IV. As moisture continues to migrate through the waste, portions of the biodegradable material that were previously unavailable will be converted.

Control of Landfill Gas Migration When methane is present in the air in concentrations between 5 and 15 percent, it is explosive. Because only limited amounts of oxygen are present in a landfill when methane concentrations reach this critical level, there is little danger that the landfill will explode. However, methane mixtures in the explosive range can be formed if landfill gas migrates off site and is mixed with air.

The lateral migration of methane and other gases can be controlled by impermeable cutoff walls or barriers or by the provision of a ventilation system such as gravel-filled trenches around the perimeter of the landfill. Gravel-packed perforated pipe wells or collectors may also be used to collect and diffuse the gas to the atmosphere, if not recovered. To be effective, the system must be carefully designed, constructed, and maintained.

Cutoff walls or barriers should extend from the ground surface down to a gas-impermeable layer such as clay, rock, or groundwater. Clay soils must be water saturated to be effective. Perforated pipes have been shown to be of limited effectiveness and are not recommended for the reduction of gas pressure when used alone. Gravel-filled trenches may permit migration of gases across the trench, especially when covered by snow or ice; vertical perforated pipes reduce somewhat the effect of snow or ice. Gravel-filled trenches require removal of leachate or water from the trench bottom and are susceptible to plugging by biomass buildup.

Gravel-filled trenches in combination with an impermeable barrier provide good protection against gas migration when keyed to a gas-impermeable strata below the landfill. Induced exhaust wells or trenches with perforated pipes and pump or blower are reported to be very effective. Where enclosed structures are constructed over or in close proximity to a landfill, it is necessary to have these places continuously monitored. A combustible gas detection system to provide early warning (light and alarm) can alert personnel. The monitors comprising the detection system can also activate ventilation fans at present low methane levels. Soil and cement bentonite trenches or cutoff walls have also been used to prevent lateral gas migration. Methane Recovery and Utilization Methane is produced in a landfill when anaerobic methane-producing bacteria are active.

4.5. BRIQUETTE DEFINITION

According to the international ISO 17225 STANDARD, solid biofuels, fuel specifications and classes, a briquette is a "densified biofuel made with or without additives, having a cubic, prismatic or cylindrical shape, with a 25 mm diameter, produced from woody biomass compression or crushed herb."

4.6. COMPOSITION MATERIAL BRIQUETTES are made of combustible material obtained from agricultural, forestry waste, or coal dust (Table I). Briquettes are produced by the densification of these raw materials. The densification process is mainly composed of two parts: - Compaction (reduction of raw material volume) - Sealing (ensuring that the product remains in a stable, compacted state) Current regulations (for example ISO 17225), allow the use of specific additives to enhance and maintain briquettes' compaction. These additives contain starch (rice flour, cassava flour, mashed sweet potato), or molasses and Arabic gum to give greater consistency to the resulting product.

Origin	Raw materials that can be used
Agricultural wastes	Cassava stalk, coconut frond, cotton stalks, corn stalks, straw, millet, oat straw, frond palm oil, rice straw, rye straw, sorghum straw, soybean straw, sugar reed leaves, wheat straw
Industrial processing residues from agriculture	Cocoa beans, coconut shells, coffee husks, cotton seed hulls, peanut shells, cobs and wrap corns, oil palm stalks, waste from olive pressing, rice ball, sugar cane bagasse
Forestry development	Leaves, branches and twisted trunks.
Plantation and forestry residues	Leaves, branches, stumps, roots, etc.
Wood industry wastes	Sawdust
Bioenergy crops	Acacia spp, Cunninghamia lanceolata, Eucalyptus spp, Pinus spp., Populus spp., Platanus spp., Robinia pseudoacacia y Salix spp.

Table-I

The competitiveness of briquettes in the biofuel market is linked to several parameters, namely, the development of renewable energy in the global market and specifically of biomass compared to fossil fuels. Their advantages are described below:

4.7. ENVIRONMENTAL BENEFITS:

- Using renewable energies can contribute to sustainable forest management.
- Neutral CO2 emissions balance
- Low sulfur emissions (which usually causes acid rain).
- If it has a forest origin under a proper management scheme, it contributes to forest regeneration and prevention of forest fires.
- If it is sourced from agricultural or industrial waste, it enables a residue with a second life.
- Ash from briquettes burning can be used as fertilizer.

4.8 SOCIAL BENEFITS

- Creates jobs throughout the supply chain, especially in rural areas, thus preventing rural migration to urban areas.
- If it has a forest origin, it will promote its sustainable management, improving the state of forests: - With direct incidence to the decreased risk of fire and the corresponding damages to human health and properties. - With indirect incidence in perception of the forest as a source of jobs and wealth creation (e.g. tourism).
- It promotes confidence in renewable energy at local and rural levels.

4.9. ECONOMIC BENEFITS

- Positive life cycle economic balance, cost lower than fossil fuels.
- Decreases the dependence on energy imports, thus favouring greater energy price stability by not depending on international markets volatility.
- Local added value, fostering local or regional businesses along the supply chain (forest operators, transportation and warehousing, briquette manufacturers, dealers, installers and maintenance services providers, etc.).
- Enables the valorisation of sub-products and even waste. b) The ability of briquettes' competitiveness compared to other solid bio fuels

4.10 ADVANTAGES

- High calorific fraction
- Moisture content, density and constant and homogeneous granulometry
- Lower ash content
- International marketing with standardized composition

4.10. DISADVANTAGES

• Potentially higher price conditioned by the manufacturing (compaction) process and the availability of other cheaper biofuels closer to the customer premises.

4.11. ENVIRONMENTAL BENEFITS

Thermo chemical conversion processes such as gasification, pyrolysis and incineration can remove materials from the solid waste stream and can also create:

i. Liquid fuels such as biodiesel, ethanol and oil
ii. Electricity, heat and steam from combustible gases such as methane
iii. Chemicals and consumer products from oils and syngas
iv. Activated carbon for the food processing industry.

UNIT – V
E-WASTE MANAGEMENT

5.1. INTRODUCTION TO E-WASTE

Advances in the field of science and technology brought about industrial revolution in the 18th Century which marked a new era in human civilization. In the 20th Century, the information and communication revolution has brought enormous changes in the way we organize our lives, our economies, industries and institutions. These spectacular developments in modern times have undoubtedly enhanced the quality of our lives. At the same time, these have led to manifold problems including the problem of massive amount of hazardous waste and other wastes generated from electric products. These hazardous and other wastes pose a great threat to the human health and environment. The issue of proper management of wastes, therefore, is critical to the protection of livelihood, health and environment. It constitutes a serious challenge to the modern societies and requires coordinated efforts to address it for achieving sustainable development.

According to the Basel Convention, wastes are substances or objects, which are disposed of or are intended to be disposed of, or are required to be disposed of by the provisions of national laws. Additionally, wastes are such items which people are required to discard, for example by law because of their hazardous properties. Our daily activities give rise to a large variety of different wastes arising from different sources. Thus, municipal waste is waste generated by households and consists of paper, organic waste, metals, etc. The wastes generated by production processes, households and commercial activities are hazardous waste. Biomedical waste is waste generated by hospitals and other health providers and consists of discarded drugs, waste sharps, microbiology and biotechnology waste, human anatomical waste, animal waste, etc.

Radioactive waste is any material that contains a concentration of radio nuclides greater than those deemed safe by national authorities, and for which, no use is foreseen. Other sources of waste include end-of-life vehicles, packaging waste, tyres, agricultural waste, etc.2 These waste substances are in the long run hazardous in nature as they are ignitable, corrosive, reactive, toxic, explosive, poisonous or infectious. Hence, they pose substantial or potential threat to public health and the environment.

5.2. WHAT IS E-WASTE?

Like hazardous waste, the problem of e-waste has become an immediate and long term concern as its unregulated accumulation and recycling can lead to major environmental problems endangering human health. The information technology has revolutionized the way we live, work and communicates bringing countless benefits and wealth to all its users. The creation of innovative and new technologies and the globalization of the economy have made a whole range of products available and affordable to the people changing their lifestyles significantly. New electronic products have become an integral part of our daily lives providing us with more comfort, security, easy and faster acquisition and exchange of information. But on the other hand, it has also led to unrestrained resource consumption and an alarming waste generation. Both developed countries and developing countries like India face the problem of e-waste management.

The rapid growth of technology, upgradation of technical innovations and a high rate of obsolescence in the electronics industry have led to one of the fastest growing waste streams in the world which consist of end of life electrical and electronic equipment products. It comprises a whole range of electrical and electronic items such as refrigerators, washing machines, computers and printers, televisions, mobiles, i-pods, etc., many of which contain toxic materials. Many of the trends in consumption and production processes are unsustainable and pose serious challenge to environment and human health. Optimal and efficient use of natural resources, minimization of waste, development of cleaner products and environmentally sustainable recycling and disposal of waste are some of the issues which need to be addressed by all concerned while ensuring the economic growth and enhancing the quality of life.

The countries of the European Union (EU) and other developed countries to an extent have addressed the issue of e-waste by taking policy initiatives and by adopting scientific methods of recycling and disposal of such waste. The EU defines this new waste stream as 'Waste Electrical and Electronic Equipment' (WEEE). As per its directive, the main features of the WEEE include definition of 'EEE', its classification into 10 categories and its extent as per voltage rating of 1000 volts for alternating current and 1500 volts for direct current. The EEE has been further classified into 'components', 'sub-assemblies' and 'consumables'.3 Since there is no definition of the WEEE in the environmental regulations in India, it is simply called 'e-waste'. E-waste or electronic waste, therefore, broadly describes loosely discarded, surplus, obsolete, broken, electrical or electronic devices

5.3. COMPOSITION OF E-WASTE

E-waste consists of all waste from electronic and electrical appliances which have reached their end-of- life period or are no longer fit for their original intended use and are destined for recovery, recycling or disposal. It includes computer and its accessories monitors, printers, keyboards, central processing units; typewriters, mobile phones and chargers, remotes, compact discs, headphones, batteries, LCD/Plasma TVs, air conditioners, refrigerators and other household appliances.5 The composition of e-waste is diverse and falls under 'hazardous' and 'non-hazardous' categories. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete, ceramics, rubber and other items. Iron and steel constitute about 50% of the waste, followed by plastics (21%), non-ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminium and precious metals like silver, gold, platinum, palladium and so on.6 The presence of elements like lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants beyond threshold quantities make e-waste hazardous in nature. It contains over 1000 different substances, many of which are toxic, and creates serious pollution upon disposal.7 Obsolete computers pose the most significant environmental and health hazard among the e-wastes. 1.2.2 E-waste generation in India All over the world, the quantity of electrical and electronic waste generated each year, especially computers and televisions, has assumed alarming proportions. In 2006, the International Association of Electronics Recyclers (IAER)8 projected that 3 billion electronic and electrical appliances would become WEEE or e-waste by 2010. That would tantamount to an average e-waste generation rate of 400 million units a year till 2010. Globally, about 20-50 MT (million tonnes) of e-wastes are disposed off each year, which accounts for 5% of all municipal solid waste.9 Although no definite official data exist on how much waste is generated in India or how much is disposed of, there are estimations based on independent studies conducted by the NGOs or government agencies. According to the Comptroller and Auditor-General's (CAG) report, over 7.2 MT of industrial hazardous waste, 4 lakh tonnes of electronic waste, 1.5 MT of plastic waste, 1.7 MT of medical waste, 48 MT of municipal waste are generated in the country annually.10 In 2005, the There are 10 States that contribute to 70 per cent of the total e-waste generated in the country, while 65 cities generate more than 60 per cent of the total e-waste in India. Among the 10 largest e-waste generating States, Maharashtra ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Among the top ten cities generating e-waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat and Nagpur. The main sources of electronic waste in India are the government, public and private (industrial) sectors, which account for almost 70 per cent of total waste generation. The contribution of individual households is relatively small at about 15 per cent; the rest being contributed by manufacturers. Though individual households are not large contributors to waste generated by computers, they consume large quantities of consumer durables and are, therefore, potential creators of waste.15 An Indian market Research Bureau (IMRB) survey of 'E-waste generation at Source' in 2009 found that out of the total e-waste volume in India, televisions and desktops including servers comprised 68 per cent and 27 per cent respectively. Imports and mobile phones comprised of 2 per cent and 1 per cent respectively.

Recycling Plant in Roorkee opened in January 2010. Despite 23 units currently registered with the Government of India, Ministry of Environment and Forests/ Central Pollution Control Board, as e-waste recyclers/reprocessors, having environmentally sound management facilities, the entire recycling process more or less still exists in the unorganised sector. The Cobalt-60 radiation tragedy at Mayapuri in Delhi in which one person lost his life and six persons were admitted to hospital served as a wakeup call drawing attention to the mounting quantity of hazardous waste including e-waste in the country while revealing systemic problems on the issue of waste disposal.16 The Ministry of Environment and Forests (MoEF) has notified the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 for effective management of hazardous wastes, including e-waste in the country. But these rules do not apply to the radioactive wastes such as Cobalt – 60 which are covered under the Atomic Energy Act, 1962.

5.4. ELECTRONIC WASTE IN THE GLOBAL CONTEXT

As the fastest growing component of municipal waste across the world, it is estimated that more than 50 MT of e-waste is generated globally every year. In other words, these would fill enough containers on a train to go round the world once. However, since the markets in the West have matured, it is expected to account for only 2 per cent of the total solid waste generated in developed countries by 2010. Therefore, with increasing consumerism and an anticipated rise in the sales of electronic products in the countries experiencing rapid economic and industrial growth, the higher percentage of e-waste in municipal solid waste is going to be an issue of serious concern. A report of the United Nations predicted that by 2020, e-waste from old computers would jump by 400 per cent on 2007 levels in discarded mobile phones would be about seven times higher than 2007 levels and, in India, 18 times higher by 2020.19 Such predictions highlight the urgent need to address the problem of e-waste in developing countries like India where the collection and management of e-waste and the recycling process is yet to be properly regulated.

According to the UN Under-Secretary General and Executive Director of the United Nations Environment Programme (UNEP), Achim Steiner, China, India, Brazil, Mexico and others would face rising environmental damage and health problems if e-waste recycling is left to the vagaries of the informal sector. China already produces about 2.3 million tonnes of e-waste domestically, second only to the U.S. with about three million tonnes.20 The EU and the U.S. would account for maximum e-waste generation during this current decade. As per the Inventory Assessment Manual of the UNEP, 2007, it is estimated that the total e-waste generated in the EU is about 14-15 kg per capita or 5MT to 7MT per annum. In countries like India and China, annual generation per capita is less than 1kg.21 In Europe, e-waste contributes up to 6 million tonnes of solid waste per annum. The e-waste generation in the EU is expected to grow at a rate of 3 per cent to 5 per cent per year. In the past, e-waste had increased by 16 per cent to 28 per cent every five years which is three times faster than average annual municipal solid waste generation. In the U.S., e-waste accounts for 1 to 3 per cent of the total municipal waste generation. As per the United States Environmental Protection Agency (USEPA), it generated 2.6 MT of e-waste in 2005, which accounted for 1.4 per cent of total wastes. Electronic waste is generated by three major sectors in the U.S.: Individuals and small businesses; Large businesses, institutions and governments; and Original equipment manufacturers (OEMs)

5.5. STEP-BY STEP PROCESS OF E-WASTE RECYCLING

The e-waste recycling process is highly labor intensive and goes through several steps. Below is the step-by-step process of how e-waste is recycled,

1. **Picking Shed**
   When the e-waste items arrive at the recycling plants, the first step involves sorting all the items manually. Batteries are removed for quality check.
2. **Disassembly**
   After sorting by hand, the second step involves a serious labor intensive process of manual dismantling. The e-waste items are taken apart to retrieve all the parts and then categorized into core materials and components. The dismantled items are then separated into various categories into parts that can be re-used or still continue the recycling processes.
3. **First size reduction process**
   Here, items that cannot be dismantled efficiently are shredded together with the other dismantled parts to pieces less than 2 inches in diameter. It is done in preparation for further categorization of the finer e-waste pieces.
4. **Second size reduction process**
   The finer e-waste particles are then evenly spread out through an automated shaking process on a conveyor belt. The well spread out e-waste pieces are then broken down further. At this stage, any dust is extracted and discarded in a way that does not degrade the environmentally.
5. **Over-band Magnet**
   At this step, over-band magnet is used to remove all the magnetic materials including steel and iron from the e-waste debris.
6. **Non-metallic and metallic components separation.**
   The sixth step is the separation of metals and non-metallic components. Copper, aluminum, and brass are separated from the debris to only leave behind non-metallic materials. The metals are either sold as raw materials or re-used for fresh manufacture.

7. **Water Separation.**
   As the last step, plastic content is separated from glass by use of water. One separated, all the materials retrieved can then be resold as raw materials for re-use. The products sold include plastic, glass, copper, iron, steel, shredded circuit boards, and valuable metal mix.

5.5.1. E-CYCLE COMPONENTS RE-USE

Plastic: All the plastic materials retrieved are sent to recyclers who use them to manufacture items such as fence posts, plastic sleepers, plastic trays, vineyard stakes, and equipment holders or insulators among other plastic products.

Metal: Scrap metals materials retrieved are sent to recyclers to manufacture new steel and other metallic materials.

Glass:. Glass is retrieved from the Cathode Ray Tubes (CRTs) mostly found in televisions and computer monitors. Extracting glass for recycling from CRTs is a more complicated task since CRTs are composed of several hazardous materials. Lead is the most dangerous and can adversely harm human health and the environment. Tubes in big CRT monitors can contain high levels of lead of up to 4 kilograms. Other toxic metals such as barium and phosphor are also contained in CRT tubes. To achieve the best environmentally friendly glass extraction, the following steps ensure a specialized CRT recycling:

- Manual separation of the CRT from the television or monitor body
- Size reduction process where the CRT is shredded into smaller pieces. Dust is eliminated and disposed in an environmentally friendly way.
- All metals are removal through over-band magnets, where ferrous and non-ferrous components are eliminated from the glass materials.
- A washing line is then used to clear oxides and phosphors from the glass
- Glass sorting is the final step whereby leaded glass is separated from non-leaded glass. The extracts can then be used for making new screens.

Mercury: Mercury containing devices are sent to mercury recycling facilities that uses a specialized technology for elimination for use in dental amalgams and metric instruments, and for fluorescent lighting. Other components such as glass and plastics are re-used for manufacture of their respective products.

Printed Circuit Boards: Circuit boards are sent to specialized and accredited companies where they are smelted to recover non-renewable resources such as silver, tin, gold, palladium, copper and other valuable metals.

Hard Drives.: Hard drives are shredded in whole and processed into aluminum ingots for use in automotive industry.

Ink and Toner Cartridges: Ink and toner cartridges are taken back to respective manufacturing industries for recycling. They are remanufactured while those that can't are separated into metal and plastic for re-use as raw materials.

Batteries. Batteries are taken to specialized recyclers where they are hulled to take out plastic. The metals are smelted is specialized conditions to recover nickel, steel, cadmium and cobalt that are re-used for new battery production and fabrication of stainless steel.Batteries are taken to specialized recyclers where they are hulled to take out plastic. The metals are smelted is specialized conditions to recover nickel, steel, cadmium and cobalt that are re-used for new battery production and fabrication of stainless steel.

5.6. GLOBAL TRADE IN HAZARDOUS WASTE

The global waste trade is the international trade of waste between countries for further treatment, disposal, or recycling. Toxic or hazardous wastes are often exported from developed countries to developing countries, also known as countries of the Global South. Therefore, the burden of the toxicity of wastes from Western countries falls predominantly onto developing countries in Africa, Asia, and Latin America. The World Bank Report What a Waste: A Global Review of Solid Waste Management, describes the amount of solid waste produced in a given country. Specifically, countries which produce more solid waste are more economically developed and more industrialized.[2] The report explains that "generally, the higher the economic development and rate of urbanization, the greater the amount of solid waste produced." Therefore, countries in the

Global North, which are more economically developed and urbanized, produce more solid waste than Global South countries.[2]

Current international trade flows of waste follow a pattern of waste being produced in the Global North and being exported to and disposed of in the Global South. Multiple factors affect which countries produce waste and at what magnitude, including geographic location, degree of industrialization, and level of integration into the global economy.

Numerous scholars and researchers have linked the sharp increase in waste trading and the negative impacts of waste trading to the prevalence of neoliberal economic policy. With the major economic transition towards neoliberal economic policy in the 1980s, the shift towards "free-market" policy has facilitated the sharp increase in the global waste trade. Henry Giroux, Chair of Cultural Studies at McMaster University, gives his definition of neoliberal economic policy:

"Neoliberalism -removes economics and markets from the discourse of social obligations and social costs. ...As a policy and political project, neoliberalism is wedded to the privatization of public services, selling off of state functions, deregulation of finance and labor, elimination of the welfare state and unions, liberalization of trade in goods and capital investment, and the marketization and commodification of society."

Given this economic platform of privatization, neoliberalism is based on expanding free-trade agreements and establishing open-borders to international trade markets. Trade liberalization, a neoliberal economic policy in which trade is completely deregulated, leaving no tariffs, quotas, or oth restrictions on international trade, is designed to further developing countries' economies and integrate them into the global economy. Critics claim that although free-market trade liberalization was designed to allow any country the opportunity to reach economic success, the consequences of these policies have been devastating for Global South countries, essentially crippling their economies in a servitude to the Global North Even supporters such as the International Monetary Fund, "progress of integration has been uneven in recent decades"

5.7. IMPACT OF HAZARDOUS WASTE IN INDIA

According to the very recent "the e-waste (Management and Handling) Rules, 2011", 'electrical and electronic equipment' means equipment which is dependent on electric currents or electro-magnetic fields to be fully functional and 'e-waste' means waste electrical and electronic equipment, whole or in part or rejects from their manufacturing and repair process, which are intended to be discarded. A wide range of literature is available on the generation and management of E-waste, especially in the developed countries.

Major issues related to E-waste in India While considering the problems related to E-waste in India, there are five major components which should be focused upon. These are Main Sources of E-waste in India, Magnitude of the Problem with respect to the Indian scenario, Health and Environmental Implications of Ewaste, Current Management practices of E-waste in India and Policy level initiatives in the country.

Some of the major sources of E-waste include

Formal Sector

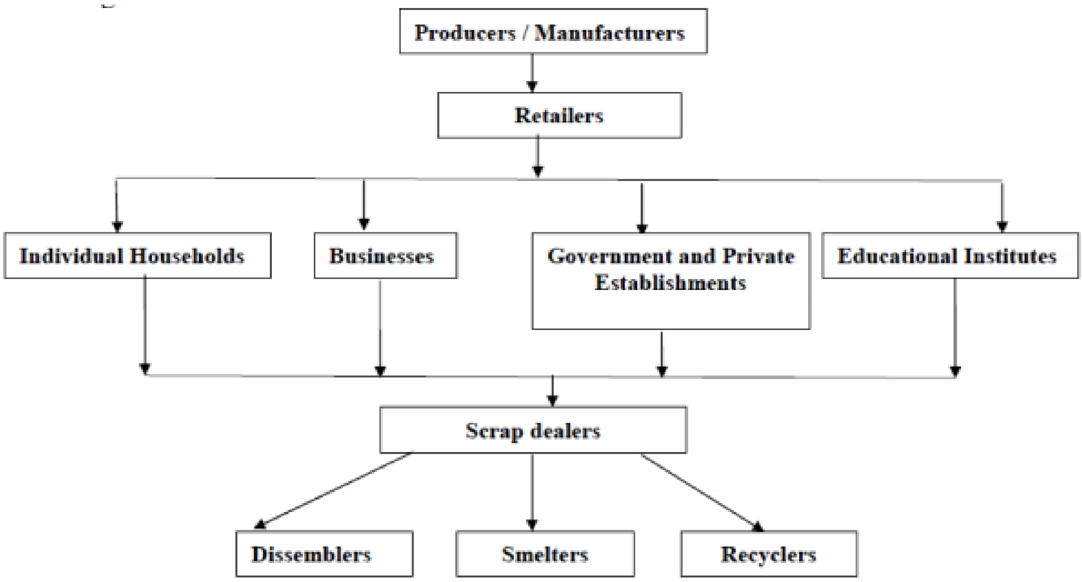
- Importers
- Producers / manufacturers
- Retailers (businesses/ government/ others)
- Consumers (individual households, businesses, government)
- Traders
- Scrap dealers

Informal Sector

- Dissemblers / dismantlers
- Smelters
- Recyclers

5.7.1 MAIN SOURCES OF E-WASTE

The involvement of various sectors could be observed as the sources of generation of Ewaste. The general flow of E-waste across different sectors are tried to represent by the following flow chart.



5.7.2. HEALTH AND ENVIRONMENTAL IMPLICATIONS OF E-WASTE

Electronic and Electrical Equipment are composed of an enormous amount of components. Many of them fall under the hazardous category. Majority of these components contain toxic substances that have adverse impacts on human health and the environment if not handled properly. Often, these hazards arise due to the improper recycling and disposal processes that are in practice in most of the developing countries including India. Such offensive practices can have serious aftermath for those staying in proximity to the places where E-waste is recycled or burnt.

Disposal of E-wastes is an unembellished problem faced by many regions across the globe. Electronic wastes that are land filled produces contaminated leachates which eventually pollute the groundwater. Acids and sludge obtained from melting computer chips, if disposed on the ground causes acidification of soil. For example, Guiyu, Hong Kong a flourishing area of illegal E-waste recycling, is facing acute water shortages due to the contamination of water resources. This is due to disposal of recycling wastes such as acids, sludges etc. in rivers.

Mercury leaches when certain electronic devices, such as circuit breakers are destroyed. The same is true for polychlorinated biphenyls (PCBs) from condensers. When brominated flame retardant plastic or cadmium containing plastics are land filled, both polybrominated diphenyl ethers (PBDE) and cadmium may leach into the soil and groundwater.

It has been found that significant amounts of lead ion are dissolved from broken lead containing glass, such as the cone glass of cathode ray tubes, gets mixed with acid waters and are a common occurrence in landfills. In addition, uncontrolled fires may arise at landfills and this could be a frequent occurrence in many countries. When exposed to fire, metals and other chemical substances, such as the extremely toxic dioxins and furans (TCDD tetrachloro dibenzo-dioxin, PCDD polychlorinated dibenzodioxins. PBDDs-polybrominated dibenzo-dioxin and PCDFs-poly chlorinated dibenzo furans) from halogenated flame retardant products can be emitted1 .

The most dangerous form of burning E-waste is the open-air burning of plastics in order to recover copper and other metals. The toxic fall-out from open air burning affects the local environment and broader global air currents, depositing highly toxic byproducts in many places throughout the world. Incineration of E-waste possesses another threat. It can emit toxic fumes and gases, thereby polluting the surrounding air. Moreover, shipping of hazardous waste to developing countries is a major alarm. It happens because of cheap labour and lack of environmental legislations in developing countries.

5.8. MANAGEMENT OF E-WASTE IN INDIAN CONTEXT

In India, it has been observed that in most of the cases, electronic items are stored unattended because of lack of knowledge about their management. Such electronic junks lie in houses, offices, warehouses etc. Generally, these wastes are mixed with household wastes, which are finally disposed of at landfills. This necessitates implementation of appropriate management measures including stringent regulations. The management practices currently in operation in India have severe health and environmental implications. The composition of E-waste consists of diverse items many of which contain hazardous elements. Therefore, the major approach to treat E-waste is to reduce the concentration of these hazardous chemicals and elements through recycle and recovery. In the process of recycling or recovery, certain E-waste fractions act as secondary raw material for recovery of valuable items. In Indian context, primarily recycling, reuse and recovery are done as measures to treat E-waste. The recycle and recovery includes the unit operations like dismantling, segregation of ferrous metal, non-ferrous metal and plastic by shredder process, refurbishment and reuse, recycling / recovery of valuable materials and treatment/disposal of dangerous materials and waste. Dismantling includes removal of parts of the electrical and electronic equipment containing perilous substances (CFCs, Hg switches, PCB); removal of easily accessible parts containing valuable substances (cable containing copper, steel, iron, precious metal containing parts etc.). Refurbishment and reuse of E-waste has potential for those used electrical and electronic equipment which can be easily renovate to put to its original use. Recycling / recovery of valuable materials includes recycling and recovery of valuable materials from the E-waste stream like non-ferrous metals in smelting plants, precious metals in separating works.

As most of the electrical and electronic equipment contain many precious metals, this process is an important step in the management of E- waste. The materials of potential hazard are disposed of in landfill sites or sometimes incinerated. However, the process of incineration is quite expensive. CFCs are treated thermally, PCB and Mercury is often recycled or disposed of in underground landfill sites. In India, primarily two types of disposal options based on the composition are in practice. These are Landfilling and Incineration. However, the environmental risks from landfilling of E-waste cannot be neglected because the conditions in a landfill site are different from a native soil, particularly concerning the leaching behaviour of metals.

In addition it is known that cadmium and mercury are emitted in diffuse form or via the landfill gas combustion plant. Although the risks cannot be quantified and traced back to E-waste, landfilling does not appear to be an environmentally sound treatment method for substances, which are volatile and not biologically degradable (Cd, Hg, CFC), persistent (PCB) or with unknown behaviour in a landfill site (brominated flame retardants). As a consequence of the complex material mixture in E-waste, it is not possible to exclude environmental (long-term) risks even in secured landfilling (Guidelines for Environmentally Sound Management of E-waste, 2008).

Advantage of incineration of E-waste is the reduction of waste volume and the utilization of the energy content of combustible materials. By incineration some environmentally hazardous organic substances are converted into less hazardous compounds. Disadvantage of incineration are the emission to air of substances escaping flue gas cleaning and the large amount of residues from gas cleaning and combustion (Guidelines for Environmentally Sound Management of E-waste, 2008). Waste incineration plants contribute significantly to the annual emissions of cadmium and mercury. The assessment of E-waste recycling sector in India indicates that E-waste trade starts from formal dismantling sector and moves to informal recycling sector (Guidelines for Environmentally Sound Management of E-waste, 2008).

The entire E-waste treatment is being carried out in an unregulated environment, where there is no control on emissions. There are two E-waste dismantling facilities in formal sector in India. These facilities are M/s. Trishiraya Recycling facilities, Chennai and M/s E-Parisara, Bangalore.

5.9. EWASTE LEGISLATION, GOVERNMENT REGULATIONS ON E-WASTE MANAGEMENT

India’s Ministry of Environment and Forest (moef) is to place legal liability for reducing and recycling electronic waste with producers for the first time under the E-waste (Management and Handling) Rules 2011. The rules, which form part of the Environment Protection Act, will come into effect from 1 May 2012.Manufacturers and importers of computers, mobile phones and white goods will be required to come up with e-waste collection centres or introduce ‘take back’ systems.

‘These rules will apply to every producer, consumer and bulk consumer involved in manufacture, sale, purchase and processing of electronic equipment or components,’ an environment ministry official told India newspaper Business Standard. The ministry is granting a one-year grace period for collection centres to be to set up.

India currently generates 400,000 tonnes of e-waste annually, of which only 19,000 tonnes is recycled, according to manufacturers’ association Mait.It believes around 40% of obsolete electronic products sit unused at home or in warehouses, as people do not know what to do with them and there is no systematic mechanism for dispose of them.

Under the new rules, producers will have to issue consumers with information on disposing of equipment after use to prevent e-waste from being dropped in domestic waste, and must make the public aware of the hazardous components present.Commercial consumers and government departments will become responsible for recycling the e-waste they generate, channeling it to authorised collection centres or ensuring it is taken back by suppliers. They will have to maintain e-waste records and make these available to state Pollution Control Boards or other authorities.

NGO Greenpeace India welcomes the transition from the current out-of-sight, out-of-mind approach to proper recycling, but claimed the new legislation 'fails to provide safeguards' against the import and export of e-waste.

A provisional rule drafted by the Ministry last year included a ban on import of second-hand electronic equipment for charity or other re-use – much of which passed into the hands of informal recyclers. This clause has been removed from the final rule.

5.10. ENVIRONMENTAL LAWS IN INDIA

The Centre is likely to amend six crucial environmental laws to be tabled in the Parliament after the recess ends on April 23, the Union Ministry of Environment, Forests and Climate Change. To this end, a two-day conference was inaugurated on Monday by Prime Minister Narendra Modi. At the meeting, state environment ministers, officials and experts discussed issues like forests, wildlife, pollution, biodiversity and climate change over three breakout sessions.

After it ends, the ministry will finalise its recommendations, prepare a note and bring it before the cabinet so that the amended bills can be tabled in the second half of the Parliament session.

The conference is part of the ongoing consultation with the states to improve the condition of environment and forests in the country, senior ministry officials told Down To Earth. Various news reports suggest that over 100 changes have been suggested by the Prime Minister's Office (PMO) to ensure the ease of doing business in India. According to the ministry, some of these changes call for a single clearance window to save time for various development projects like power infrastructure,roads. According to an environment ministry official, the government will also finalise the changes made in the Environment Impact Notification 2006 by suggesting standardised terms of references for industrial projects.

The ministry will also finalize the issue of land banks that will be access.
Prime Minister Narendra Modi was presented with a copy of the annual tiger census and the national air-pollution.Modi, in his address to state environment ministers, said India should lead the global fight against climate change. He added that the world should ease restrictions on India for importing nuclear fuel so that the country could produce clean energy in a big way. He said the government's focus was on clean energy-generation through solar-radiation,wind .

The six laws related to environmental protection and wildlife are:

- The Environment (Protection) Act, 1986;
- The Forest (Conservation) Act, 1980;
- The Wildlife Protection Act, 1972;
- Water (Prevention and Control of Pollution) Act, 1974;
- Air (Prevention and Control of Pollution) Act, 1981 and
- The Indian Forest Act, 1927.