UNIT 11 SOLID WASTE MANAGEMENT AND WASTE TO ENERGY

Structure

11.1 INTEGRATED SOLID WASTE MANAGEMENT (ISWM)

The strategic approach towards sustainable management of the waste including all aspects and sources from the waste generation to disposal in an integrated manner in order to maximize the resource use efficiency is generally referred as integrated solid waste management. The role of ISWM is recovery of energy and materials from the waste by reduction in the amount of waste disposed on land which in turn makes less usage of raw materials and input energy for industrial process.

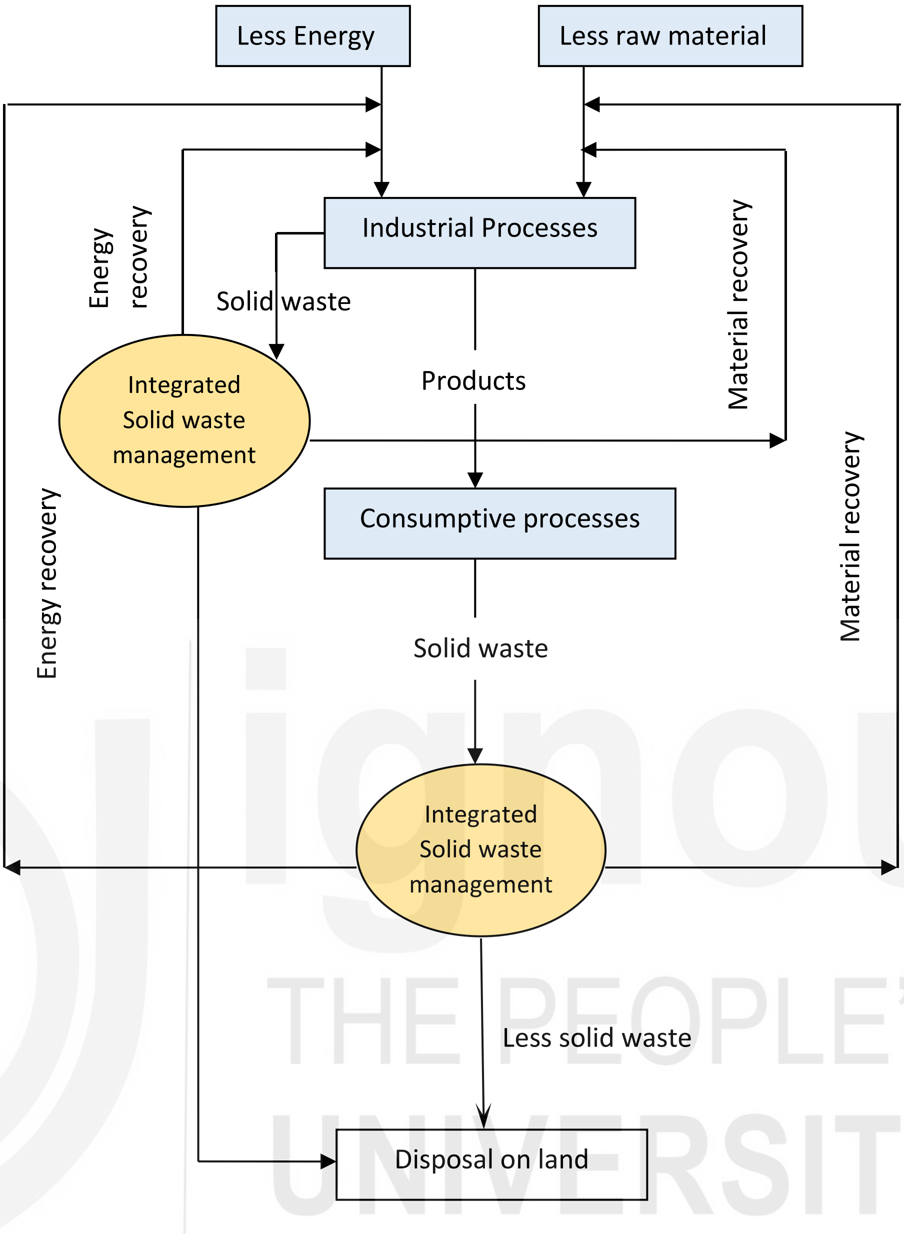


Figure 11.1: Role of ISWM

ISWM is the application of suitable methods and management programs by covering the various types of solid waste materials from various sources to attain the two objectives. They are

i. Less waste
ii. Effective management of waste generated.

Less waste: Sustainable development can be attained only if the production of more products with minimum use of the available resources and minimize generation of waste. On-site energy recovery or internal recycling of materials has been introduced by many nations as a part of waste reduction schemes. These steps helps to minimize the quantity of the solid waste produced which in turn results in the improved efficiency and less waste generation. The increase in the cost of energy, raw materials and the increase in the cost of disposal of solid waste will make sure that reduction of waste will be followed continuously by the industrialized societies for the economic and environmental reasons.

Waste minimization generally refers to reduce the waste generation however there will be always some quantity of waste that remains for disposal. Source reduction affects the volume and the nature of waste to some extent. But beyond source reduction an effective management system is needed in order to manage this solid waste.

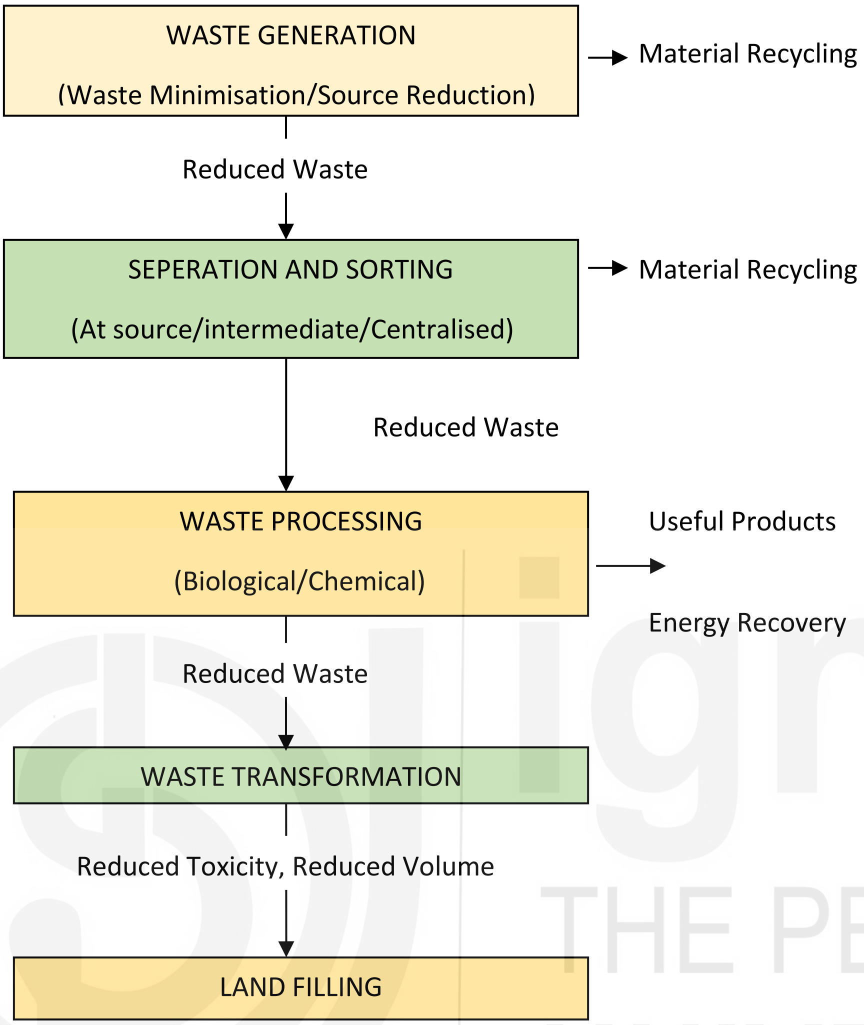


Figure 11.2: Waste Reduction by ISWM

Effective management of solid waste: In order to ensure human health and safety the effective solid management systems are required such that they must ensure workers safety and safeguard public health. Environmental and economical sustainability is always a prerequisite condition for an effective system for SWM. To ensure environmental sustainability it must minimize the environmental impacts like land, air and water pollution including energy consumption. Similarly to ensure economic sustainability it must operate at a low cost that is accepted by the community. The required cost for operating an effective solid waste system depends on the available local infrastructure. An environmentally and economically SWM system is said to be effective, if it follows an integrated approach that it considers all types of solid waste materials and solid waste from all sources. An effective SWM system includes

- Waste minimization
- Waste transformation i.e. volume reduction, change the physical properties of waste etc.
- Recovery of the resources by processing the waste i.e. material recovery, energy recovery etc.
- Recovery of resources by recycling.

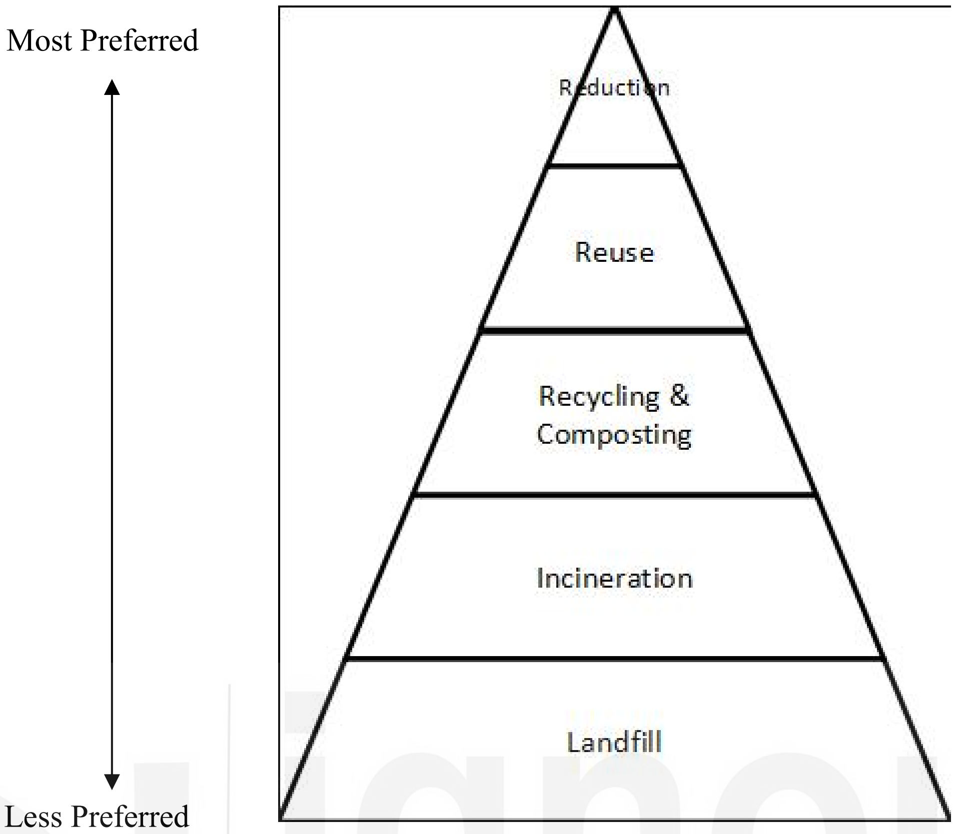


Figure 11.3: Hierarchy of ISWM

SAQ 1

a) How sustainable development can be implemented in ISWM?

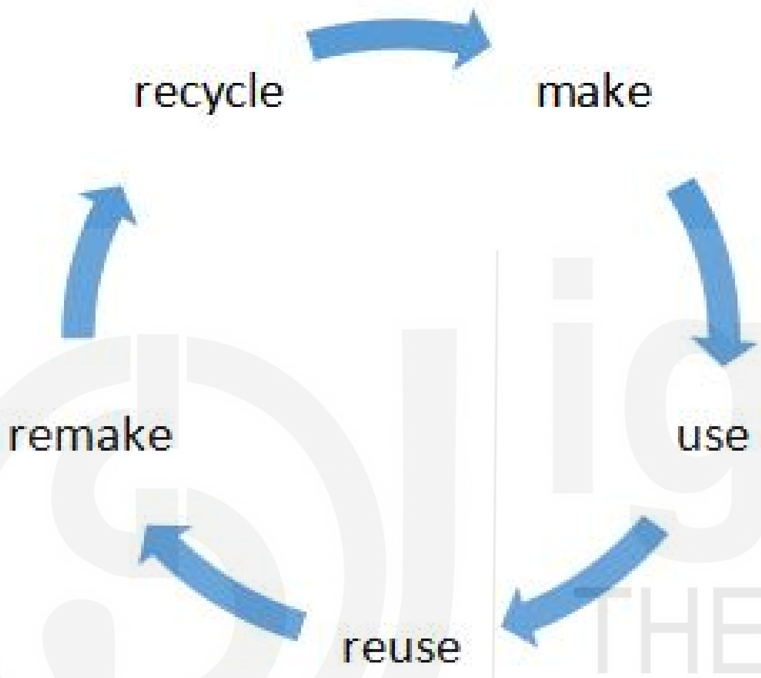
b) What are the key objectives of effective waste management?

11.2 CONCEPT OF CIRCULAR ECONOMY IN WASTE MANAGEMENT

India by establishing the waste management centres regionally using biological and mechanical processing technologies of waste is upgrading its municipal solid waste management systems in order to attain a way towards sustainable waste management. Managing the municipal solid waste within many Indian cities is a serious problem due to the current SWM system that is considered to be as inefficient. Ultimately the aim was treating the waste generated in an economic and environmentally sustainable way also to minimize land filling to only residual waste. Land filling can be replaced by efficient and modern processes which should be sustainable. However, In order to fulfil the target of effective solid waste management India has to make an exceptional effort as the increase in biodegradable municipal waste since 1997 makes it difficult. In addition, to fulfil such targets requires great support from the local authorities and the government in order to reach the required treatment capacity.

The circular economy concept is relatively new which deals with various economic and sustainable approaches that essentially target the circularization of linear value chains. As the earth's natural resources are limited and the rapid increase in the use of these resources makes the governing bodies globally to look into the approaches, frameworks and models that drive the path towards sustainable development. The deterioration of bio-physical system effects are expressed in terms of pollution, depletion of resources and increase in emissions of greenhouse gases (GHGs) effects the environment restricting the local development confining to the economic and social measures of sustainability.

Circular economy is a closed loop system and it functions with the industries and the societies that imitate the behaviour of the ecosystems. It requires the resources which can be permanently reused and which are biodegradable in nature. It is it is a paradigm shift from cradle-grave to cradle - cradle, from disposability to restorability, from take-make-dispose to take-make-recreate. The major objective of the circular economy is to minimise the environmental impacts by reducing the waste generation and wastage of resources and improving the human well being.



One strategy in adapting to the principles of circular economy which is one of the emerging models within environmental management is for the transition towards a less polluting economy and low carbon footprint. However, inspite of the obstacles, circular economy has recognised widely within policy frameworks and business model. Circular economy on a whole can be defined as a system which predicts the approach or operational process at the industry that mimics with the natural systems. This essentially gives rise to generation of the products through recycling and reducing the waste generation and elimination thereby ensuring the development to be sustainable. Circular economy is generally considered as an economic model which aims at the effective use of available resources by minimising the waste, primary resources reduction etc by confining to the boundaries of the environment protection and socio-economic benefits.

11.2.1 Principles and scales in circular economy

Principles: The concept of circular economy is based on sustainability through materials recycling or recycling nutrients. This is similar to that of ecological recycling in which the organic and inorganic matter is circulated in nature through uptake, digestion, release and storage for the production of living matter. There are two circular economy nutrients

(1) Biotic nutrients – which are ultimately returned as nutrients to the soil by following metabolic pathways of recycling by the biosphere.

(2) Technical nutrients -which are reused and recycled infinitely, where there is no loss in quality.

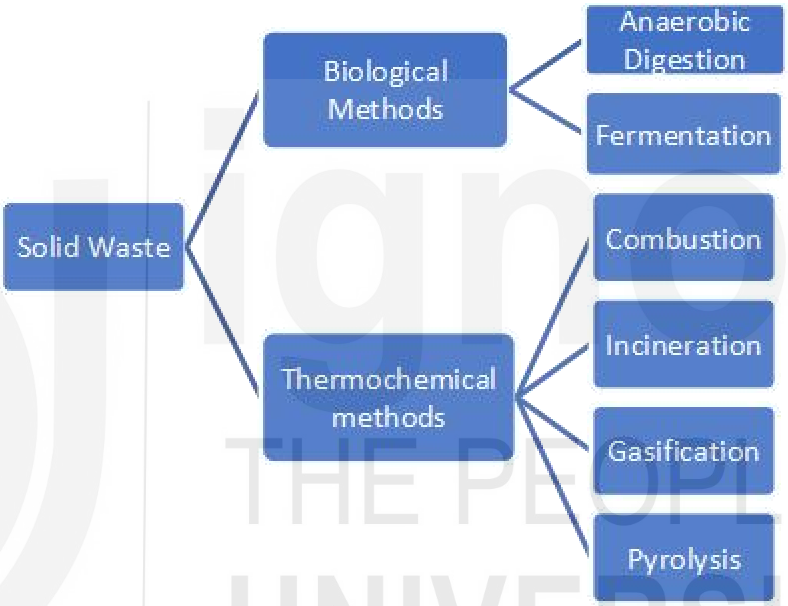
Scales or Spatial Levels: The circular economy concept can be applied at three spatial levels

(1) Micro level – It is the level where the firms or individual enterprises using cleaner production.

(2) Meso level – It is the industrial park level which involves a chained mechanism or industries as a cluster. It is also known as the inter-enterprise level

(3) Macro level – It is the level between production and consumption systems in regions, between industries and urban environment in an eco-region or municipality. It is also known as the societal level.

Solid Waste Conversion Technologies



11.3 BIOLOGICAL CONVERSION TECHNOLOGIES

[A] Anaerobic Digestion

Anaerobic digestion is a biological process performed by active microbes for the decomposition of organic matter in the absence of oxygen to generate biogas which consists of methane and carbon dioxide in higher amounts. In the recent times, manure from livestock, municipal solid waste care used largely as a feedstock. Generally, anaerobic digestion process follows a stepwise procedure, In the first step of anaerobic digestion the complex organic solids of municipal solid waste are broken into simple monomers by bacteria i.e., amino acids, monosaccharide's and fatty acids. In the second stage the conversion of these simple monomers to organic acid takes place, such as volatile fatty acids (VFA), H_2 and CO_2. The next step is followed by the action of methanogenic bacteria that converts the organic acid into methane and carbon dioxide. The energy resulting from the fossil fuels can be substituted by methane gas. The digestate from the anaerobic digestion can be used as a fertilizer. The general chemical equation is

$$\text{Organic matter} \rightarrow CH_4 + CO_2 + H_2 + NH_3 + H_2S$$

The trace gases like oxides of nitrogen and sulphur and H_2S escapes into the atmosphere while the generation of energy through anaerobic digestion of organic wastes which pollutes the environment. Degradation of nitrogen-rich protein constituents results in the generation of high concentration of NH_3. Cations such as calcium, potassium, sodium and magnesium are produced due to high salts content in food waste hinder the anaerobic digestion process.

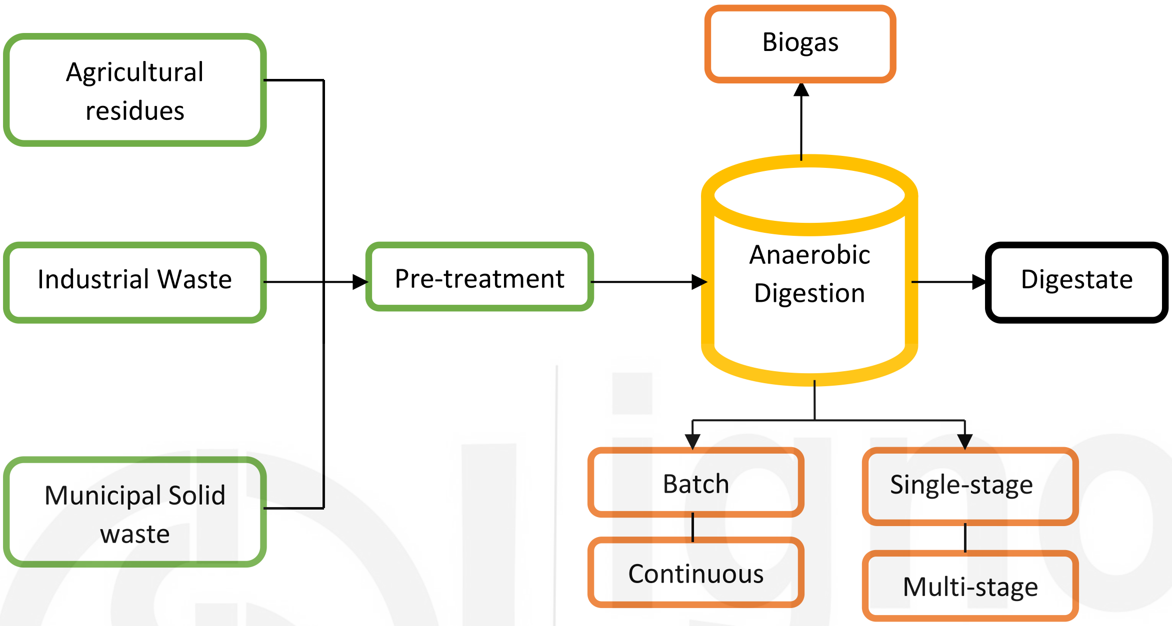


Figure 11.4: Anaerobic digestion process

The generation of renewable energy, nutrient recovery from the waste and minimising the quantity of waste disposal is the environmental benefit that can be gained by using anaerobic digestion. Anaerobic digestion can enhance the production of biogas based on type of waste used in the digestion process. Anaerobic co-digestion can be considered as a viable option in treating the waste with suitable substrates in order to quicken the process and also to optimize the biogas production. Although several factors depends on the biogas production such as variables like pH, temperature, type of reactor used, co-substrate used and the process stability of the Anaerobic digestion the main aim is to minimise the waste and maximize the benefits from it. At present, several bioreactors like a tubular reactor, anaerobic sequencing batch reactor (ASBR), continuously stirred tank reactor (CSTR), upflow anaerobic sludge blanket (UASB) and fixed film reactor in batch, continuous one-stage, and continuous two-stage process depending on the methanogenic bacteria variability are used for anaerobic digestion. The reactor should be essentially self mixing, but in order to prevent the uneven reactions, manually stirring should be done at least one time in a week. However stirring is not required once stable state is reached. The sand particles and the grit that are settled at bottom of the tank should be taken out once in a year and to prevent corrosion and leaks from the gas equipment it should be regularly cleaned. The main

Advantages

i. Highly recommended to treat the wastes with high moisture content.

ii. Optimization of this technique can be done on any scale.

iii. The greenhouse gases emission can be reduced considerably.

Disadvantages

i. Affected by temperature and it is less efficient in colder countries.

ii. Controlling of microbial activity becomes difficult if the size of the digester exceeds certain limit.

[B] Ethanol Fermentation

Waste to energy conversion process involves a different approach on the production of ethanol from food waste when compared to biogas. Ethanol fermentation id generally biochemical process which involves hydrolysis of sucrose followed by the fermentation of sugars. Several food wastes are used in the production of ethanol like pineapple waste, banana peel, potato peel, household waste etc. Various pre-treatment methods like thermal, acid, alkali and enzymatic processes are used to enhance the digestibility of cellulose due to the complexity of lignocelluloses component present in food waste. The most common pre-treatment technology in ethanol fermentation is enzymatic hydrolysis which not only used in treating the food waste but also used in reducing the carbon footprint.

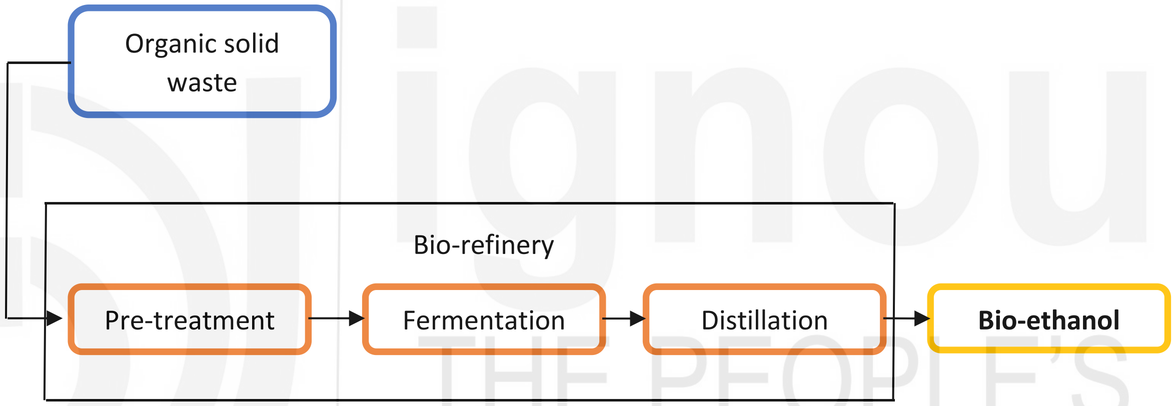


Figure 11.5: Ethanol Fermentation of organic matter

SAQ 2

a) What are the different biological conversion technologies?
b) Explain different types of anaerobic bioreactors?

11.4 CHEMICAL TECHNOLOGIES.

[A] Incineration

Oxidation of organic material at high temperature under continuous supply of oxygen is done in incineration of sludge. The waste is converted to heat in this treatment and the waste is dried prior to treatment. Incinerators are more useful in combustion of waste from households, biomedical wastes etc rather than disposing them to landfill. This treatment also helps in avoiding the open burning of municipal waste which endangers human health and environment by releasing harmful emissions. This treatment process requires high quantum of electrical energy. The volume of the solid waste is reduced by 80% using incineration process. The heat produced is used to run the turbines. Incinerators produce toxic emissions and the ash from the incinerator is incombustible which contains concentrated inorganic content which needs a proper disposal. The toxic emissions contain heavy metals and dioxins which may lead to health problems and air pollution. Treatment of solid waste by incineration is considered as one of the best method as the reduction of waste is immediately carried out while other processes take more time. Incineration process also reduces the transportation cost as the incinerators can be installed at the collection points. The moisture content of the waste is reduced by using pre treatment process to improve the process efficiency.

Advantages

i. Heat and energy may be recovered in this process.

ii. Effective technology in the treatment of all kinds of waste.

Disadvantages

i. For the proper functioning of incinerators, trained operators are required.

ii. Requires high cost and liberates considerable amounts of emission.

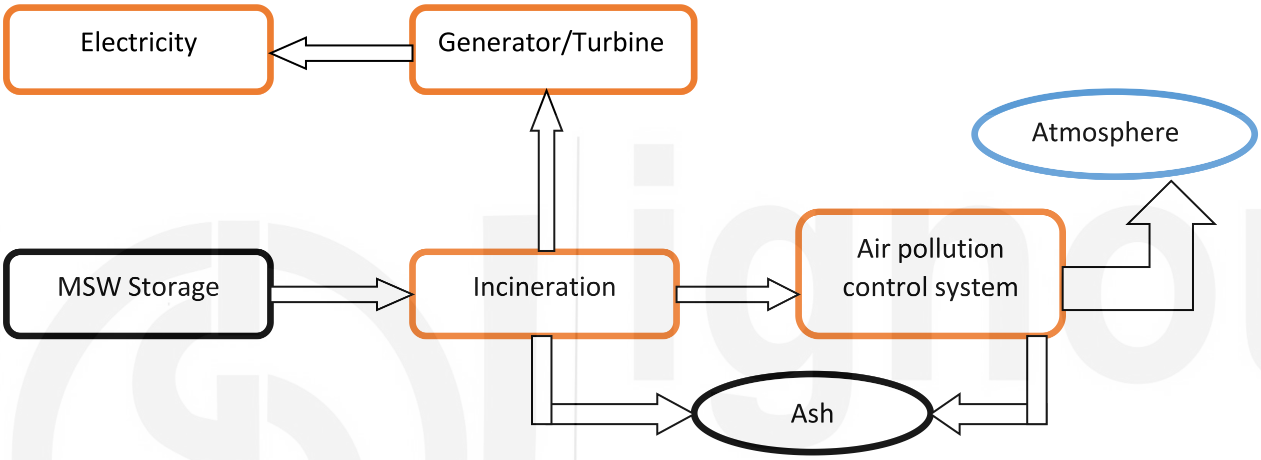


Figure 11.6: Schematic incineration process

[B] Gasification

Organic matter of the solid waste is thermally transformed which takes place under controlled supply of oxygen at high temperature. The solid waste is converted to biochar and synthesis gas. The waste is dried prior for treatment. The process takes place at around 800-900°C. The produced gas which is of low calorific value can be used as a fuel in gas turbines and gas engines or else it can be burnt directly. The produced syngas can be used as a feedstock in the production of some chemicals. Biomass integrated gasification is considered as one of the promising process where the gaseous fuel is converted to electricity by the turbines. The main advantage of using these biomass integrated gasification systems is that cleaning of gas takes place before the combustion in the turbine as the overall efficiency increases. Methanol and hydrogen which are considered as the future fuel can be produced by the production of syngas.

Advantages

i. The produced synthesis gas can be converted into fuel.

ii. Best suitable for dry feedstock.

Disadvantages

i. Wet feedstock cannot be used directly in a gasifier and process is very energy intensive.

ii. Process is economically less viable.

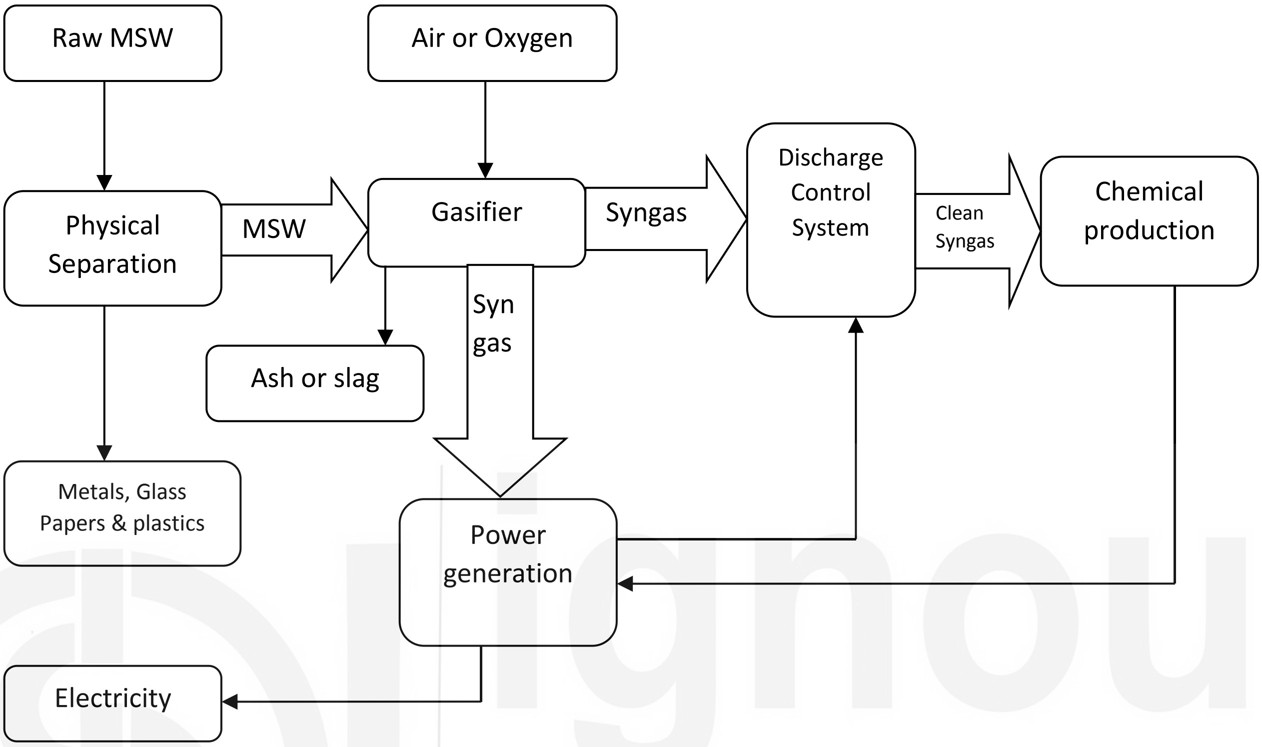


Figure 11.7: Schematic process of gasification

[C] Pyrolysis

The carbonaceous materials present in the solid waste are thermally converted in the absence of oxygen to produce complex oil. The solid waste is converted to biochar and bio-oil. The waste is dried prior for treatment. There will be risk of malfunction in the operation process, if the maintenance is weak.

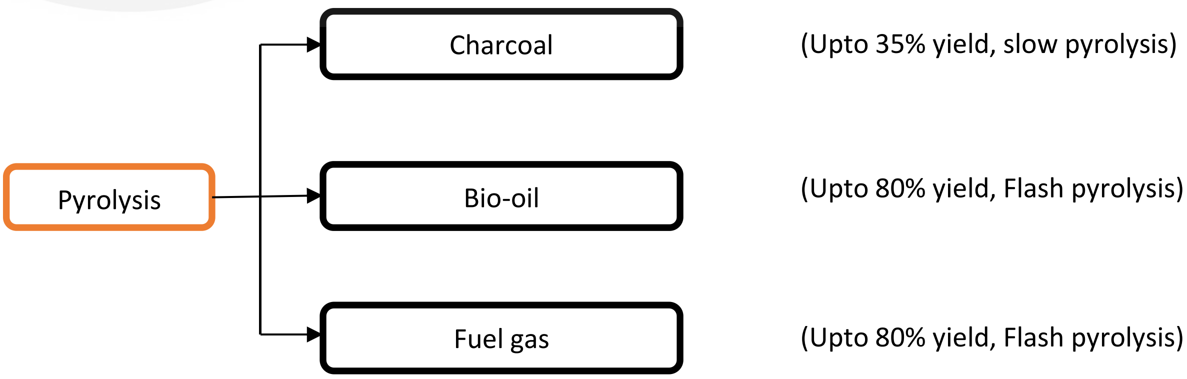


Figure 11.8: End products of pyrolysis

The process takes place at around 500°C. Bio-oil is produced predominantly with high efficiency by flash pyrolysis. The produced bio-oil is used as a feedstock for refineries and also used to run the turbines and engines. Catalytic cracking and hydrogenation may be required for removing the alkalis and enhancing the production of bio-oil. Problems such as corrositivity and poor thermal stability in the production of bio-oil have to be overcome in order to make the process efficient.

Advantages

i. The efficiency of energy recovery is high.

ii. Reduces greenhouse gas emissions.

Disadvantages

i. High capital costs make economically less viable.

ii. Energy intensive process.

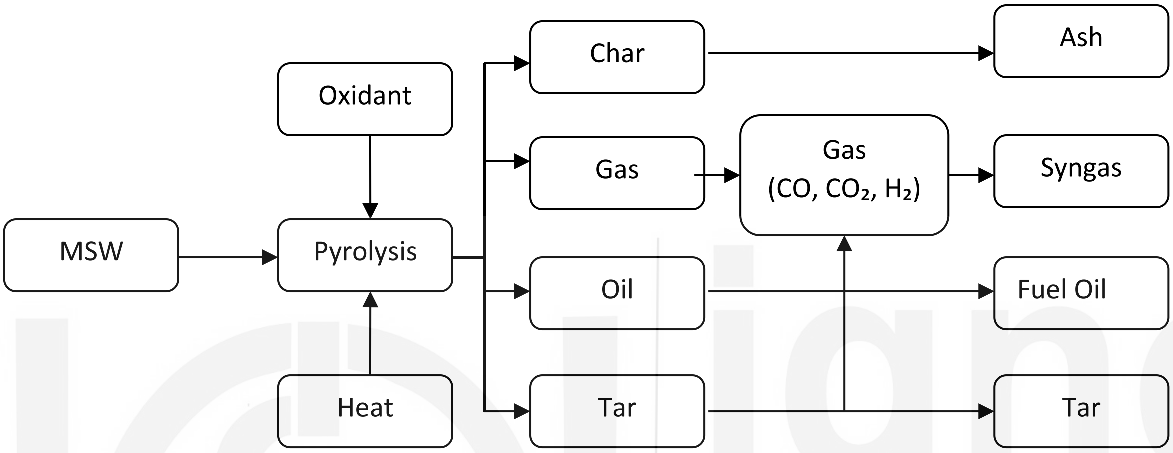


Figure 11.9: Schematic pyrolysis process

SAQ 3

a) What are the different chemical technologies in waste management?

b) Compare the different chemical technologies by discussing the principle involved, advantages and disadvantages?

11.5 ADVANCED TREATMENT METHODS

[A] Dark Fermentation

It is decomposing the organic matter by anaerobic microorganisms in the oxygen and light free environment to convert the complex organic compounds to bio-hydrogen. The process stability and the production of bio-hydrogen depends on the formation of acids and the microorganisms involved in the process. The production of bio-hydrogen is comprised of a series of chemical reaction with initially hydrolysis of the organic polymers into sugar molecule. These monomers are converted into volatile fatty acids along with hydrogen in the next step by the acidogenic bacteria. The production of acetate by the reduction of H_2 and CO_2 is carried and finally the methanogenic bacteria utilise these acetate, H_2 and CO_2 and results in the production of methane and carbondioxide.

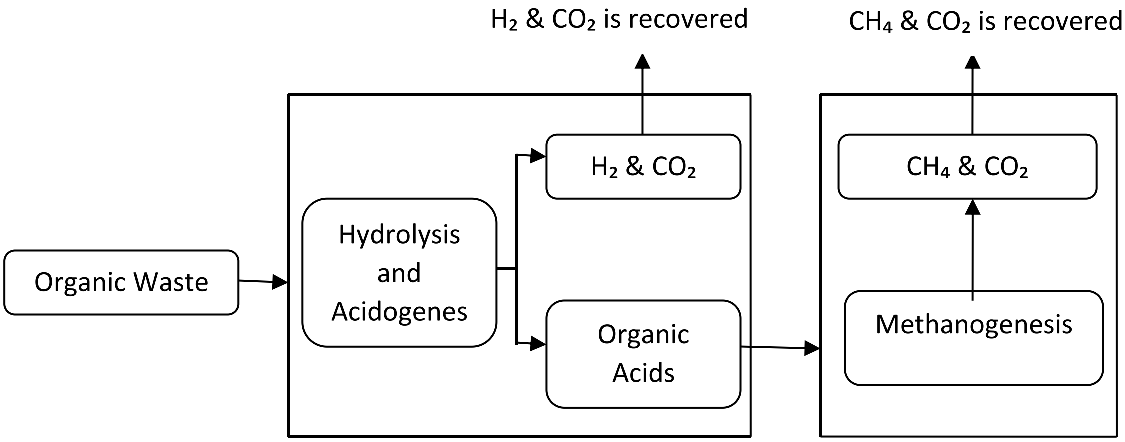


Figure 11.10: Dark Fermentation **Biomethanation**

The production of bio-hydrogen from solid waste can be considered as most viable method by dark fermentation method. The yield of the hydrogen depends on various factors such as the solid waste composition, the type of substrates used and the reactor conditions. The most important step to enhance the bio-hydrogen production depends on the degradation of glycerol and monosaccharides in the dark fermentation process. The major substrate for the bio-hydrogen production is the carbohydrates when compared with proteins and lipids. The change in the composition of the solid waste influences the bio-hydrogen yield.

[B] Microbial fuel cells (MFCs)

These are bio-electrochemical devices where decomposition of various organic wastes that takes place by bio electrogenic microorganisms for production of energy. Electrochemically active microorganisms are used in microbial fuel cells device for the electricity generation. It uses bacteria as a catalyst and involves both aerobic and anaerobic processes and considered as a good approach in fabrication of bio-hydrogen for the future generation. Various organic wastes such as animal waste, domestic waste and waste sludge are used as a feedstock. The rise in the demand for the energy requirements makes MFC technology as most promising by converting solid waste into electricity and hydrogen gas. For the metabolism of the microbial population fruit waste, which contains mono, di and polysaccharides are commonly used, while the polysaccharides in the vegetable waste are used for energy consumption for the metabolic activity and their decomposition.

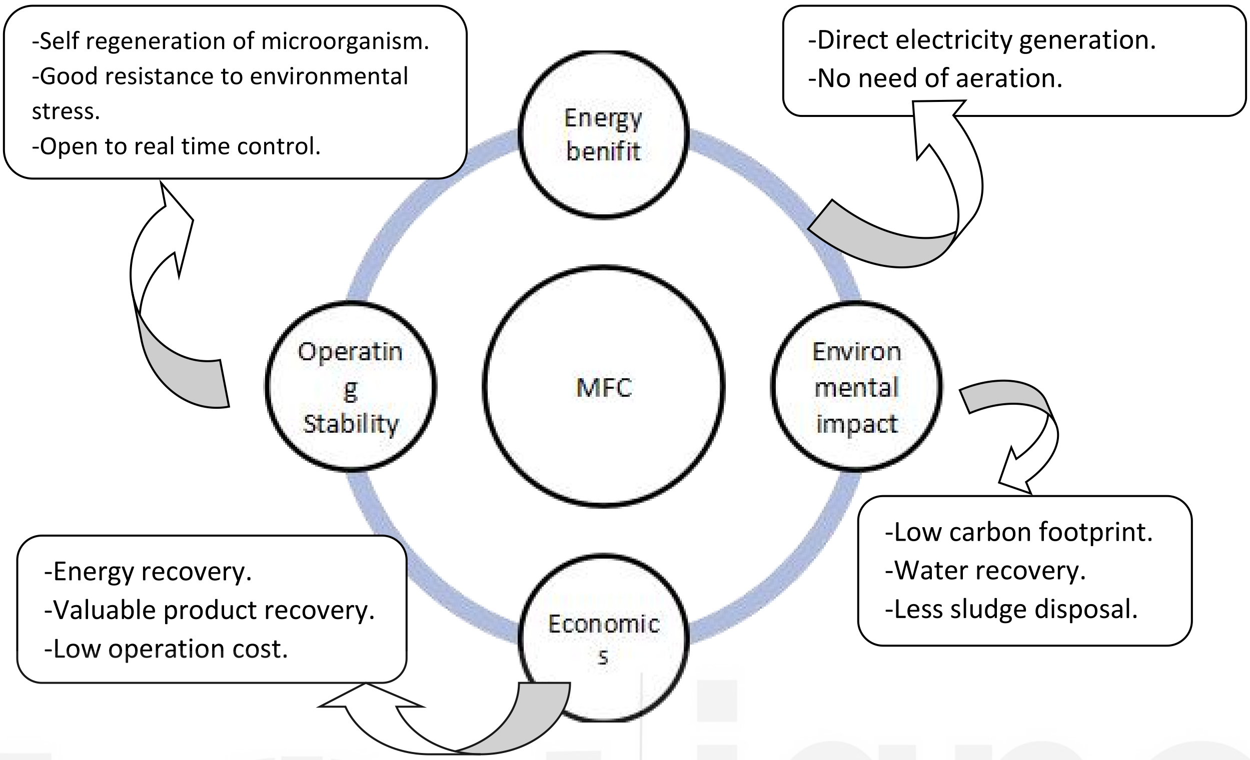


Figure 11.11: MCF Overview

In the metabolism the electrons present in fats, proteins and sugars of the waste substrate, for the generation of energy follows microorganism metabolic pathway. Inside mitochondrial cells conversion into carbondioxide and acetyl-CoA takes place by pyruvate distraction. The formed acetyl-CoA participates in the Krebs cycle after converting into oxaloacetate, after which it. The end product is NADH which stores CO_2 and high-energy electrons. Continuously regeneration of NAD+ takes place in kerbs cycle by using molecular oxygen. Within mitochondrial and cellular membranes the transport chains of electrons takes place in eukaryotic and prokaryote cells respectively.

11.6 WASTE TO FUELS

[A] Bio-ethanol

Rapid increase in the usage of fossil fuels results in the fossil fuels depletion and strives to move towards an alternative source of energy. This lead a way for production of bio-ethanol from solid waste generated from the households mainly food waste. Utilization of potato peel waste for bio-ethanol production is considered as a viable approach and has solved the problems of environmental pollution and the depletion of fossil fuels. Evaluation of the bio-ethanol production was done using the food waste and potato peel waste with co-culturing of Saccharomyces cerevisiae and Aspergillus Niger. Simultaneous saccharification and fermentation is carried out for the bio-ethanol production under controlled optimized conditions.

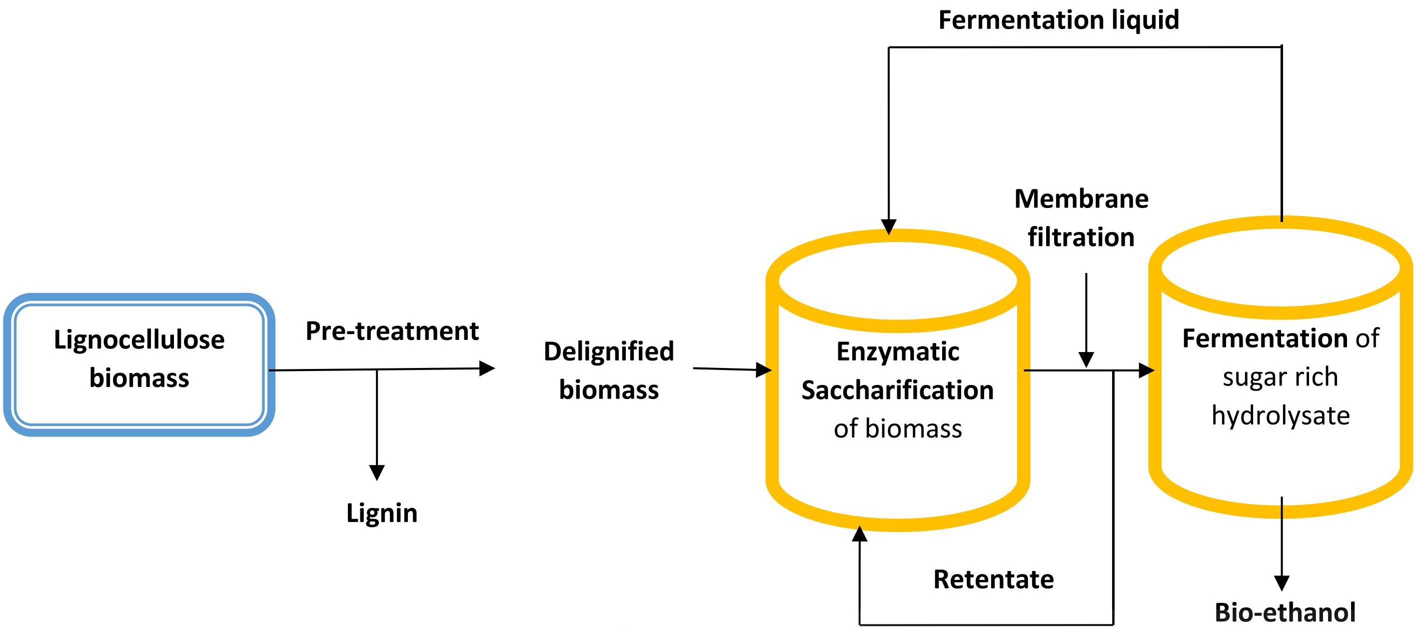


Figure 11.12: Conversion of food waste to bio-eth

Unprocessed food waste is also converted into bio-ethanol by simultaneous hydrolysis and fermentation using thermophilic anaerobic bacteria. The production of ethanol from a single reactor using anaerobic bacteria under thermophilic conditions is considered as a clean and green technology eliminating the harmful chemicals. In order to enhance the bio-ethanol production and to make the process to be cost effective addition of food waste to the kitchen waste and waste paper was proved to be viable and successful. The kitchen waste acts as nutrient source, acidity regulator and as a carbon source Simultaneous saccharification and fermentation is carried out after liquification of kitchen waste for effective fermentation.

[B] Bio-butanol

Bio-butanol is non-polar and is used as a fuel for internal combustion engine. Gasoline compatible engines are worked with using bio-butanol without any further modifications. The cost of the substrate required for the production of bio-butanol is the major limiting factor. Starchy food waste is considered to be viable for the butanol production. Starchy food waste like batter liquids, inedible dough, bread etc are used as substrate and batch fermentation is carried out for the butanol production.

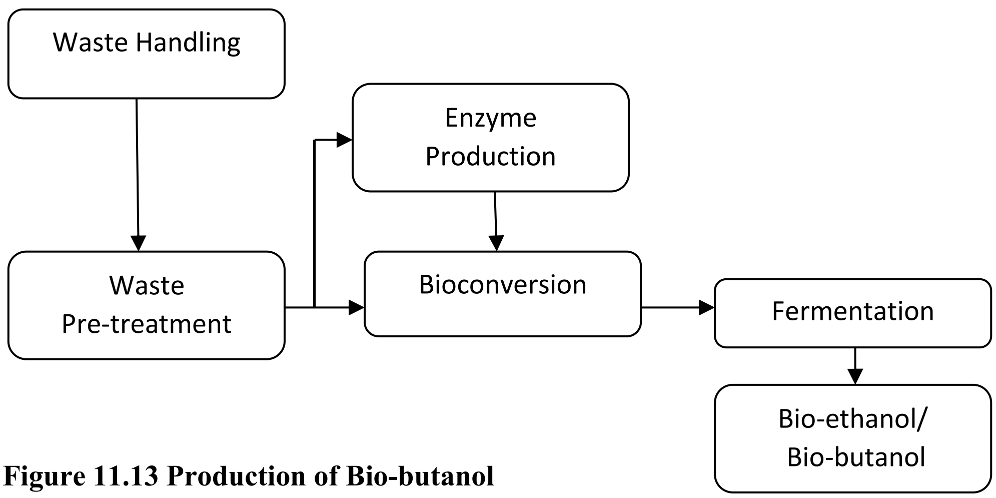


Figure 11.13 Production of Bio-butanol

[C] Bio-diesel

Biodiesel is composed of mono-alkyl-esters of long chain fatty acids. It is produced from the waste cooking oils. At low temperatures biodiesel has gelling issues due to its high viscosity and low volatility which leads to the clogging of pumps. This can be improved by blending and the common blend used is B-20. The major limitation in the production of biodiesel is the huge percapita for generation. Sources like castor seed oil, mixed non-edible oil ate used to overcome the high cost of production. The major sources of the waste oil are the restaurants, chips shops etc. In order to enhance the production of biodiesel different blends were carried under controlled conditions. Various parameters such as temperature, catalyst concentration, reaction time etc influences the production of biodiesel are to be optimised. In order to make the process feasible and economically viable use of mixed oil for biodiesel production has reduced the energy input.

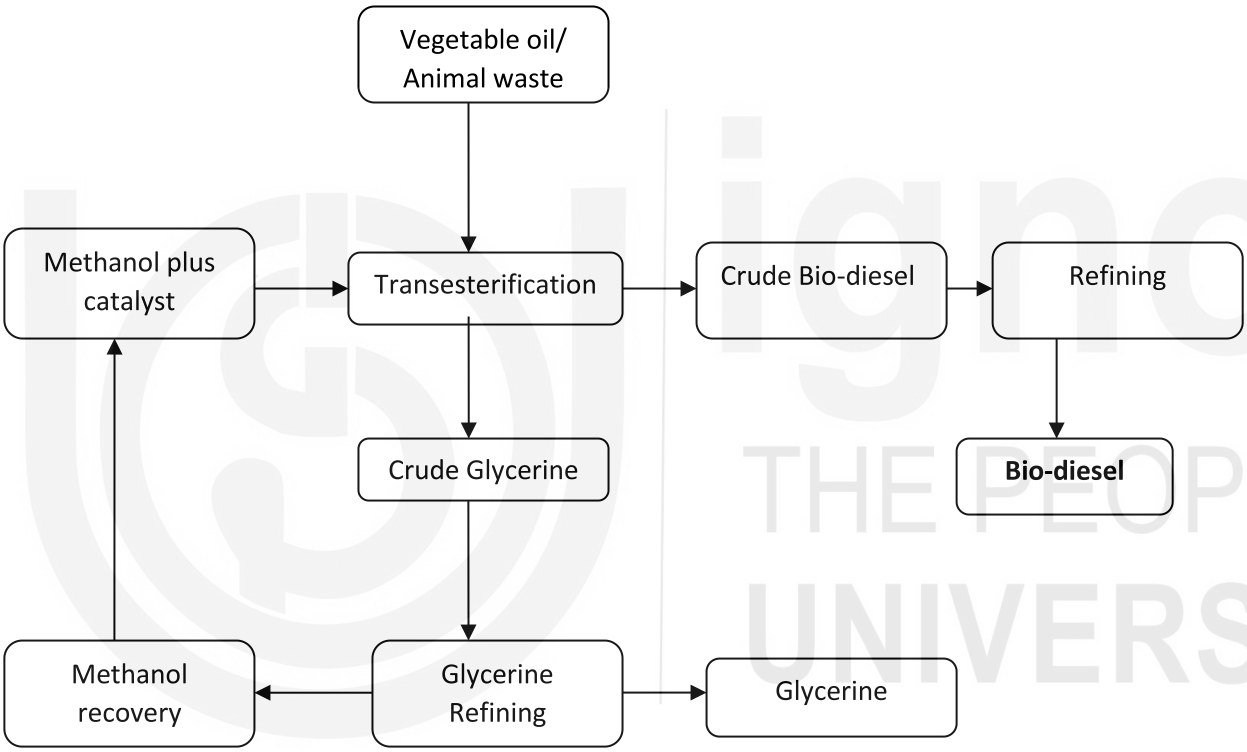


Figure 11.14: Schematic bio-diesel production path

SAQ 4

a) What the different types of bio-fuels that can be obtained from solid waste?

b) What are microbial fuel cells (MFC's)?

c) Explain the advanced treatment methods used in the treatment of solid waste?

11.7 WASTE TO BIO ENERGY

[A] Biogas

Biogas is produced of different organic wastes by anaerobic digestion. Biogas production by anaerobic digestion of kitchen waste and food waste is promising. Biogas is mixture of CH_4, CO_2, H_2S, moisture and siloxanes which is considered as a renewable gas. The pre-treatment of substrate have considerable effects on the biogas production from solid waste. Autoclave, ultrasonication and microwave are some of the pre-treatment methods and then followed by anaerobic digestion. Pre-treatment of the substrate by ultrasonication is considered to be the best method in improving the biogas production. In order to increase the production of biogas, co-digestion with a suitable substrate such as cow manure, pig manure, grease trap waste etc could lead to better results when compared with the mono-digestion.

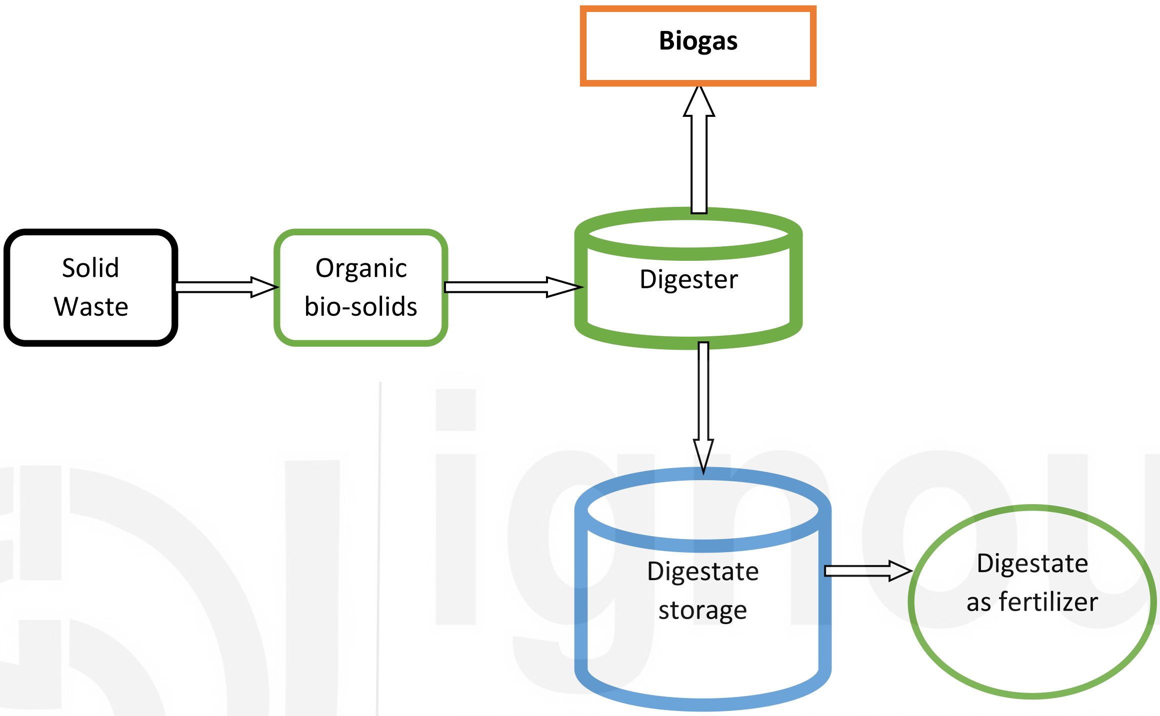


Figure 11.15: Schematic view of Biogas Production

Various parameters effect the biogas production such as pH, temperature etc. So by maintaining the optimum conditions the waste should be minimised and the production of biogas is to be maximised. Several bioreactors like a tubular reactor, anaerobic sequencing batch reactor (ASBR), continuously stirred tank reactor (CSTR), upflow anaerobic sludge blanket (UASB) and fixed film reactor in batch, continuous one-stage, and continuous two-stage process depending on the methanogenic bacteria variability are used for anaerobic digestion.

[B] Bioelectricity

Bioelectricity is mainly produced through the combustion of lignocellulose feedstock .These lignocellulose feedstock is obtained from biomass sources such as agricultural products and residues, sawmill residue, plantation forests etc. For the generation of electricity the agricultural and forest resides are converted to biomass feedstock. The production of bioelectricity is considered as economically feasible and also reduces the green house gas emissions. The bioelectricity production is enhanced by combining of the agricultural and forest wastes are done using simulated standards. Production of bioelectricity from the urban solid waste is also considered as a best option to meet the electricity needs of the urban population and to minimise the generated waste. The generation of waste increases with the economic growth and urbanization. By knowing the average amount of waste generated daily can help in the policy making for the production of bio-energy from locally available biomass which can contribute a sustainable electricity system.

Thermo-chemical conversion processes can be used for the production of bioelectricity. One such process is combustion. It is chemical conversion of the biomass into CO_2 , water and heat in presence of oxygen at high temperature. The biomass is transformed to volatile gases and char, where the volatile gases give heat when they reacted with oxygen. Biomass gasification is another process for the generation of bioelectricity. Syngas is formed by the conversion of solid waste through gaseous conversion. When compared in terms of energy required and economical, gasification is considered as a best option than combustion. Gasification technology is best used in the rural areas for treating the local solid waste generated by using gasifiers, as it reduces the issues of waste generated in rural areas and electricity supply. The combination of both gasifiers and combustion boilers could significantly improve the electrical efficiency.

Use of microbial fuel cell (MFC) technology is also considered as one of the promising process in the conversion of solid waste to bioelectricity. MFC process involves electrogenic bacteria foe the conversion of biomass into bioelectricity under anaerobic conditions. Treatment of various types of wastes such as municipal solid waste, household waste, food waste etc can be done simultaneously by using MFCs for the generation of bioelectricity. It consists of two chambers separated by a proton exchange membrane which is biotic anode and abiotic cathode. Various factors can influence on the generation of bioelectricity using MFCs such as pH, concentration of substrate, temperature, hydraulic retention time and activity of microorganisms.

11.8 WASTE TO BIO-HYDROGEN

Hydrogen can replace as alternative fuel in place of fossil fuel due to many advantages. Hydrogen can be used for direct conversion into electricity in fuel cells. It is considered as environmentally friendly as it produces water upon combustion. Production of bio-hydrogen is done by both reforming and non-reforming methods. Steam reforming of methane and other hydrocarbons can be used for the production of bio-hydrogen. Several non-reforming methods are used in the production of bio-hydrogen such as dark fermentation, photo fermentation, use of hybrid systems etc. The most feasible and efficient method is dark fermentation which does not require any external energy and is also considered as a low cost treatment technique.

At present the overall production of hydrogen is more than 1 billion m^3 for a day from various sources like oil, natural gas, coal and water electrolysis. Hydrogen does not exist in its elemental form and is most abundantly element which is available on the earth. The major sources of production of H_2 molecule are the fossils and several studies predicted that hydrogen could be the future fuel as hydrogen could replace as a renewable resource with the non renewable resources globally. Hydrogen production by biological process from waste is considered as sustainable due to its renewability and is on emerging demand. Biologically synthesized H_2 is beneficial, the low investment cost and low energy requirement makes the production of hydrogen by biological synthesis beneficial, as it has high calorific value high energy yield of 142 kJ/g which is 2.7 times higher than any hydrocarbon fuel. For a chemical industry hydrogen is an important feedstock. Physico–chemical method requires lot of energy and generates GHGs which leads to global warming. Biological methods have a low-cost substrate, reduce energy usage and are environmentally sustainable. Biological H_2 production is generally followed by anaerobic fermentation, which is categorized into light independent and light dependent group. The annual generation of municipal solid waste is increasing due to increase in the urbanisation, so the nutrient rich municipal solid waste is considered as a best source for the production of bio-hydrogen as its is availability is cheap and abundant. Moreover the solid waste from the municipalities contains both the micro and the macronutrients such as carbohydrates, lipids, proteins etc. Various parameters such as the solid waste composition, pH, temperature etc influence the bio-hydrogen production. By controlling these factors production of bio-hydrogen from municipal solid waste is considered as the viable and economic sustainable process.

11.9 WASTE TO VALUE ADDED PRODUCTS

Waste contains many high value substances that can be reused. Based on the conversion technology adapted the solid waste can be converted into commercial products as new product ingredients or as raw material for secondary processes. At the end of life cycle of food production a number of valuable substances can be separated and recycled, but the only backdrop is that those processes are not cost. Several value added products such as sugars, organic acids, antioxidants, activated carbon adsorbent, antioxidants etc can be produced from municipal solid wastes.

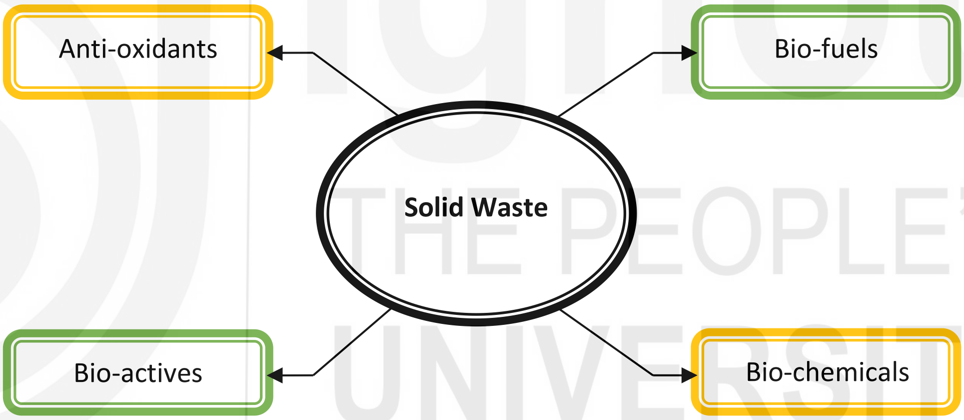


Figure 11.16: Waste to value added products

[A] Activated carbon adsorbent

Activated carbon adsorbent is effectively used in the removal of anionic and cationic dyes from aqueous solution. It is obtained from the conversion of grape processing waste. Activated carbon adsorbent is mainly used in the adsorption of anionic and cationic dyes in the industries in various fields like separation and purification process. Hence, its demand is increasing day by day. The production of activated carbon adsorbent from grape processing waste is considered as the low cost technique and cleaner technology and also it is found that the adsorption capacity is higher when compared with the locally available adsorbent from the agricultural waste.

[B] Antioxidants

These are the compounds used to from free radicals by preventing the oxidation of molecules. They are used in the food preservatives and cosmetic industry. The consumption of the natural antioxidants has increased at a rapid pace as the use of natural antioxidants reduce the risk of some human diseases while the use of synthetic antioxidants lead to potential health hazards. Food wastes such as seeds, peel etc are the sources for the antioxidants production. The enhancement in the production of antioxidants depends on various parameters like, temperature, extraction time and solvent concentration. It was found that the potato peel waste as a good source for antioxidants production which can effectively limit oxidation of oils, whereas grape seeds are used for the production of vitamin-E. These antioxidants production technologies are considered as the best and viable methods compared to the conventional strategies in terms of processing time and energy consumption which lead to many environmental and ecological benefits.

[C] Bio-actives

These are the compounds that are produced form the fish processing waste. These are generally used to show an effect on living organisms like potential health benefits functioning as antidiabetic, anticancer, anticoagulant, antimicrobial agents. The efficient sources of bio-actives are the shell fish and fish processing wastes. Various bioactive proteins, peptides and amino acids are produced from fish processing waste. The production of bioactives from fish waste is considered as economically viable as the peptides derived from the waste function as promising nutraceuticals.

Ammonia

Ammonia is produced by chemical synthesis from syngas. It is considered as one of the largest synthetic chemical product. Ammonia is used in the production of fertilizers such as urea and for the organic chemical feedstock manufacturing in plastic industry. It is used in the production of explosives such as hydrazine in less quantity and can be converted to cyanides and nitric acid. The industrial production of ammonia includes production of syngas followed by the conditioning of the gas, compressions and synthesis of ammonia. The main purpose of production of syngas and the gas conditioning is to provide clean H_2 for input to the ammonia synthesis. More than half of the H_2 produced from the production of syngas is used for the ammonia production. For the ammonia synthesis a feed stream which contains clean synthesis gas, steam and nitrogen is considered. A water-gas shift reaction takes place at high temperature which is followed by low temperature to convert the carbon monoxide into H_2. Hot potassium carbonate solution is used for the removal of carbon dioxide from the gaseous stream because both CO and CO_2 can be poisonous in the synthesis of ammonia.

The gaseous stream of N_2 and H_2 is cooled after the removal of CO and CO_2 and the excess steam is removed by condensation. The next step is to compress and preheating the gaseous stream before entering the ammonia synthesis reactor

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

The ammonia synthesis reactor consists of a pressure vessel with sections for heat exchangers and catalyst beds. The removal of the generated heat by the synthesis reaction which is exothermic is the main design challenge to control reactor temperature.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

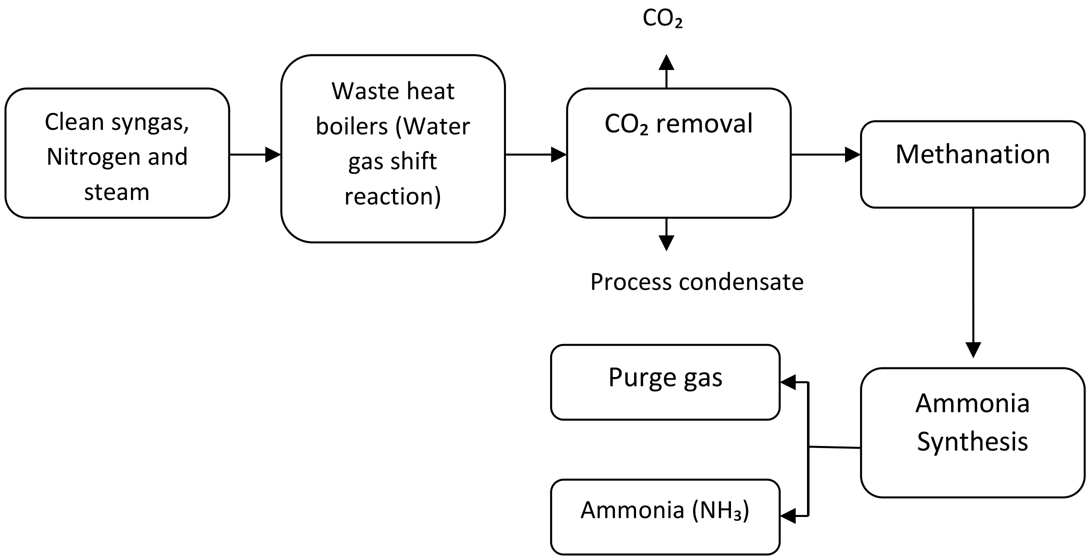


Figure 11.17: Flow Diagram for Conversion of Syngas to Ammonia

The maximum conversion at equilibrium occurs at low temperatures and high pressures, as the reaction is highly exothermic. The ammonia produced is finally condensed, removed by a separator and sent to storage.

SAQ 5

a) What are different types of bio energies? Discuss the mechanism involved in each method?

b) What is bio hydrogen? Discuss the process of conversion of waste to bio hydrogen?

c) Discuss how syngas is converted to ammonia?

11.10 SUMMARY

In this unit we mainly discussed about the role of ISWM, application of ISWM, and hierarchy of ISWM. The concept of circular economy i.e. Circular economy is a closed loop system and it functions with the industries and the societies that imitate the behaviour of the ecosystems. Various biological and chemical conversion technologies used in solid waste management. Subsequently, advanced treatment methods of solid waste management and different waste to energy conversion techniques like waste to fuels, waste to bio-hydrogen, waste to bio-energy and waste to value added products were discussed.

11.11 KEYWORDS AND DESCRIPTIONS

Keywords	**Meaning/ Definition**
Integrated solid waste management (ISWM)	It is a system that considers how to prevent, recycle and manage solid waste in ways that most effectively protect human health and environment.
Sustainability	Avoiding the depletion of natural resources in order to maintain an ecological balance.
Syngas	Mixture of gas containing hydrogen, carbon monoxide, and carbondioxide.
Bio-energy	Energy generated from organic matter.

11.12 REFERENCES

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