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ONLINE COURSE WORK

SUBJECT NAME: Waste Management of Food Industry

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Module 1 8L

Lecture 1:

Due to rapid increase in the production and consumption processes, societies generate as well as reject solid materials regularly from various sectors – agricultural, commercial, domestic, industrial and institutional. The considerable volume of wastes thus generated and rejected is called solid wastes. In other words, solid wastes are the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted. This inevitably places an enormous strain on natural resources and seriously undermines efficient and sustainable development.

Types of Environmental Pollution :

There are three forms of environmental pollutants viz , gases, liquids and solids. The pollutants emitted through industrial chimneys and exhausts, mainly oxides of nitrogen, hydrocarbons CO_2, H_2S, SO_2, Cl_2, etc. , cause air pollution. There are no direct biological means by which these pollutants can be arrested

Waste discharge from various sources pollute water, which leads to land pollution too, in four ways. Accordingly, there are four types of water pollution.

1. Physical pollution
2. Chemical pollution
3. Physicological pollution
4. Biological pollution

Physical pollution:

Physical pollution of water is caused by the solid constituents of industrial effluents and sewage water. The nature of these solids varies depending on type of industry. For example , in tannery effluent, the total solid content, including suspended solids, may vary from 20,000ppm to 150000 ppm, of which a major portion may be $CaCO_3$, hair, flesh, etc. from the lime yard and sludge from the vegetable tanning yard. Most of the solids can be separated from the liquid by some physical process as settling tank and filtration

Chemical pollution:

Solid and colloidal chemicals that cannot be separated easily by any physical method, even by ultra-filtration, cause chemical pollution. These may be either organic or inorganic in nature. For examples, an appropriate pH of water is important for the healthy living of aquatic species. For fish to survive, the desirable pH range is 5-9. However, due to the discharge of effluents containing inorganic soluble chemicals such as acids, salts and alkalies, the pH of a naturalwater source may change, which is not desirableheavy metals , such as Cr, Ba and As are also responible for the toxicity of water when effluents containing such contaminants are discharged into water bodies.

Lecture 2:

Physicological pollution:

Physicological pollution, though different from chemical pollution, is also caused by the soluble chemicals and colloidal substances present in waste water.

Biological pollution:

Biological pollution is caused by the organic compounds present in waste water or solid waste. The various types of micro organismspresent in air, water and soil decompose these polymeric complex compounds into simplier ones and finally convert them into CO_2 and H_2O by consuming large quantities of dissolved oxygen, thereby rendering the water or the surroundings oxygen deficient. The following correlations show how oxygen is consumed during biological degradation processes:

Organic complexes compound + $O_2 \rightarrow$ smaller intermediate compound + CO_2

Intermediate compound + $O_2 \rightarrow CO_2 + H_2O$

If proteinaceous materials are present in the waste, then micro organisms convert the nitrogen into nitric acid by oxidation- reduction reactions. CO_2, H_2O, and HNO_3, are the end products of biological degradation leading to stabilization of biodegradable organic compounds.

Lecture 3:

Different waste disposal technique :

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.

Waste Disposal

It is the management of waste to prevent harm to the environment, injury or long term progressive damage to health. Disposal of waste is where the intention is to permanently store the waste for the duration of its biological and chemical activity, such that it is rendered harmless. Disposal of wastes can be made to three locations namely surface water, atmosphere and land. The land represents not only the appropriate disposal medium for many wastes but also provides opportunity to manage wastes with a minimum of adverse environmental eff

ects. Disposal of waste could be done through the following methods.

Methods of Waste disposal

1. Integrated waste management (IWM)

Integrated waste management using LCA (life cycle analysis) attempts to offer the best option for waste management. IWM entails using a combination of techniques and programmes to manage the municipal/urban waste stream.

2. Landfill

Disposing of waste in a landfill involves burying the waste, and this remains a common practice in most countries. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials.

Advantages:	Disadvantages:
• volume can increase with little addition of people/equipment • filled land can be reused for other community purposes	• completed landfill areas can settle and requires maintenance • requires proper planning, design, and operation

Lecture 4:

3. Incineration

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

Advantages:	Disadvantages:
• requires minimum land • can be operated in any weather • produces stable odor-free residue • refuse volume is reduced by half	• expensive to build and operate • high energy requirement • requires skilled personnel and continuous maintenance • unsightly - smell, waste, vermin

4. Recycling

Recycling refers to the collection and reuse of waste materials such as empty beverage containers. The materials from which the items are made can be reprocessed into new products. Material for recycling may be collected separately from general waste using dedicated bins and collection vehicles, or sorted directly from mixed waste streams.

Advantages:	Disadvantages:
• key to providing a liviable environment for the future	• expensive • some wastes cannot be recycled • technological push needed • separation of useful material from waste may be difficult

5. Ocean Dumping

This is the deposition of waste into the water bodies, particularly the ocean. Controversy surrounds ocean dumping as a waste disposal method. Although the waste may provide nutrients for some sea life, it's widely believed that the harmful effects would outweigh any benefits.

Advantages:	Disadvantages:
• convenient • inexpensive • source of nutrients, shelter and breeding	• ocean overburdened • destruction of food sources • killing of plankton • desalination

6. Open Dumping

This method involves disposing waste on an open land. As simple as this is, it is not without its own shortcoming.

Advantages:	Disadvantages:
• inexpensive	• health - hazard - insects, rodents etc. • damage due to air pollution • ground water and run-off pollution

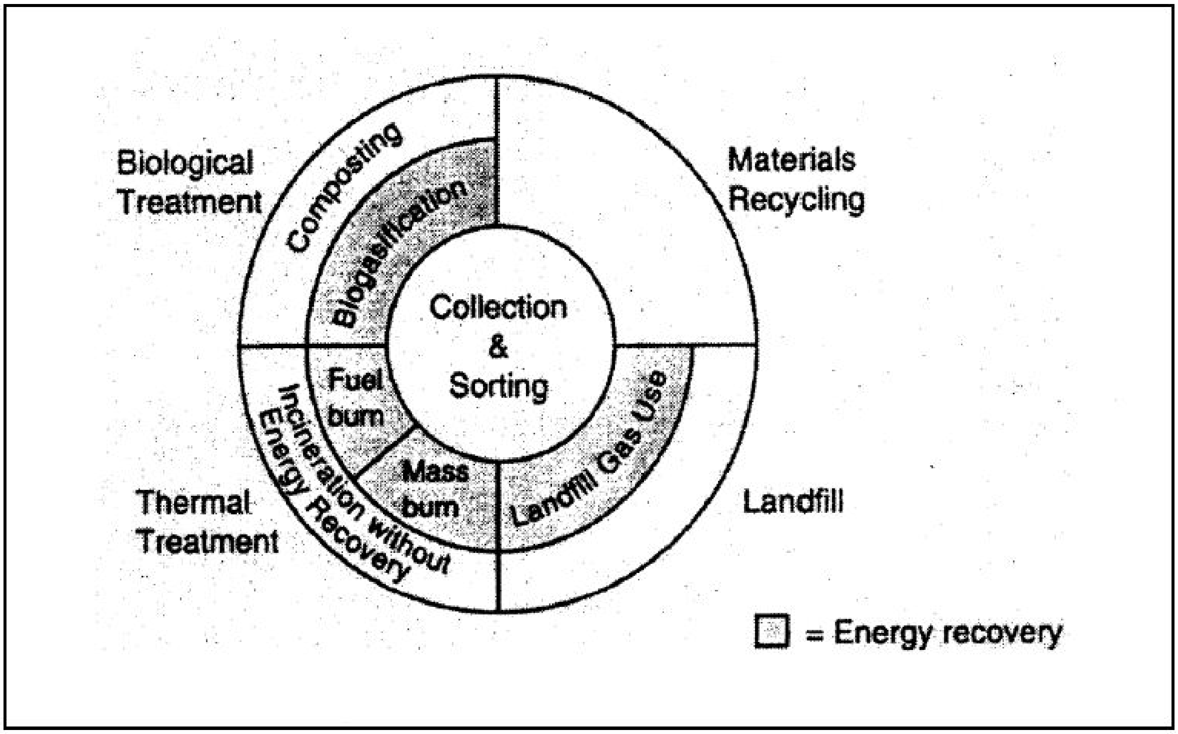
7. Biological reprocessing

Waste materials that are organic in nature, such as plant material, food scraps, and paper products, can be recycled using biological composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes

8. Energy recovery

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

Elements of Integrated Waste Management



Lecture 5:

Bioremediation is the biological treatment and removal of pollutants from the environment. In biological treatment processes, the nature of the pollutants, solid waste or liquid effluents plays an important role. The basic constituents of biodegradable organic waste are usually cellulosic, starchy, lipid, proteinaceous or mixed in nature. The quality of the waste depends on its source. Depending on their origin , waste have been grouped into seven categories:

1. Agricultural
2. Fruit and vegetable
3. Animal
4. Plant
5. Community
6. Industrial
7. Construction material

Physico-chemical characteristics of waste material:

The various biological treatment treatment

Processes , including biomethanation , involve micro organisms that derive the requisite amount of nutrients essential for their growth and metabolism from the organic material they act on. Hence an ideal substrate or pollutant , which needs to provide these nutrients, should posses the following characteristics

1. Proper carbon to nitrogen (C/N) ratio
2. Appropriate concentration of volatile matter
3. In the case of solid substrate,the smallest possible particle size

Type of waste	Examples
Crop waste	Sugarcane trash, weeds, corn and related crop stubble, straw, spoiled fodder, spoiled vegetables, rotten grains
Animal waste	Cattle shed waste (dung, urine, litter), poultry litter, sheep and goat droppings, slaughterhouse waste (blood, meat), fishery waste, leather and wool waste, night soil
Plant waste	Aquatic waste (algae, seaweed, water lettuce, water hyacinth), forest litter (twigs, barks, branches, leaves, *Lantana camara*, *Ipomea* sp.)
Industrial waste	Oil cakes, bagasse, rice bran, tobacco waste and seeds, waste from fruit and vegetable processing, press mud from sugar factories, tea waste, cotton dust from textile industries, waste paper, wheat bran, paper mill, and tannery effluents
Municipal waste	Garbage, sewerage sludge, wastewater

Types of waste suitable for anaerobic digestion

Lecture 6:

Proper carbon to nitrogen (C/N) ratio:

A very high C/N ratio reduces the efficiency of the process due to the limited availability of nitrogen. On the other hand, a very low ratio results in the formation of large quantities of ammonia, which is toxic to the bacterial population. It has been found that in order to achieve an optimum rate of digestion, it is important to maintain the C/N ratio(by weight) close to 30.

Material	N (%)	C/N
Animal waste		
Urine	15–18	0.8
Blood	10–14	3
Fish scraps	6.5–10	5.1
Mixed slaughter	7–10	2
Poultry manure	6.3	6
Sheep manure	2.7	16
Pig manure	3.8	14
Horse manure	2.3	25
Cow manure	1.7	18
Farmyard manure (average)	2.15	14
Night soil	5.5–6.5	6–10
Plant waste		
Young grass clippings (hay)	4	12
Grass clippings (average mixed)	2.4	19
Seaweed	1.9	19
Cut straw	1.1	48
Wheat straw	0.3	128
Rotten sawdust	0.25	208
Raw sawdust	0.1	511
Water hyacinth	2.16	20.5
Sorghum	0.5	100.85
Rice straw	1.34	78.58
Household waste		
Raw garbage	2.2	25
Bread	2.1	30
Potato peel	1.5	25
Paper	0.0	-
Municipal solid waste	0.58	26.23

Approximate nitrogen content and C/N ratio of various waste materials (dry weight basis)

Concentration of volatile matter:

In the substrate prepared for feeding to the digestor, the concentration of the volatile solid matter is a crucial parameter. The volatile solid content of a waste material is expressed as the difference between the total dry solid content and ash

Raw material	Total solids (%)	Volatile solids (%)	N (%)	P (%)	K (%)
Cattle dung (wet weight basis)	20–25	10–15	0.4–0.7	0.1–0.2	-
Night soil and urine	5	3.4	0.57	0.052	0.22
Poultry manure (wet)	17	-	1.2	1.2	-
Agricultural waste (dry basis)					
Linseed stock	-	30	-	-	-
Rice bran	-	60	-	-	-
Cotton	-	90	-	-	-
Groundnut shell	70.50	30	1.21	-	-
Bagasse	-	40	-	-	-
Jute stalk	-	40	-	-	-
Spent coconut shell	71.51	30	1.14	-	-
Rice husk	-	10	-	-	-
Young rye plants	-	50	-	-	-
Mature wheat straw	-	70	0.30	-	-
Soya bean tops	-	50	-	-	-
Young corn stalks	-	60	-	-	-
Mature corn stalks	-	70	-	-	-
Municipal solid waste	68.2	27.57	0.58	0.59	0.67

Percent total and volatile solid content in various waste materials

Particle size of substrate:

The size of the particles of the substrate, prepared from various waste materials, is another important controlling criterion in the bioconversion process. It has been observed that materials shredded into small pieces ferment better and pose fewer problems than bulky and dense materials. The higher rate of fermentation increases the rate of gas production, as it increases the surface area exposed to bacterial attack and thereby reduces the retention time in the digester. Shredding the waste material can also minimize other problems that arise due to clogging of the inlet and outlet pipes.

Lecture 7:

It has been seen that the characteristics of liquid waste vary widely, depending upon the type of process industry. Therefore , a good combination of physic-chemical methods and low cost biological oxidation methods is adequate for the treatment of most liquid waste obtained from process industries.it would be helpful to note that, in general, the equipment used for controlling water pollution includes the following:

1. Chemical recovery equipment.
2. Coarse screening.
3. Fine screening
4. Grit removal equipment.
5. Oil removal equipment.
6. Flocculators
7. Clarifiers
8. Sludge disposal system
9. Chemical preparation and dosing systems
10. Mixing/ pumping systems
11. Biological oxidation/ clarifiers/ sludge disposal systems
    - Activated sludge process, trickling filters, rotating biological contractors, fluidized bed contactors

Lecture 8:

Recommended effluent treatment practices for major industries

Industry	Nature of waste	Recommended treatment practices
Cane sugar	Slightly acidic, high solid content, moderate BOD, low nitrogen content	Segregation of waste; reuse of cooling water; marketing of molasses and bagasse; composting of high strength waste with night soil (to make up for nitrogen deficiency); stabilization pond (after achieving C/N of 30)
Tanning	Alkaline, high suspended solid content, high BOD, highly persistent colour from vegetable tanners, chromium in chrome tanneries	Segregation of waste; recovery of tannin; lime treatmentof spent tan liquor; subsequent aeration (to oxidize catechol and pyrogallol) followed by anaerobic digestion for combined waste; subsequent stabilization pond or oxidation ditch
Alcohol	Acidic, high solid content, BOD, COD, chlorides, potash, sulphates and nitrogen	Segregation of waste; reuse of cooling water; better utilization of raw materials; by-product (e.g. potash and methane) recovery; discharge into municipal sewer; two stage treatment: anaerobic lagoon and oxidation ditch
Dairy	Alkaline, high volatile solid content, moderate BOD, high nitrogen content grease	Waste volume and strength reduction; segregation of waste; anaerobic lagoon followed by stabilization pond; oxidation ditch; disposal in municipal sewers
Canning	High BOD and suspended solid content	Screening for recovery; anaerobic lagoon; floatation; chemical precipitation
Slaughter	High total and volatile solid content; moderate BOD, grease	Grease recovery; aerobic stabilization ponds

Module 2 8L

Lecture 9:

The treatment of water can be classified into three categories,

- *Treatment of raw water for drinking purposes*
- *Treatment of raw water specialised industrial applications.*
- *Treatment of waste water to make it acceptable for release or reuse.*

Water that has to be used for domestic purposes should be thoroughly disinfected to eliminate disease causing microorganisms but can contain appreciable amounts of dissolved salts such as calcium and magnesium. The water that has to be used for industrial purposes must be soft to prevent scale formation in boilers but can contain microorganisms. Although most of the physical and chemical processes used to treat water involve similar phenomena, the method and degree of water treatment are site specific. These processes, which consist of series of unit operations, are applied in different combinations and sequences depending upon the prevailing situations of influent concentration, composition and specifications of the effluent.

Municipal Water Treatment For Raw Water:

For a water treatment system to bring raw water to drinking water quality, depends to a large extent on the quality of the source of water. Some water requires only simple disinfection. Surface water will usually need to be filtered and disinfected, while ground water will often need to have hardness (calcium and magnesium) removed before disinfection.

A typical treatment plant for surface water might include the following sequence of steps:

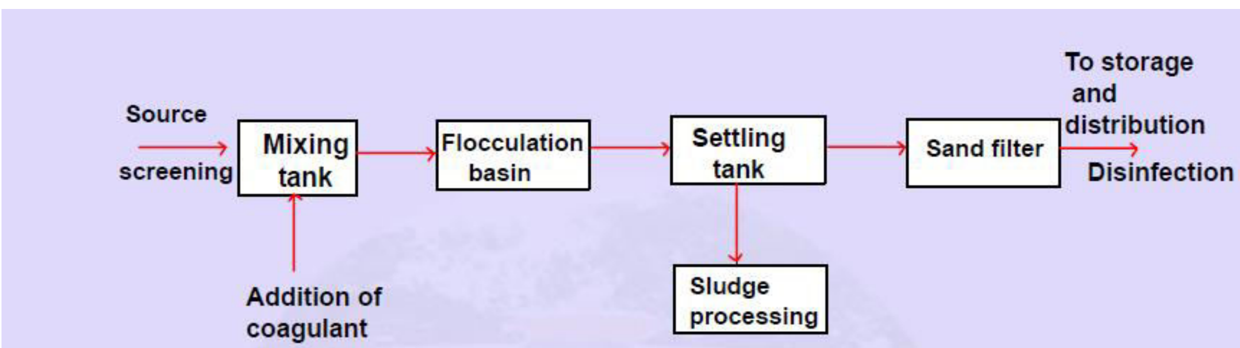


Fig: Typical water treatment for waste water

- ***Screening*** *to remove relatively large floating and suspended debris.*
- ***Mixing*** *the matter with chemicals that encourage suspended solids to coagulate into larger particles that will more easily settle.*
- ***Flocculation****, which is the process of gently mixing the water and coagulant, allowing the formation of large floc.*
- ***Sedimentation*** *in which the flow is slowed enough so that gravity will cause the floc to settle.*
- ***Sludge processing*** *where the mixture of solids and liquids collected from the settling tank are dewatered and disposed of.*
- ***Disinfection*** *of the liquid effluent to ensure that the water is free from harmful pathogens.*

Treatment Of Raw Water For Industrial Use:

The following factors must be taken into account for designing and operating an industrial water treatment facility.

- *Quantity of Water requirement*
- *Quantity and quality of available water sources*
- *Successive uses for applications requiring progressively lower water quality*
- *Water recycle*
- *Discharge standards.*

The basic external treatment that is usually applied to the entire water supply is as follows. It consists of processes such as aeration, filtration, and clarification to remove materials from water such as suspended or dissolved solids, hardness and dissolved gases from water that may cause problems. After this basic treatment, the water may be divided into different streams, some to be used without further treatment and the rest to be treated for specific applications.

Internal treatment is designed to modify the properties of water for specific applications. Examples of the internal treatment include the following:

- *Addition of either hydrazine or sulfite to remove dissolved oxygen.*
- *Prevention of formation of calcium deposits by the addition of chelating agents to bind the dissolved calcium.*
- *Removal of calcium by the addition of precipitants such as phosphate .*
- *Treatment with dispersants to inhibit scale formation.*
- *Prevention of corrosion by the addition of inhibitors.*
- *pH adjustment.*
- *Disinfection for food processing uses or to prevent bacterial growth in cooling water.*

- ***Waste Water Treatment:***
  Basic processes of water treatment:

The purpose of waste water treatment is to remove the contaminants from water so that the treated water meet the acceptable quality standards. The quality standards usually depend upon whether the water will be reused or discharged into a receiving stream. Available waste water treatment processes can be broadly classified as physical, chemical or biological. These processes which consists of series of unit operations, are applied in different combinations and sequences depending upon the prevailing situations of influent concentration, composition and condition and specification of the effluent.

Physical processes principally comprise screening, sedimentation, floatation and filtration. Chemical processes utilise the chemical properties of the impurities of the added reagents. Comonly used chemical processes are precipitation, coagulation and disinfection. Other physical and chemical processes such as air stripping, carbon adsorption, oxidation and reduction ion-exchange and membrane processes like reverse osmosis and electrodialysis are also important in certain cases. Biological processes utilise biochemical reactions; typical examples are biofiltration and activated sludge process.

These processes are usually grouped as primary treatment, the secondary treatment, and the tertiary or the advanced waste treatment. Primary treatment removes identifiable suspended solids and floating matter. In the secondary treatment which is also known as biological treatment, organic matter that is soluble or in the colloidal form is removed. Advance waste treatment involves physical, chemical or biological processes or their various combinations depending on the impurities to be removed. These processes are employed to remove residual soluble non-biodegradable organic compounds including surfactants, inorganic nutrients and salts, trace contaminants of various types, and dissolved inorganic salts. The advanced waste treatment processes are expensive, and are used only when water produced is required to be of higher quality than that by secondary treatment.

- ***Primary treatment of waste water:***

The primary treatment comprises of pretreatment step and sedimentation step.

Pretreatment:

It consists of screening and grit removal. Screening removes or reduces the size of trash and large solids that get in to sewage system. These solids are collected on screens and scraped off for subsequent disposal. Comminuting devices shred and grind solids in the sewage. Particle size may be reduced to the extent that the particles can be returned to the sewage flow. After screening, the waste water is allowed to enter a grit chamber for the removal of inorganic grit consisting of sand, gravels and pebbles. Grit chambers are provided to protect pumps from abrasion and to reduce the formation of heavy deposits in pipes and channels. Grit is normally allowed to settle in a tank under conditions of low flow velocity and it is then scraped mechanically from the bottom of the tank.

- **Primary sedimentation:**

Primary sedimentation removes both the settleable and floatable solids. Also the flocculant particles which tend to aggregate will be allowed to settle by the addition of chemicals (iron salts, lime and alum). The material that floats in the primary settling basin is known collectively as grease. Normally some of the grease settles with the sludge and floats to the surface, which can be removed by skimming.

This process of flocculant settling takes place when the settling velocity of the particles increases due to coalescence with other particles. This type of phenomenon is clearly observed in primary clarifiers.

The opportunity for coalescence increases with increase in bed depth, and as a result the particle removal efficiency depends on both the overflow and bed depth.

- **Secondary treatment for municipal waste water :**

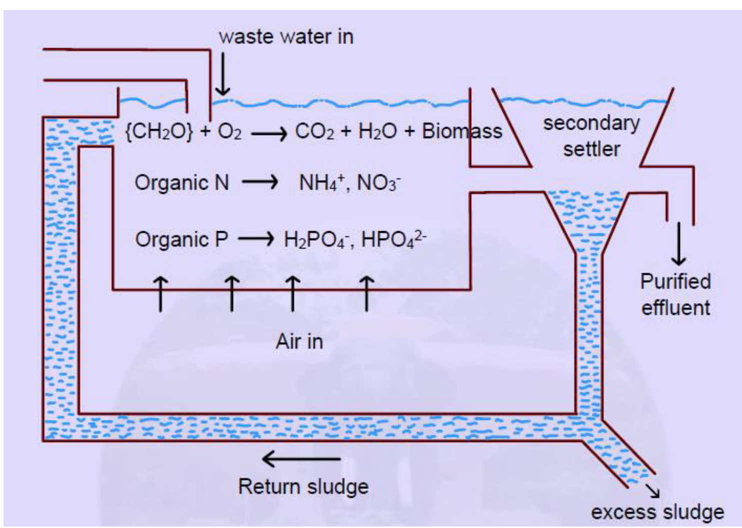
In secondary or biological treatment, oxygen supplied to the bacteria is consumed under controlled conditions so that most of the BOD is removed in the treatment plant rather than in the water course. Thus, the principal requirements of a biological waste treatment process are an adequate amount of bacteria that feed on the organic material present in waste water, oxygen and some means of achieving contact between the bacteria and the organics.

Two of the most commonly used systems for the biological waste treatment are the biological film system and the activated sludge system. In the biological-film system also known as trickling filters, the waste water is brought into contact with a mixed microbial population in the form of a film of slime attached to the surface of a solid support medium whereas in the activated sludge system the waste water is brought in contact with a diverse group of microorganisms in the form of a flocculant suspension in an aerated tank. In both cases the organic matter is metabolised to more stable inorganic forms. The most popular means of treating domestic sewage has been the biological film system because of its ease of operation. However the activated sludge process can be more reliably be handled when handling large volumes of waste water, and a high degree of treatment is achieved.

Lecture 10:

- ***Activated sludge process :***

The most versatile and effective of all the waste treatment processes is the activated sludge process. A typical activated sludge plant is shown in fig . The essential features of the process are: an aeration tank where the organic matter is brought into intimate contact with the sludge from the secondary clarifier. This sludge is heavily laden with microorganisms which are in an active state of growth. Air is introduced into the tank, either in the form of bubbles through diffusers or by surface aerators. The microorganisms utilise oxygen in the air and convert the organic matter containing N and P into stabilised, low energy compounds such as CO_2, H_2O and synthesise new bacterial cells. The effluent from the aeration tank containing the flocculent biomass, known as the sludge, is separated in a settling tank, sometimes called a secondary settler or clarifier.



The essential features of the process are: an aeration tank where the organic matter is brought into intimate contact with the sludge from the secondary clarifier. This sludge is heavily laden with microorganisms which are in an active state of growth. Air is introduced into the tank, either in the form of bubbles through diffusers or by surface aerators. The microorganisms utilise oxygen in the air and convert the organic matter containing N and P into stabilised, low energy compounds such as NO_3^- , SO_4^{2-} , NH_4^+, $H_2PO_4^-$, H_2O, CO_2 and synthesise new bacterial cells. The effluent from the aeration tank containing the flocculent biomass, known as the sludge, is separated in a settling tank, sometimes called a secondary settler or clarifier.

These solids settle out in the settler and a fraction of them is discarded. Part of the solids is recycled as return sludge to the head of the aeration tank and comes into contact with fresh sewage. The combination of high concentration of "hungry" cells in the return sludge and a rich food source in the influent sewage provides optimum conditions for waste degradation.

(1) In the activated sludge process, BOD is removed by two path ways. Organic matter is oxidised in the course of providing energy for the metabolic processes of the microorganism, and

(2) Synthesis and incorporation of organic matter into cell mass. In the first pathway, carbon is removed in the gaseous form as CO2. The second pathway provides for removal of carbon as a solid in biomass. That portion of the carbon converted to CO2 is vented to the atmosphere and does not present a disposal problem. What remains to be disposed of is a mixture of solids and water called sludge. The collection, processing and disposal of sludge can be the most costly and complex aspect of waste water treatment. The concentration of solids in the primary sewage sludge is about 5% ; in the activated sludge it is less than 1% and the sludge from trickling filters has about 2% solids. This means that the sludge is composed almost entirely of water and volume reduction is the key to economic disposal. In addition to reducing its water content, the sludge must be stabilised so that its biological activity and tendency towards putrefaction are reduced drastically.

Lecture 11:

Design Consideration:

Mixed Liquor Suspended Solid (MLSS) It represents the strength of mixed liquor suspended solid in term of conc of micro organism in aeration tank. Its value in A.T varies from 1500-3000 mg/l and the permissible limit being 2100-2500 mg/l. MLSS above (75000-10000) mg/l is too much.

F/M Ratio. It represents the food to micro organism ratio and is given by

F/M = BOD/MLSS*(V/Q) = BOD/MLSS*td (day^{-1})

V = Volume of AT (m^3)

Q = flow rate (m^3/day)

T_d = detention time (day)

BOD (mg/l) and MLSS (mg/l)

Its allowable value is (0.2 – 0.5) day^{-1}

A great value means more food which is wasted and less value means less food and death of bacteria.

- **Sludge Volume Index (S.V.I)**

It is the volume in ml occupied by 1gm of settled suspended solid. It is used to indicate the degree of concentration of sludge reflecting the physical state of sludge and also shows the settleability of sewage. It is found with the help of Imhoff. One liter of sample collected at the outlet of A.T is placed at rest for about 30 minutes in Imhoff tank. The volume of settled sludge (V_s) is found and Sludge Volume Index (SVI) is calculated from

$$S.V.I = (V_s \text{ x } 1000)/MLSS \qquad (ml/g)$$

The value of SVI ranges from 50-150 ml/g means good settleability.

Sludge Recirculation Ratio (r). It is the ratio of return sludge to sewage flow. It is also called **return sludge ratio**.

Return sludge ratio = $Qr/Q = V_s/ (1000-V_s)$

Where

V_s = volume of settled sludge in Imhoff cone. Its value varies from 0.25 to .5 ml/l.

Detention time = td = 4 – 8 hrs (in A.T)

Air supply = 10 m^3/m^3 of sewage treated / day

L : B = 5 : 1

Depth of A.T = 3.5 m

Dissolved oxygen level (D.O) < 2mg/l

Minimum number of A.T = 2

- **Aeration and Methods of Aeration in Activated Sludge Process**

The process of absorbing oxygen from air is known as aeration. High amount of O^2 is provided in the aeration tank because of high BOD in sewage. This cannot be provided naturally therefore aerators are used to provide O_2 artificially. When the dissolved oxygen level (D.O) falls below 2mg/l anaerobic activities starts.

There are three methods for aeration in activated sludge process.

1. Diffused air aeration
2. Mechanical aeration
3. Combine aerator

Lecture 12:

- **Oxidation ponds:**

Oxidation ponds are large, shallow typically 1-2m deep, where raw or partially treated sewage is decomposed by microorganisms. The conditions are similar to those that prevail in an eutrophic lake. The ponds can be designed to maintain aerobic conditions throughout, but more often the decomposition taking place near the surface is aerobic, while that near the bottom is anaerobic. Such ponds having a mixture of aerobic and anaerobic conditions, are called facultative ponds. The oxygen required for aerobic decomposition is derived from surface aeration and algal photosynthesis; deeper ponds called lagoons, are mechanically aerated. The reactions taking place ina facultative pond is shown in figure:

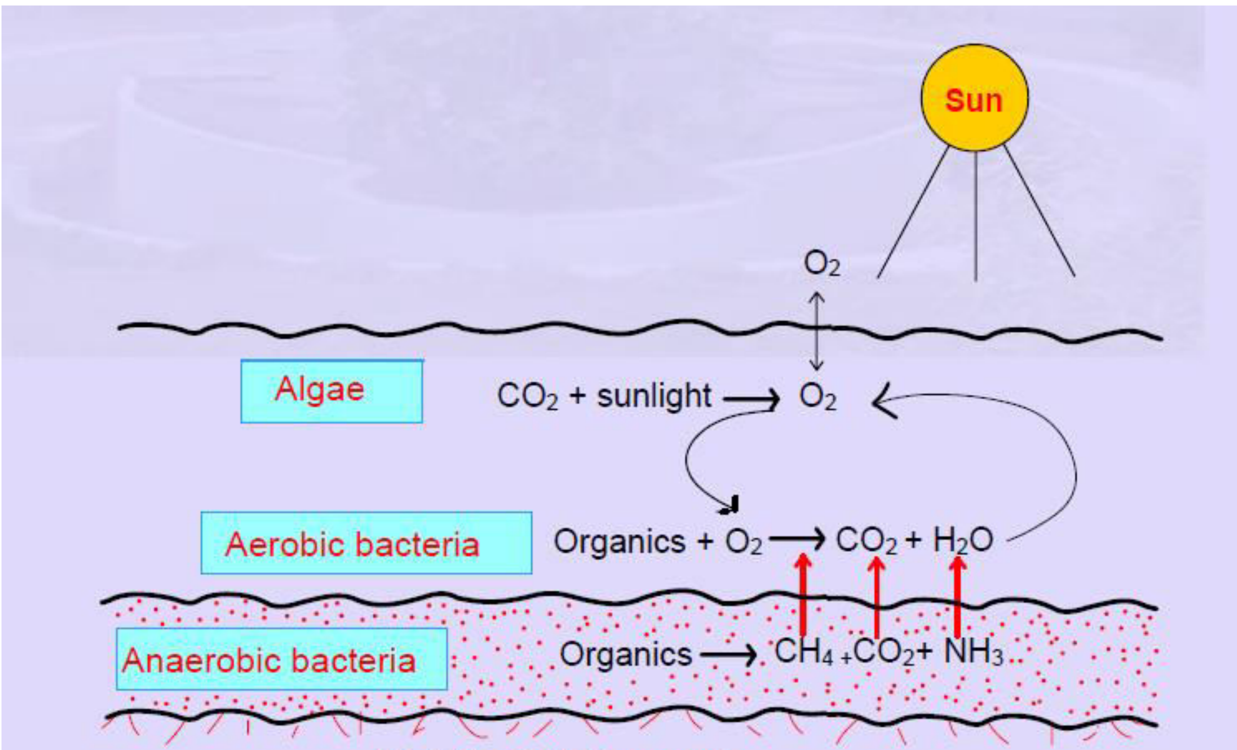


Fig.4 An Oxidation pond

Oxidation ponds, can be designed to provide complete treatment to raw sewage, but they require good deal of space. These ponds have been used extensively in small communities where land constraints are not so critical. They are easy to build and manage. They accommodate large fluctuations in flow, and they can provide treatment that approaches that of conventional biological systems but at much lower cost. The effluent however may contain undesirable concentrations of algae and, especially in the winter when less oxygen is liberated by photosynthesis which may produce unpleasant odours. They have the disadvantage that the effluent may not meet the EPA secondary treatment requirement of 30 mg/L BOD5 and suspended solids. However they are simple and effective in destroying pathogenic organisms which make these ponds useful in developing countries. Oxidation ponds are also used to suppliment secondary treatment and in such cases they are called polishing ponds.

- **Factors Affecting Pond Reactions**

Various factors affect pond design:

- wastewater characteristics and fluctuations.
- environmental factors (solar radiation, light, temperature)
- algal growth patterns and their diurnal and seasonal variation)
- bacterial growth patterns and decay rates.
- solids settlement, gasification, upward diffusion, sludge accumulation.

The depth of aerobic layer in a facultative pond is a function of solar radiation, waste characteristics, loading and temperature. As the organic loading is increased, oxygen production by algae falls short of the oxygen requirement and the depth of aerobic layer decreases. Further, there is a decrease in the photosynthetic activity of algae because of greater turbidity and inhibitory effect of higher concentration of organic matter.

Gasification of organic matter to methane is carried out in distinct steps of acid production by acid forming bacteria and acid utilization by methane bacteria. If the second step does not proceed satisfactorily, there is an accumulation of organic acids resulting in decrease of pH which would result in complete inhibition of methane bacteria. Two possible reasons for imbalance between activities of methane bacteria are: (1) the waste may contain inhibitory substances which would retard the activity of methane bacteria and not affect the activity of acid producers to the same extent. (2) The activity of methane bacteria decreases much more rapidly with fall in temperature as compared to the acid formers.

Thus, year round warm temperature and sunshine provide an ideal environment for operation of facultative ponds.

- **Algal Growth and Oxygen Production**

Algal growth converts solar energy to chemical energy in the organic form. Empirical studies have shown that generally about 6% of visible light energy can be converted to algal energy.

The chemical energy contained in an algal cell averages 6000 calories per gram of algae.

Depending on the sky clearance factor for an area, the average visible radiation received can be estimated as follows:

Avg. radiation= Min. radiation + [(Max. radiation - Min. radiation) x sky clearance factor]

- **Areal Organic Loading**

The permissible areal organic loading for the pond expressed as kg BOD/ha.d will depend on the minimum incidence of sunlight that can be expected at a location and also on the percentage of influent BOD that would have to be satisfied aerobically. The Bureau of Indian Standards has related the permissible loading to the latitude of the pond location to aerobically stabilize the organic matter and keep the pond odour free. The values are applicable to towns at sea levels and where sky is clear for nearly 75% of the days in a year. The values may be modified for elevations above sea level by dividing by a factor (1 + 0.003 EL) where EL is the elevation of the pond site above MSL in hundred meters.

- **Detention Time**

The flow of sewage can approximate either plug flow or complete mixing or dispersed flow.

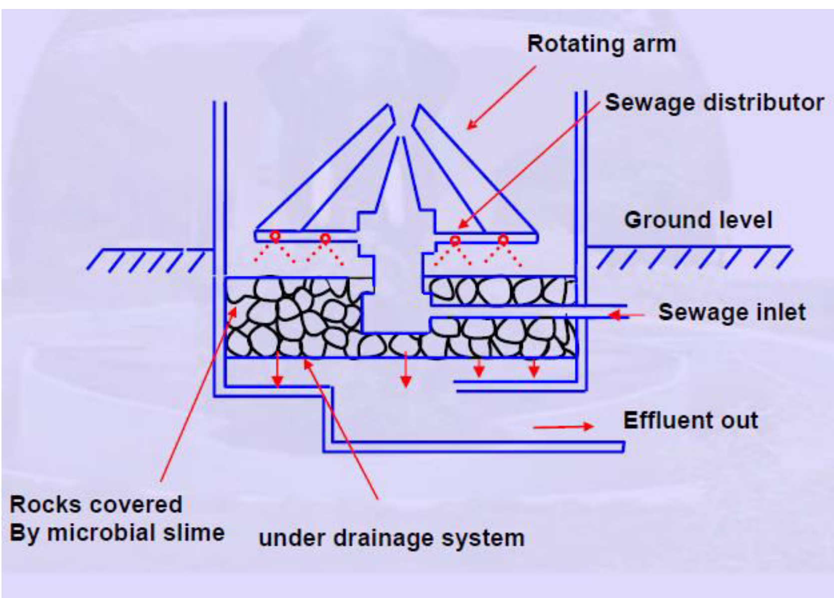
- **Depth**

Having determined the surface area and detention capacity, it becomes necessary to consider the depth of the pond only in regard to its limiting value. The optimum range of depth for facultative ponds is 1.0 - 1.5m.

Lecture 13:

Trickling filters:

Conventional trickling filters normally consist of a rock bed, 1 to 3 meters in depth, with enough opening between the rocks to allow air to circulate easily. The influent is sprinked over a bed of packing which is coated with a biological slime. As the liquid trickles over the packing, oxygen and the dissolved organic matter diffuse into the film to be metabolised by the microorganisms in the slime layer. End products such as CO_2, etc.,



diffuse back, out of the film and appear in the filter effluent. Milk processing, paper mills and pharmaceuticals wastes are among those treated by trickling filters. Like all biological units trickling filters are affected by temperature; therefore cold weather slows down the biological activity in the filter.

Lecture 14:

Rotating biological contactor:

Trickling filters as discussed previously are examples of devices that rely on microorganisms that grow on the surface of the rocks, plastic or other media. A variation of this attached growth approach is provided by the rotating biological contactactor (RBC). An RBC consists of a series of closely spaced, circular, plastic disks, that are typically 3.6 m in diameter and attached to a rotating horizontal shaft. The bottom of 40% of each disc is submerged in a tank containing the waste water to be treated. The biomass film that grows on the surface of the disks moves into and out of the waste water as RBC rotates. While the microorganisms are submerged in waste water, they absorb organics; while they were rotated out of waste water, they are supplied with needed oxygen. By placing modular RBC units in series, treatment levels that exceed the conventional secondary treatment can be achieved. They are easier to operate under varying load conditions than trickling filters, since it is easier to keep the solid medium wet at all times.

Lecture 15:

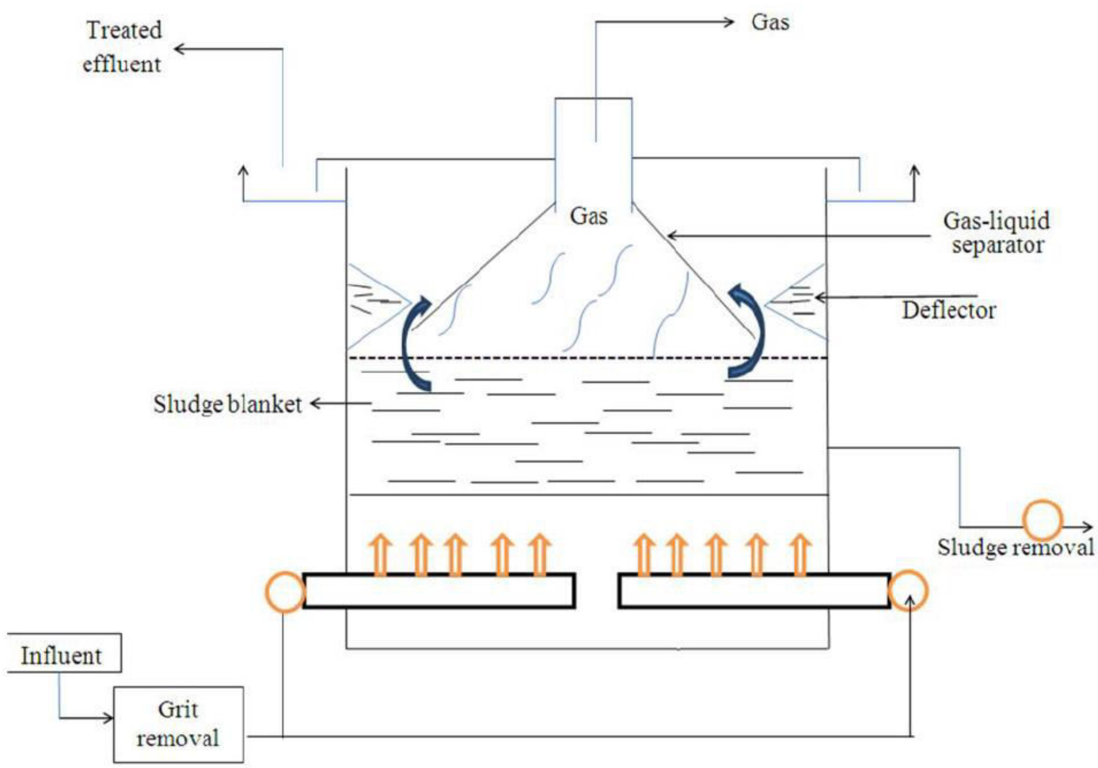
UASB Technology:

For developing countries, the anaerobic treatment offers an attractive prospect. With many options available for treatment of municipal and industrial effluents, the anaerobic treatment process stands ahead because of minimum sludge formation and production of energy in the form of methane. For the past several decades the research on fundamentals of anaerobic digestion was going on and the total duration of digestion process has come down with the advancement of high rate anaerobic processes. The relative size of these high rate digesters is quite small and the space occupied is also less. Instead of flat and short reactors as used earlier, tall reactors are being applied. The loading rates for high rate anaerobic digesters are comparatively high, because of the retention of active granular settle able sludge in the reactor. The basic studies of the microbiological and biochemical aspects of anaerobic digestion have revealed many of the characteristics and nutritional requirements of individual and groups of anaerobic bacteria, while pilot and full scale engineering studies have demonstrated the operational requirements and instabilities often encountered in the process.
Among the high rate anaerobic digestion processes, the UASB process stands ahead for its wide ranging applications for all types of wastes . The only drawback of the process is slow start-up in the absence of granular seed sludge .

Advantages of using UASB technique:
1) Less energy requirement
2) Less biological sludge production
3) Fewer nutrients required
4) Methane production
5) Elimination of off shore gas pollution
6) Rapid response to substrate addition
7) Periods without feeding
8) Methane from sludge dewatering plants can be converted into biogas, but it can also be converted into hydrogen, which can be used in direct fuel cells. Thus another option for the powering of wastewater plants is also possible.

Disadvantages of UASB technique:
1) Sensitive to adverse effects of low temperature
2) More susceptible to upsets due to toxic substances
3) May require alkalinity addition
4) Biological N and P removal is not possible.

Design of upflow anaerobic sludge blanket reactor (UASB)



Important Design Points

- For temperature >20 ℃, SRT of around 30-50 days is used.
- At equilibrium, sludge produced per day = sludge withdrawn per day
- Average concentration of sludge in UASB reactor $\cong 70 \dfrac{kg}{m^3}$
- Ration of height of sludge blanket to total height is ≈0.4-0.5.

- HRT (Hydraulic Retention Time) $= \dfrac{\text{Reactor Volume (V)}}{\text{Flow rate (Q)}}$

- Solid Retention Time (SRT) $= \dfrac{\text{Total sludge in the reactor (kg)}}{\text{Sludge wasted per day (kg/d)}}$

Where, total sludge in the reactor= $\left(\text{Average concentration of sludge in the reactor } \dfrac{\text{kg}}{\text{m}^3}\right)$

$\times\left(\dfrac{\text{sludge blanket height}}{\text{total reactor height}}\left(\dfrac{\text{m}}{\text{m}}\right)\right) \times$ Effective Coefficient × Reactor volume (m^3)

Lecture 16:

Problem 4.6.1: Given that the influent to UASB reactor has following characteristics: BOD = 350 mg/l; COD = 820 mg/l, TSS= 395 mg/l, VSS= 270 mg/l, flow rate=8000 m^3/d, depth of sludge blanket=2.2 m, reactor height (including settler)=5 m, effective coefficient (ratio of sludge to total volume in sludge blanket)= 0.85.

Determine HRT for sludge age of 30 days assuming 80% BOD removal efficiency; reactor area, and organic loading on reactor and the sludge blanket.

Solution:

$$\text{SRT} = 30 \text{ days} = \frac{70\frac{\text{kg}}{\text{m}^3} \times \frac{2.2}{5.0}\left(\frac{\text{m}}{\text{m}}\right) \times 0.85\frac{\text{m}^3}{\text{d}} \times \text{HRT}\frac{\text{h}}{24}}{315\left(\frac{\text{kg}}{\text{m}^3}\right)\left(\text{flowrate}\frac{\text{m}^3}{\text{d}}\right)}$$

$$\text{HRT} = \frac{30 \times 315}{70 \times \frac{2.2}{5.5} \times 0.85 \times \frac{1000}{24}} = 8.66 \text{ h}$$

$$\text{Upflow velocity} = \frac{\text{Reactor height}}{\text{HRT}} = \frac{5}{8.66} \text{m/h}$$

Reactor area required:

$$\text{Reactor area required} = \frac{\text{flow rate}\left(\frac{\text{m}^3}{\text{d}}\right)}{\text{Upflow rate}\left(\frac{\text{m}}{\text{d}}\right)} = \frac{8000\left(\frac{m^3}{d}\right)}{0.57\left(\frac{m}{h}\right)} = \frac{8000\left(\frac{m^3}{d}\right)}{0.57\left(\frac{m}{h}\right) \times 24\left(\frac{m}{d}\right)} = 577.7 m^2$$

$$\text{Organic loading rate (OLR)} = \frac{\text{COD load}}{\text{volume of reactor}} = \frac{\text{influent COD} \times \text{flow rate}}{\text{volume of reactor}}$$

$$\text{Organic loading rate (OLR)} = \frac{820\frac{g}{m^3} \times 8000\frac{m^3}{d}}{1000 \times (20 \times 34 \times 5)} = 1.93 \ kg/m^3/day$$

Organic loading on sludge blanket (SLR)

$$= \frac{\text{influent COD} \times \text{flow rate}\left(\frac{\text{kg COD}}{d}\right)}{0.4 \times \left(\frac{VSS}{TSS}\right) \times (Avg \text{ conc. of sludge in the reactor}) \times (\text{sludge blanket volume})}$$

$$\text{SRT} = \frac{820\frac{\text{g}}{\text{m}^3} \times 8000\frac{\text{m}^3}{\text{d}}}{0.4 \times 1000 \times \left(\frac{\text{VSS}}{\text{TSS}}\right) \times \left(70\frac{\text{kg}}{\text{m}^3}\right) \times (20 \times 34 \times 2.2)} = 0.156 \text{kgCOD/kgVSS/day}$$

Module 3 8L

Lecture 17:

Classification of solid waste: source based and type based. Functional elements of solid waste management.

Overview :

Due to rapid increase in the production and consumption processes, societies generate as well as reject solid materials regularly from various sectors – agricultural, commercial, domestic, industrial and institutional. The considerable volume of wastes thus generated and rejected is called solid wastes. In other words, solid wastes are the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted. This inevitably places an enormous strain on natural resources and seriously undermines efficient and sustainable development.

Classification of solid waste:

Solid wastes are the organic and inorganic waste materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen refuse, paper, appliances, paint cans, batteries, etc., produced in a society.

Source-based classification:

Sector	Source
Residential	Vegetable peels, clothes, ashes etc
Commercial	Left over foods, glasses, metals etc from hotels, motels, medical facilities etc.
Institutional	Paper, plastic, plates from educational and administrative buildings
Municipal	Dust, leafy matter, building debris generatd from various municipal activities
Agricultural	Spoiled food grains and vegetables, agricultural remains, litter, etc., generated from fields, orchards,

Classification of wastes based on types, i.e., physical, chemical, and biological characteristics of wastes, is as follows: biodegradable and non – biodegradable.

Functional elements of solid waste management (SMW):

(i) **Waste generation:** Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted into goods for consumption. The source of waste generation determines quantity, composition and waste characteristics For example, wastes are generated from households, commercial areas, industries, institutions, street cleaning and other municipal services. The most important aspect of this part of the SWM system is the identification of waste.

(ii) **Waste storage:** Storage is a key functional element because collection of wastes never takes place at the source or at the time of their generation. The heterogeneous wastes generated in residential areas must be removed within 8 days due to shortage of storage space and presence of biodegradable material. Onsite storage is of primary importance due to aesthetic consideration, public health and economics involved. Some of the options for storage are plastic containers, conventional dustbins (of households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc

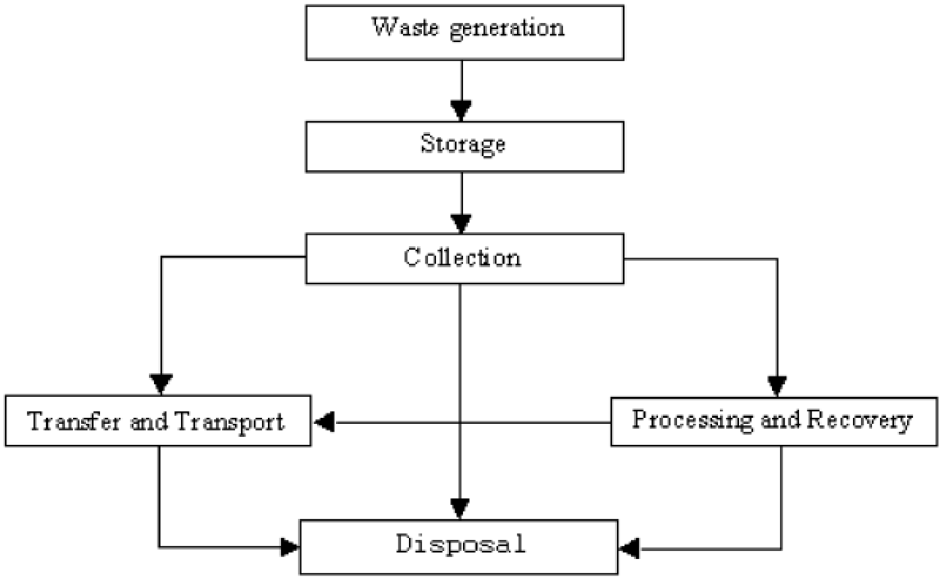
(iii) **Waste collection:** This includes gathering of wastes and hauling them to the location, where the collection vehicle is emptied, which may be a transfer station (i.e., intermediate station where wastes from smaller vehicles are transferred to larger ones and also segregated), a processing plant or a disposal site. Collection depends on the number of containers, frequency of collection, types of collection services and routes. Typically, collection is provided under various management arrangements, ranging from municipal services to franchised services, and under various forms of contracts.

(iv) **Transfer and transport:** This functional element involves: the transfer of wastes from smaller collection vehicles, where necessary to overcome the problem of narrow access lanes, to larger ones at transfer stations; the subsequent transport of the wastes, usually over long distances, to disposal sites.

(v) **Processing:** Processing is required to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling. The important processing techniques include compaction, thermal volume reduction, manual separation of waste components, incineration and composting.

(vi) **Recovery and recycling:** This includes various techniques, equipment and facilities used to improve both the efficiency of disposal system and recovery of usable material and energy. Recovery involves the separation of valuable resources from the mixed solid wastes, delivered at transfer stations or processing plants. It also involves size reduction and density separation by air classifier, magnetic device for iron and screens for glass. The selection of any recovery process is a function of economics, i.e., costs of separation versus the recovered-material products. Certain recovered materials like glass, plastics, paper, etc., can be recycled as they have economic value.

(vii) **Waste disposal:** Disposal is the ultimate fate of all solid wastes, be they residential wastes, semi-solid wastes from municipal and industrial treatment plants, incinerator residues, composts or other substances that have no further use to the society. Thus, land use planning becomes a primary determinant in the selection, design and operation of landfill operations. A modern sanitary landfill is a method of disposing solid waste without creating a nuisance and hazard to public health.



Lecture 18:

Treatment processes for Solid wastes:

There are two methods by which by which solid wastes can be disposed. These are :
1. Thermal conversion process 2. Biological conversion process

The thermal conversion of solid waste can be achieved by three methods: incineration, pyrolysis, gasification.

Among the biological conversion process , the important system are aerobic composting, anerobic composting.

Thermal conversion :

- ***Incineration :***

Incineration is used for the process of complete combustion of solid waste. This may be mass-fired or processed solid waste fired.

`In a mass-fired combustion system, the solid waste requires very little processing; such wastes are known as unprocessed solid wastes (USW). In this type, the solid waste may enter the system , including bulky or oversized non-combustible objects.

- ***Gasification :***

The term gasification is generally used to define the process of incomplete or partial combustion of a solid combustible material. Different types of gasifiers are used for solid waste treatment. The most common among them are vertical fixed bed (VFB) , horizontal fixed bed (HFB) and fluidized bed gasifier (FB).

Vertical fixed bed:

It is normally cylindrical or rectangular in structure and usually made of fire-claybrick. The operating temperature varies from 650^{o}C- 800^{o}C. It produces a high calorie fuel and average gas composition would be 50% CO, 30% H_2, 14% CO_2 and 4% CH_4 ; the rest is nitrogen and hydrocarbons.

Horizontal fixed bed gasifier:

This gasifier consists of two major conponents , viz, primary and secondary combustion chambers. In primary chamber, solid waste is gasified under limited oxygen (air) supply. Thus a low calorie fuel gas is produced, which then flows into the secondary combustion chamber, where complete combustion occurs in the presence of excess air.

Lecture 19:

Fluidized bed gasifier:

The fluidized bed system is a modern development used for the combustion of MSW.

- ***Pyrolysis :***

Pyrolysis refers to the strictly anaerobic thermal processing of solid waste. It is the conception of thermal cracking and condensation reactions of thermally unstable organic substances in an oxygen-free atmosphere into gaseous, liquid, and solid fractions.

Lecture 20:

Biological Conversion process:

Biological conversion of solid waste in general and Municipal Solid Waste (MSW) is the most preferred and economical method of waste treatment. Depending on whether the operation is performed in the presence or absence of oxygen, the process can be either aerobic or anaerobic. Accordingly, the nature of the end products also differs , as the conversion reactions of aerobic and anaerobic processes are differently accomplished.

- ***Aerobic composting of solid waste:***

It is an uncontrolled process of biological conversion of organic matter. The extent and the time period over which decomposition occurs in controlled by various factors such as the availability of oxygen, nutrients, moisture content and the nature of waste.
The transformation reaction occurs during aerobic composting of SW can be represented as follows :

$$\text{Organic matter + nutrients} + O_2 \rightarrow \text{new cell mass + residual organic matter} + CO_2 + H_2O + NH_3 + SO_4^{--} + \text{heat}$$

We assume the decomposable organic matter of SW on a molar basis to $C_aH_bO_cN_d$ and the hard-to-decompose residual organic matter to be $C_wH_xO_yN_z$. The production of new cells and sulfate during the process needs to be ignored.

$$C_aH_bO_cN_d + \tfrac{1}{2}(ny+2s+r-c)O_2 = nC_wH_xO_yN_z + sCO_2 + rH_2O + (d-nz)\,NH_3$$

Design aspects of aerobic composting:

Particle size: A reduced particle size increases the biochemical reaction rate during the composting process.

Carbon to nitrogen ratio: For any biological transformation process, including aerobic composting, C/N ratio for any biological process lies between 25- 30.
Seeding or inoculation: It is essential that a desired volume of microbial culture to be added to effect the decomposition of the organic fraction of solid waste at a faster rate.

Temperature: In composting , different types of organisms involved are either mesophilic or thermophilic. The process is exothermic; therefore the bed temperature also rises automatically.

Air requirement: In case of aerated static pile, and in-vessel systems, the essential design parameters are total air requirement and air flow rate.

Lecture 21:

- ***Anaerobic Composting of Solid Waste:***

Anaerobic composting of solid waste is done by treating solid waste biologically in the absence of oxygen. One group of organism is responsible for hydrolysing organic polymers and lipids to fatty acids, monosaccharides, amino acids and other compounds. A second group of anaerobic bacteria ferments the chemical produced by the first group to simple organic acids such as acetic acid. The second group of organisms consists of facultative or obligative anaerobes, indentified as acetogens. The third group of microbes, which are strictly anaerobes convert the hydrogen and acetic acid formed by acetogens into biogas (methane and CO_2)
The general anaerobic transformation of solid wastes can be described by using following correlation:

$$\text{Organic matter of SW} + H_2O + \text{inoculum + nutrients} \rightarrow \text{new cell mass + residual organic matter} + CO_2 + NH_3 + H_2S + \text{Heat}$$

Lecture 22:

Landfill Bioreactor For Solid Waste Treatment:

Landfills include any site which is used for more than a year for the temporary storage of waste; and, any internal waste disposal site, that is to say a site where a producer of waste is carrying out its own waste disposal at the place of production

- ***Waste decomposition process in landfill:***

• MSW contains a large proportion of organic materials that naturally decompose when landfilled.
• This decomposition process initially is aerobic where the main byproducts are carbon dioxide, plus contaminated water. However, after the oxygen within the waste profile is consumed, it switches over to anaerobic processes. In the anaerobic process, carbon dioxide and methane are produced as waste decomposes. Liquid byproducts contain a large concentration of various contaminants that naturally move toward the landfill's base.
• The decomposition process continues for many years. As this takes place, trace quantities of materials that may have significant impacts upon the environment can be contained in both the landfill gas and in the leachate. These trace materials are generated until the landfill becomes completely stabilized.

- ***Landfill gas:***

In landfill reactor, anaerobic digestion of organic matter generates biogas containing methane and CO2. The biogas produced from a landfill system, also known as landfill gas. Closed landfill sites pose a potential hazard because of their methane production. The greatest risk occurs at sites that are within 250 m of housing and/or industrial estates. Problems become more severe when there are no gas-control measures.

- ***Landfill leachates:***

Landfill leachates are defined as the aqueous effluent generated as a consequence of rainwater percolation through wastes, biochemical processes in waste's cells and the inherent water content of wastes themselves. It contains many organic matters, minerals, heavy metals and has high concentration of ammonia-nitrogen, all these lead to the low biodegradability. The leachate qualities changes according to the landfill climate conditions and hydrology, it also varies according to the qualities of the garbage that has been buried in the landfill The removal of organic material based on chemical oxygen demand (COD), biological oxygen demand (BOD) and ammonium from leachate is the usual prerequisite before discharging the leachates into natural waters. Conventional landfill leachate treatments can be classified into three major groups.

Conventional landfill leachate treatments can be classified into three major groups:
(a) leachate transfer: recycling and combined treatment with domestic sewage,

(b) biodegradation: aerobic and anaerobic processes and
(c) chemical and physical methods: chemical oxidation, adsorption, chemical precipitation, coagulation/flocculation, sedimentation/flotation and air stripping.

Lecture 23:

Vermicomposting:

Vermicomposting is a method of making compost, with the use of earthworms, which generally live in soil, eat biomass and excrete it in digested form. This compost is generally called vermicompost or Wormicompost. Introducing worms into SW to aid in decomposition of organic matter (end product called vermicast). These worms are however sensitive to sunlight, citrus content and cooked food leftovers.

- *Techniques of vermicomposting:*

The technique of vermicomposting consists of the following steps:

1. Preparation of worm pit
2. Bedding material
3. Addition of worms
4. Addition of organic waste
5. Controlling moisture and temperature
6. Maintenance of bin
7. Harvesting worms and vermicompost.

Biomanure:

Biomanures are microbial inoculants or carrier based preparations containing living or latent cells of efficient strains of nitrogen fixing, phosphate is solubilizing and cellulose decomposing microorganisms intended for seed or soil application and designed to improve soil fertility and plant growth by increasing the number and biological activity of beneficial microorganisms in the soil.

The objects behind the application of Biomanures /microbial inoculants to seed, soil or compost pit is to increase the number and biological / metabolic activity of useful microorganisms that accelerate certain microbial processes to augment the extent of availability of nutrients in the available forms which can be easily assimilated by plants. The need for the use of Biomanure has arisen primarily due to two reasons i.e. though chemical fertilizers increase soil fertility, crop productivity and production, but increased / intensive use of chemical fertilizers has caused serious concern of soil texture, soil fertility and other environmental problems, use of Biomanure is both economical as well as environment friendly. Therefore, an integrated approach of applying both chemical fertilizers and Biomanure is the best way of integrated nutrient supply in agriculture.

Lecture 24:

Numerical problems:

A fruit and vegetable processing unit generates 1 t of solid waste that needs to be stabilized aerobically. Estimate the amount of oxygen required to oxidize the waste. It may be assumed that the initial composition of the biodegradable organic material to be decomposed is $[C_6H_7O_2(OH)_3]_5$ and the final composition of the residual organic matter is $[C_6H_7O_2(OH)_3]_2$. After the oxidation process, 40% of the material is available as compost.

Solution

The oxygen requirement can be estimated with the help of Eqn (7.2). From the data given in the problem, the initial molar composition of SW according to Eqn (7.2) will be $C_{30}H_{50}O_{25}N_0$ and the molar composition of the residual matter is $C_{12}H_{20}O_{10}N_0$. According to Eqn (7.2), 1 mol of SW yields n mols of compost. Again from the data given in the problem, we find that 1 t of SW yields 400 kg of compost. On the other hand,

$$1\ \text{t of SW} = \left[\frac{1000}{30\times 12 + 50\times 1 + 16\times 25 + 0\times 14}\right]$$

$$= 1.23\ \text{mol}$$

$$400\ \text{kg of compost} = \left[\frac{400}{12\times 12 + 20\times 1 + 10\times 16 + 0\times 14}\right]$$

$$= 1.23\ \text{mol}$$

Thus we find $n = \dfrac{1.23}{1.23} = 1$

Further, as per Eqn (7.2), moles of oxygen required per mole of SW are given by

$$(1/2)(ny + 2s + r - c)$$

where $n = 1$, $y = 10$, $s = a - nw = 30 - 1 \times 12 = 18$, $c = 25$:

$$r = (1/2)\,[b - nx - 3(d - nz)]$$

$$= (1/2)\,[50 - 1 \times 20 - 3(0 - 1 \times 20)]$$

$$= 15$$

Substituting values in the equation used for calculating the number of moles of oxygen, we have

$$\text{Moles of } O_2 \text{ required} = (1/2)\,(1 \times 10 + 2 \times 18 + 15 - 25) = 18$$

So the total amount of oxygen required

$$= 1.23 \times 18 \text{ mol}$$

$$= 22.14 \text{ mol}$$

$$= 708.5 \text{ kg}$$

In the absence of nitrogen in SW, no ammonia will be formed. Thus, process input consists of SW and oxygen, and process output contains compost, carbon dioxide, and water. From material balance, we get

$$\text{Input} = 1000 \text{ kg (SW)} + 708.5 \text{ kg } (O_2) = 1708.5 \text{ kg}$$

$$\text{Output} = 400 \text{ kg (compost)} + 1.23 \times 18 \times 44 \text{ kg } (CO_2)$$

$$+ 1.23 \times 15 \times 18 \text{ kg } (H_2O)$$

$$= 1706.3 \text{ kg}$$

$$\text{Unaccounted mass} = 2.2 \text{ kg}$$

The modern technique used for composting of solid waste such as MSW for a large-scale operation has three basic steps. These are pre-processing; biological decomposition; and preparation and marketing of the compost.

At IIT Kharagpur, the total population is 10,000. The concerned authority has decided to design a landfilling bioreactor system to treat solid wastes. To facilitate the collection of organic solid wastes, two vats were placed at each collection point, one for biodegradable solid wastes and another for non-biodegradable waste. On an average it was found that the biodegradable solid waste generated per capita per day was, approximately, 1 kg. It was decided that the average depth of the compacted solid waste should be about 5 m, and experimentally it was found that the specific weight of the compacted solid waste is 400 kg/m^3. With this information, estimate the area of land required for the proposed landfilling operation.

Solution

Daily biodegradable solid waste generation

$$= 10{,}000 \times \frac{1}{1000} \text{ t/d}$$

$$= 10 \text{ t/d}$$

Volume required per day for landfilling

$$= 10 \times \frac{1000}{400} \text{ m}^3/\text{d}$$

$$= 25 \text{ m}^3/\text{d}$$

Area required per day

$$= \frac{25}{5} \text{ m}^2/\text{d}$$

$$= 5 \text{ m}^2/\text{d}$$

So, the minimum area required for landfilling for one year $= 5 \times 365 \text{ m}^2 = 1825 \text{ m}^2$ or 0.45 acre/year. Some additional space is required for roads, partitioning, etc.

Module 4 8L

Lecture 25:

Biofiltration/ Bioclarification:

Biofilter is one of the most important separation processes that can be employed to remove organic pollutants from air, water, and wastewater. Even though, it has been used over a century, it is still difficult to explain theoretically all the biological processes occurring in a biofilter. In this paper, the fundamental of biological processes involved in the biofilter is critically reviewed together with the mathematical modeling approach. The important operating and design parameters are discussed in detail with the typical values used for different applications. The most important parameter which governs this process is the biomass attached to the medium. The relative merits of different methods adopted in the measurement of the biomass are discussed. The laboratory-and full-scale applications of the biofilter in water and wastewater treatment are also presented.
Use of a biofilter in drinking water treatment (especially with granular activated carbon as filter media) was felt necessary only after the discovery of the re-growth of micro-organisms in water distribution pipe lines few decades ago. It has been observed that the inner surface of water distribution pipelines carrying potable water is coated with layers of biomass in few years of service period.
Because of its wide range of application, many studies have been done on biofiltration system in last few decades. However, theoretically it is still difficult to explain the behavior of a biofilter. The growth of different types of microorganisms in different working conditions makes it impossible to generalize the microbial activities in a biofilter. The biofilters operated at different filtration rates and influent characteristics can have diverse efficiency for different target pollutants. Besides, due to some of the operational drawbacks of the biofilter such as performance fluctuation, maintenance of biomass, and disinfection adequacy of the biofilter effluent, research on biofiltration process has become imperative.

Studies on biofiltration system with water and wastewater

Filter medium	Experimental parameter		Major observation
	Organic	Biomass	
Anthracite+ sand	AOC-P17, AOC-NOX, NPOC, turbidity	HPC	Backwashing technique and hydraulic transient can affect the performance of a biofilter.
Granite, blast-furnace slag	BOD, ammonia, SS	None	Performance a biofilter depends on organic load ing rate, temperature, and filter design configuration.
Anthracite	DOC, BDOC	Phospholipid analysis	DOC removal is controlled by biomass. The filter acclimatized at higher HLR had a substantially higher cumulative biomass.
Glass beads+ sand	TOC	HPC bacterial count	Biomass accumulation is not impaired by backwash with water
Plastic media-3 different shapes	BOD_5, SS, NH_3-N, NO_3-N, NO_2-N, PO_4^{-3}	None	Characteristics of filter media are more critical than the flow scheme to the biofilter in affecting the performance of the biofilter.
GAC	DOC, DO, NH_3, NO_2	Bacterial count	Shut down of biofilter promotes anaerobic conditions reducing the quality of the effluent. The biofilter should be backwashed when anaerobic condition occurs.
GAC	DOC, BDOC, NBDOC	^{14}C-Glucose respiration	Removal efficiency of a biofilter depends on EBCT, not on filtration rate
Anthracite+ sand, GAC+ sand, sand	TOC, BDOC, aldehydes, AOC-NOX, THM and TOX formation potential	Phospholipid analysis	GAC contained 3-8 times more biomass than anthracite or sand

Lecture 26:

Biogas:

Biogas is produced by putrefactive bacteria, which break down organic material under airless conditions. This process is called "anaerobic digestion". The digestion process consists of two main phases: - acid formation, - methane formation. In the first phase, protein, carbohydrate and fat give rise to fatty acids, amino acids and alcohols. Methane, carbon dioxide and ammonia form in the second phase. The slurry becomes somewhat thinner during the process of digestion. The better the two phases merge into each other, the shorter the digestion process. The conditions for this are particularly favourable in the "fermentation channel" arrangement. The following types of digestion are distinguished according to the temperature in the digester: - psychrophilic digestion (10-20 °C, retention time over 100 days), - mesophilic digestion (20-35 °C, retention time over 20 days), - thermophilic digestion (50-60 °C, retention time over 8 days). Thermophilic digestion is not an option for simple plants. The pH of the fermentation slurry indicates whether the digestion process is proceeding without disturbance. The pH should be about 7. This means that the slurry should be neither alkaline nor acid. Biogas can in principle be obtained from any organic material. Cattle manure can be used as a "starter". Feed material containing lingnin, such as straw, should be precomposted and preferably chopped before digestion. More than ten days' preliminary rotting is best for water hyacinths. Gas production is substantially improved if the preliminary rotting time is twenty days.

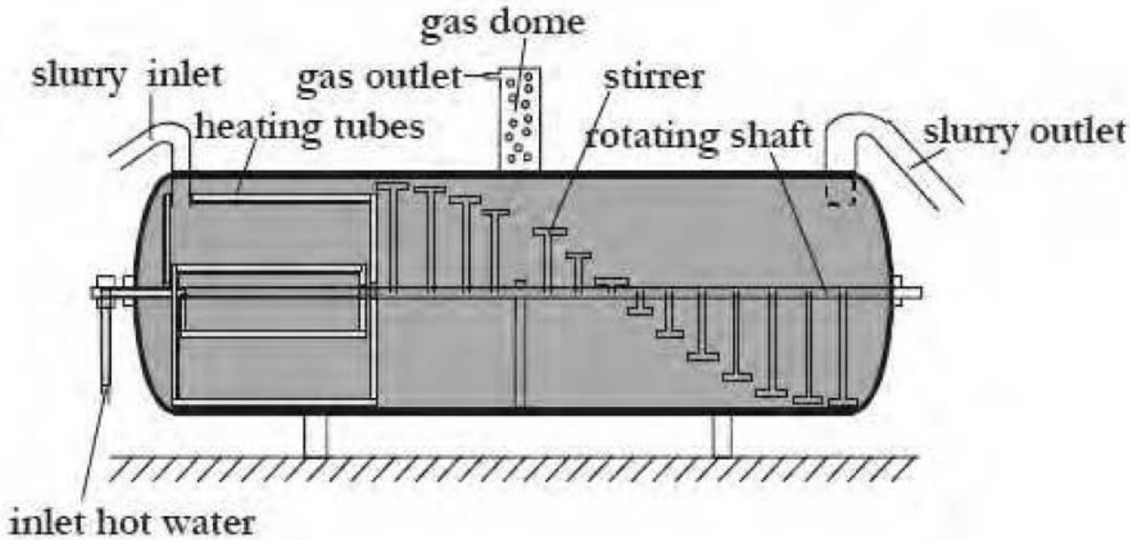
Lecture 27:

- ***Design of biogas plant:***

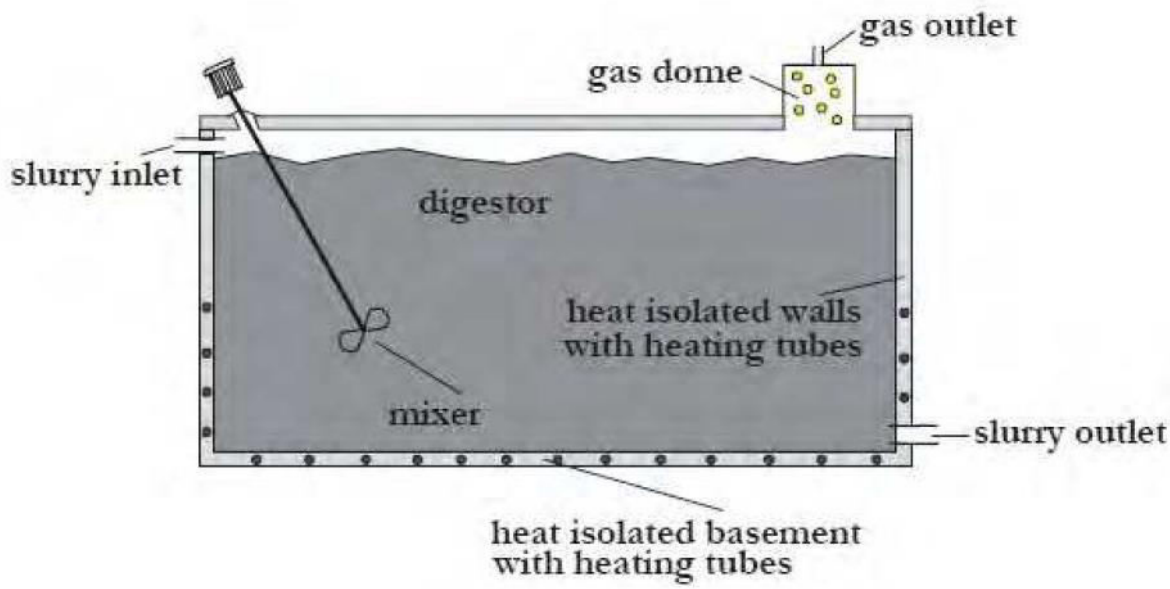
a. Planning the biogas plant layout and designing the digesters, where the rules of thumb for planning the layout of a commercial biogas plant are elucidated and a methodology for specifying the dimensions of both digester(s) and residue storage tank(s) is illustrated, and they are: internal and external diameters of the tanks, wall thickness of the tank, height,etc.
b. Undertaking the project, i.e. carrying out the excavation (digging) works, preparation of the bottom plate of the digester, integrating the heating tubes, building the fermenter, installing the insulation, and technology installation.
c. Running the biogas plant including the mechanization of the biogas plant such as: solids feeder, gas processing unit, mixing technology etc.
d. System control, i.e. how the individual facility components are monitored by computer technology even from afar as well as on-site using a computer system

- ***Components of the biogas unit***

The components of a biogas unit are:
1. Reception tank
2. Digester or fermenter
3. Gas holder
4. Overflow tank



(a)



(b)

Horizontal (a) and vertical (b) digester

Lecture 28:

Adsorption :

Adsorption is a wastewater purification technique for removing a wide range of compounds from industrial wastewater. Adsorption takes place when molecules in a liquid bind themselves to the surface of a solid substance. Adsorbents have a very high internal surface area that permits adsorption.

Not only wastewater, the raw water sources like, ground water if it is having high TDS, it is treated with the ion exchange system for the removal of dissolved ions so, that the water can subsequently be used for the industrial applications or industrial purpose like, in boiler. These are ion exchangers particularly used for softening the water, so removal of the hardness which is essentially due to the ions of calcium and magnesium. So, the ion exchanger like, zeolite or those kind of thing can be used for water softening as well.

Typically adsorption is governed by may be governed by two different kind of forces. There is physical adsorption, which is primarily due to the Van der Waal forces and that is why, we can call it Van der Waal adsorption as well or commonly known as physisorption. So, that is one type of adsorption, physisorption then, there is a chemisorption or chemical adsorption where chemical bonding takes place between the adsorbent and adsorbate. The usual adsorption processes are always exothermic mostly because, it says spontaneous it says usually adsorption is a spontaneous process, so the gibbs free energy is negative, change in the Gibbs free energy is negative and the process is spontaneous. Usually it is exothermic processes, the Van der Waal forces are weaker, so, the bonding is beak weak here whereas; chemical forces are stronger. So, in majority of the cases chemisorption is far more stronger as opposed to the physisorption. They release heat of the order of 0.1 calorie per mole and while they release the heat at the of the order of 10 kilo calorie per moles both are exothermic. Since Van der Waal forces are physical forces and if the kinetic energy of the particle increases, it will again leave back the surface, so they are reversible whereas; chemical adsorption may or may not be reversible, but depends on the nature of the reaction that has taken place. So, chemical adsorption often it is irreversible, but could be reversible as well if the nature of the forces are such that, it can be reversed.

Ion exchange process:

An ion exchanger is an insoluble substance containing loosely held ions which can be exchanged with other ions in solution which come in contact with it. These exchanges take place without any physical alteration to the ion exchange material. During ion exchange mobile ions from an external solution are exchanged for ions that are electrostatically bound to the functional groups contained within a solid matrix.

$$R - H + Cs^+ \leftrightarrow R - Cs + H^+$$

Example : where R represents the insoluble matrix of the ion exchange resin. The cation exchanger will release its hydrogen ion into solution and pick up a caesium ion from the solution.

Functional groups are negatively charged
• exchange will involve cations
Functional groups are positively charged
• exchange will involve anions •
The first commercially used ion exchange materials were naturally occurring porous sands that were commonly called zeolites. Zeolites were the first ion exchangers used to soften waters; however, they have been almost completely replaced in recent years by synthetic organic exchange resins that have a much higher ion exchange capacity. Resin is a network of crosslinked hydrocarbons attached to ionic groups. The resins are prepared as spherical beads 0.5 to 1.0 mm in diameter.

Lecture 29:

- ***Selectivity***

Ion exchange media have a greater affinity for certain ionic species than for others. Thus, a separation of these species can be made. Certain ions in the solution are preferentially sorbed by the ion exchanger solid, and because electroneutrality must be maintained, the exchanger solid releases replacement ions back into the solution.

The determination of selectivity coefficients is a complicated task and is ordinarily not undertaken in the design of waste treatment systems; most of these parameters can be extracted from manufacturers' data or research literature.

For the usual cation exchangers, the preference series for the most common cations is as follows:

$Ba^{+2} > Pb^{+2} > Sr^{+2} > Ca^{+2} > Ni^{+2} > Cd^{+2} > Cu^{+2} > Co^{+2} > Zn^{+2} > Mg^{+2} > Ag^{+} > Cs^{+} > K^{+} > NH^{4+} > Na^{+} > H^{+}$

This series is for strong acid resins - that is, those having strong reactive sites such as the sulfonic group (-S03H). Weak acid resins such as the carboxylic group (-COOH) - will have the H^{+} position to the left of that shown here. For very weak sites, the H+ may fall to the left as far as Ag^{+} .

For the usual anion exchangers the preference series for the most common anions is as follows:

$S04^{-2} > I^{-} > NO_3^{-} > Cr04^{-2} > Br^{-} > Cl^{-} > OH$

This series is for strong base resins such as the quaternary ammonium group. For weak base resins such as the secondary or tertiary amine group - the OH^{-} will fall farther to the left.

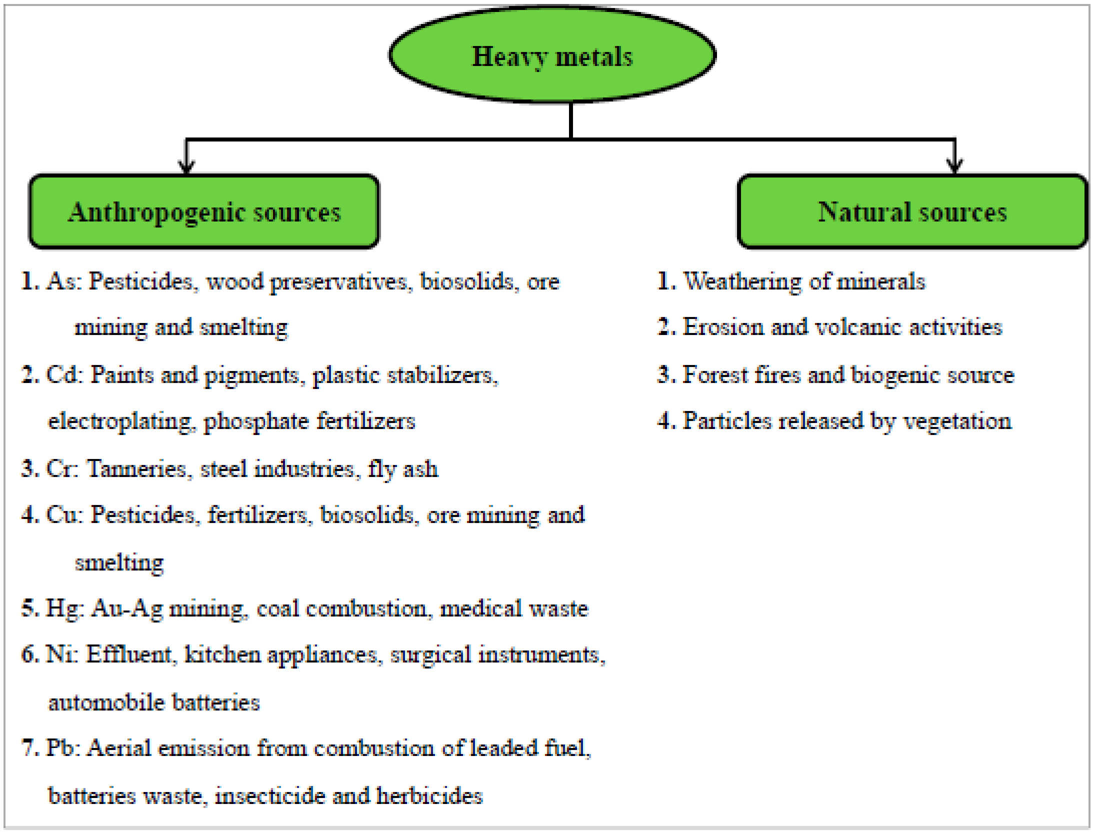
Reverse osmosis:

It must be understood that osmosis is a natural phenomenon. In case of reverse osmosis, pressure is applied on the solution side externally (using a pump or a compressor), so that the osmotic pressure is overcome and the solvents are forced out of the solution side. The efficiency of this process depends on the porosity, morphology and thickness of the membrane. These factors influence the transport of the solvent through the membrane immensely and thereby, dictating the throughput of the process and the quality of the product. Since, reverse osmosis membranes have very small pore size, this is used for separation of lower molecular weight species, like, salts. A salt having very osmotic pressure, the operating pressure in the feed side of a reverse osmosis process is therefore extremely high. This will lead to deposition of salts near the membrane surface, leading to build up of a concentration boundary layer. Therefore, the pressure gradient in this system leads to concentration difference.

Lecture 30:

Bioremediation:

Sources of heavy metal in environment



Heavy metals can be biosorbed by microbes at binding sites present in cellular structure without the involvement of energy. Among the various reactive compounds associated with bacterial cell walls, the extracellular polymeric substances are of particular importance and are well known to have significant effects on acid-base properties and metal adsorption. Studies on the metal binding behavior of extracellular polymeric substances (EPS) revealed a great ability to complex heavy metals through various mechanisms, which include proton exchange and micro-precipitation of metals . Recent studies have characterized and quantified the proton and adsorbed metals on bacterial cells and EPS free cells in order to determine the relative importance of EPS molecules in metal removal. Bioremediation research and practice are still hampered in the current scenario due to an incomplete understanding of genetics and genome level characteristics of the organisms used in metal adsorption, the metabolic pathway and their kinetics. This results in an inability to model and predict the process behavior and develop a natural bioremediation process in the field.

Bioremediation is an innovative and promising technology available for removal of heavy metals and recovery of the heavy metals in polluted water and lands. Since microorganisms have developed various strategies for their survival in heavy metal-polluted habitats, these organisms are known to develop and adopt different detoxifying mechanisms such as biosorption, bioaccumulation, biotransformation and biomineralization, which can be exploited for bioremediation either ex situ or in situ.

Toxic effect of heavy metals on human health

Heavy Metal	EPA Regulatory Limit (ppm) [9]	Toxic Effects
Ag	0.10	Exposure may cause skin and other body tissues to turn gray or blue-gray, breathing problems, lung and throat irritation and stomach pain.
As	0.01	Affects essential cellular processes such asoxidative phosphorylation and ATP synthesis
Ba	2.0	Cause cardiac arrhythmias, respiratory failure, gastrointestinal dysfunction, muscle twitching and elevated blood pressure
Cd	5.0	Carcinogenic, mutagenic, endocrine disruptor, lung damage and fragile bones, affects calcium regulation in biological systems
Cr	0.1	Hair loss
Cu	1.3	Brain and kidney damage, elevated levels result in liver cirrhosis and chronic anemia, stomach and intestine irritation
Hg	2.0	Autoimmune diseases, depression, drowsiness, fatigue, hair loss, insomnia, loss of memory, restlessness, disturbance of vision, tremors, temper outbursts, brain damage, lung and kidney failure
Ni	0.2 (WHO permissible limit)	Allergic skin diseases such as itching, cancer of the lungs, nose, sinuses, throat through continuous inhalation, immunotoxic, neurotoxic, genotoxic, affects fertility, hair loss
Pb	15	Excess exposure in children causes impaired development, reduced intelligence, short-term memory loss, disabilities in learning and coordination problems, risk of cardiovascular disease
Se	50	Dietary exposure of around 300 μg/day affects endocrine function, impairment of natural killer cells activity, hepatotoxicity and gastrointestinal disturbaces
Zn	0.5	Dizziness, fatigue *etc.*

Lecture 31:

Drinking water treatment:

- ***Objectives of water treatment*** ·
    1. The principal objective of water treatment is to provide potable water that is chemically and biologically safe for human consumption. It should also be free from unpleasant tastes and odors.
    2. Water treatment aims at producing water that satisfies a set of drinking water quality standards at a reasonable price to the consumers.
    3. Removal of solids in water. Solids maybe suspended, dissolved or colloidal. Some of the dissolved solids should stay in water at healthy concentrations.

Water treatment objective is to produce both "potable" and "palatable".

Potable: - Water that can be consumed in any desired amount without concern for adverse heath effects. Potable dose not necessarily mean that the water tastes good.
Palatable: - it is a water that is pleasing to drink but not necessarily safe.

- ***Water quality characteristics***

a. Physical characteristics:- ·
   · Turbidity
   · Color
   · Taste and odor
   · Temperature
b. Chemical characteristics:
   · Many dissolved chemicals exist in water and many of them are of concern such as:- Chloride, fluorides, Iron, lead, manganese, sodium, sulfate, zinc, toxic inorganic substances, toxic organic substances,
c. Microbiological characteristic:- Pathogens: viruses, bacteria, protozoa, helminthes (warms)

TABLE 6.3 Secondary Standards For Drinking Water

Contaminant	Level	Contaminant effects
Aluminum	0.05–0.2 mg/L	Water discoloration
Chloride	250 mg/L	Taste, pipe corrosion
Color	15 color units	Aesthetic
Copper	1 mg/L	Taste, porcelain staining
Corrosivity	Noncorrosive	Pipe leaching of lead
Fluoride	2.0 mg/L	Dental fluorosis
Foaming agents	0.5 mg/L	Aesthetic
Iron	0.3 mg/L	Taste, laundry staining
Manganese	0.05 mg/L	Taste, laundry staining
Odor	3 threshold odor number	Aesthetic
pH	6.5–8.5	Corrosive
Silver	0.1 mg/L	Skin discoloration
Sulfate	250 mg/L	Taste, laxative effects
Total dissolved solids	500 mg/L	Taste, corrosivity, detergents
Zinc	5 mg/L	Taste

Ground- vs. Surface Water

Groundwater

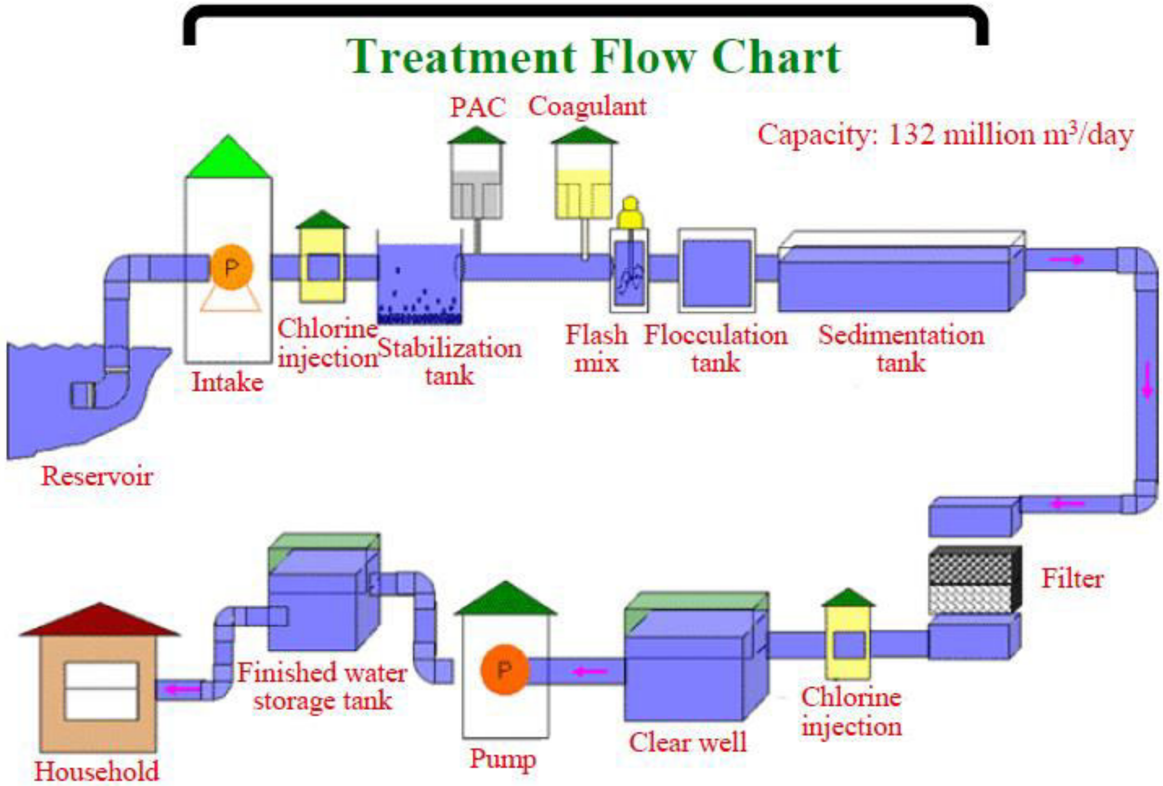
- constant composition
- high mineral content
- low turbidity
- low color
- low or no D.O.
- high hardness
- high Fe, Mn

Surface water

- variable composition
- low mineral content
- high turbidity
- colored
- D.O. present
- low hardness
- taste and odor

Most common treatment methods

- Coagulation and flocculation (UP)
- Softening (UP)
- Reverse osmosis RO (UP)
- electrodialysis (UP)
- ion exchange (UP)
- adsorption (UO)
- Precipitation (UP)
- disinfection (UP)
- sedimentation (UO)
- filtration (UO)



Lecture 32:

Recovery of useful materials from effluents by different methods:

By-products and wastes can be reused as resources and create economic efficiency. This article describes the status quo and the development of utilizing by-products and wastes, and discusses clean production and industrial ecology. By-products, as the name suggests, emerge along with a product, and all kinds of wastes emerge from time to time in the process of exploiting raw materials and producing and using products. Although they are inevitable, by-products are not necessary for production and for human life. Their emergence not only creates a waste of resources, but also influences the environment in different degrees. If we could reduce wastes and tap technologies to use the waste and by-products a second time as new resources, we could to a certain degree reduce the consumption of natural resources by humankind. This is a crucial content in the strategy of reasonable utilization of natural resources. Although at our present economic and technological level we cannot eliminate wastes and by-products completely, we are making efforts in this direction so that we can fully use various kinds of resources in essential production activities, constantly enhance cyclic utilization of wastes and by-products, raise the efficiency of resources use, reduce the consumption of resources and energy to the greatest degree, produce as little waste and by-products as possible, and help us live in harmony with nature.

Industrial and agro-industrial by-products and waste can be processed to obtain new materials and high added value products. The valorisation of industrial and agro-industrial waste is reached by their re-use in the production of innovative materials and components, following circular economy concepts.

Recovery and valorisation of industrial waste:

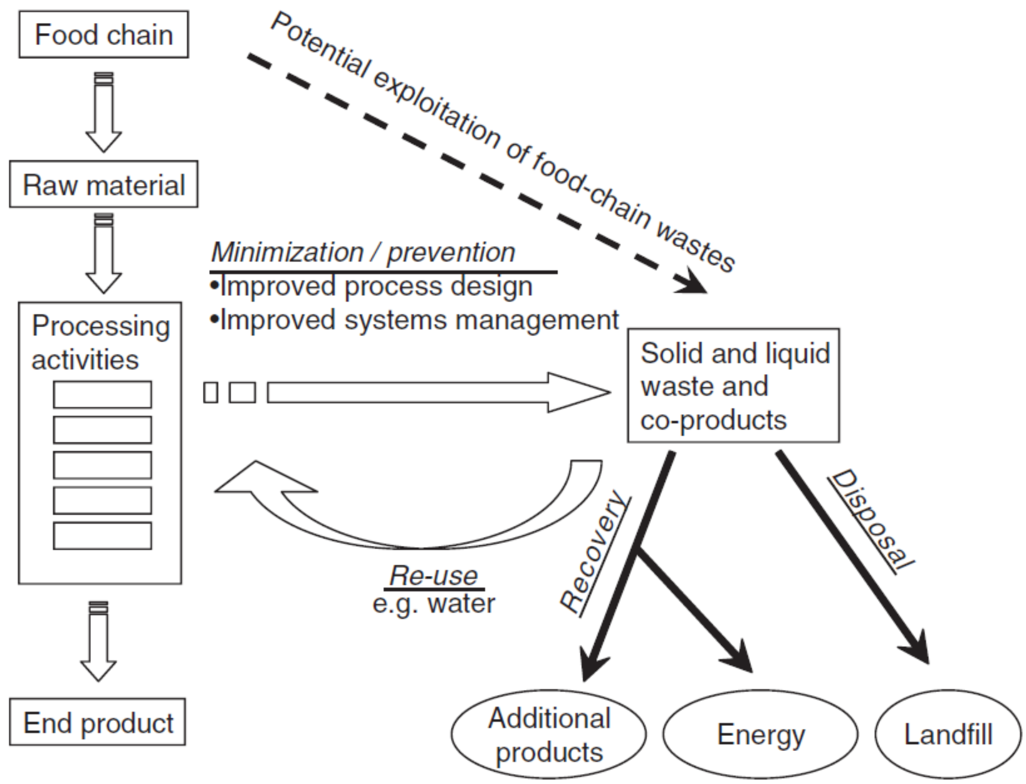
Secondary raw materials are recycled for several application fields. Ceramic materials and components are developed by the re-use of industrial by-products and waste, for example:

- recovery of waste of the super alloys casting process: re-used of ceramic shell in the production of refractories for high temperature applications as liner in combustion chamber of energy production turbine
- recovery of exhausted tyres: pyrolysis of tyres for the production of carbon powder with sulphur re-used for active sorbent based filter applied for VOC (Volatile Organic Compound) and mercury capture from gas emissions and industrial wastewater
- qualification of silicon carbide (SiC) powder obtained by using the exhausted tyres as secondary raw materials

Biobased materials:

Development of biobased materials from recovery and treatment of organic waste:

- recovery of urban, bio-char and agricultural organic waste for the development of special organic fertilizers with reduced salinity and increased qualitative, economic and environmental advantages, for a partial replacement of mineralized fertilizer; this solution is suitable especially to restore organic substances in depleted soils and to face climate change
- development of technical products as soaking additives, obtained by the recovery and treatment of fowl-manure, for leather tanning. Replacement of chemical agents to obtain new leather products characterized by a high level of eco-sustainability: example of industrial symbiosis where a by-product of egg production became a raw material for the leather tanning process.



Food processing waste in relation to the waste hierarchy.

Revision classes:

GURU NANAK INSTITUTE OF TECHNOLOGY

DEPARTMENT OF FOOD TECHNOLOGY

Setting up of the Question Paper (QP) for the odd semester examination 2017

Subject: Food Packaging Technology

Subject code: FT-701

Stream: Food Technology (7th semester)

Time:-3 hours **Full Marks:-70**

GROUP - A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any ***ten*** of the following: $10 \times 1 = 10$

i) The principle ingredient of glass is

a) Calcium oxide

b) Alumina

c) Silica

d) Potash Alumn

ii) Common lubricant system for tin plate uses

a) Dioctyle sebacate

b) Linseed oil

c) Grease

d) Wax

iii) The surface of tin free steel contains

a) Chromium oxide

b) Chromium

c) Steel

d) Oil

iv) Two piece cans can be prepared by

a) Double seaming

b) DWI

c) Welding

d) Soldering

v) Biodegradable film can be produced from

a) LDPE

b) Chitosan

c) PP

d) PVC

vi) Packaging material used for packaging of fats and oils is

a) HDPE

b) LLDPE

c) Nylon

d) PP

vii) Ideal shipping container for biscuit is

a) Paperboard

b) Flexible Pouch

c) Glass Jar

d) Aluminum Container

viii) Role of nylon laminates is basically to give

a) Stiffness and printability

b) Strength and oil resistance

c) Clarity

d) Low moisture permeability

ix) Idea packaging material for instant tea is

a) Paper

b) PET

c) Aluminium foil

d) LDPE

x) Full form of PET stands for

a) Polyester terephthalate

b) Polyester trimethyle

c) Polyethylene terephthalate

d) None

xi) Benzophenone is actually

a) Bibenzyl alcohol

b) Diphenyl ketone

c) Propyle benzene

d) Phenyl propane

xii) Which of the following natural pigments acts as corrosion accelerator pf metal cans?

a) Xanthophyll

b) Chlorophyll

c) Myoglobin

d) Anthocyanin

xiii) Safety concern for vacuum packed sausage is caused by

a) *Salmonella enteritidis*

b) *Listeria monocytogenes*

c) *Clostridium botulinum*

d) *Bacillus cereus*

xiv) Glass as packaging materials were first industrialized in which of the following civilizations?

a) Egypt

b) China

c) India

d) None

xv) Hydrapulper is used to produce which one of the following during paper manufacturing?

a) Pulp

b) Stock

c) Sheet

d) All of the above

xvi) Most common application of carbon monoxide in MAP of food is for

a) Red Meat

b) Shell Fish

c) Fresh fruit

d) None

xvii) Active packaging for foods provides

a) Oxygen, Nitrogen, Carbon-di-oxide

b) Oxygen and NO

c) Oxygen, Carbon di oxide and odour scavenger

d) Carbon di oxide, NO_2 and odour scavenger

xviii) Environmental Stress Cracking is a failure for

a) Polymers

b) Metals

c) Paper

d) None

xix) Which of the flowing is the strongest paper manufactured

a) Grease-proof paper

b) Kraft

c) Parchment

d) None of the above

xx) Which of the following is a type of laminating adhesive used in food packaging?

a) Blends of paraffins

b) Vinyl acetate

c) Both of the above

d) None of the above

xxi) What is the full form of LLDPE?

a) Linear Low Density Polyethylene

b) Linear Low Density Polystyrene

c) Labeled Low Density Polyethylene

d) None of the above

xxii) Inner layer of laminates for food pouches preferably consists of

a) LDPE

b) PP

c) Nylon film

d) All of the above

xxiii) For greater strength pure aluminum is alloyed with

a) Magnesium

b) Zinc

c) Copper

d) Chromium

GROUP - B

(Short Answer Type Questions)

Answer any ***three*** of the following. $3 \times 5 = 15$

2. Define Packaging and explain primary, secondary and tertiary packaging. (2+1+1+1)
3. What function does packaging material play in conserving the environment? (5)
4. Give some examples of co-polymers of Ethylene which can be used as packaging materials?What is Environmental Stress Cracking? (2+3)
5. What are the advantages of edible packaging materials? (5)
6. What is addition polymerization? Briefly explain atactic and isotactic polymers. (3+2)
7. What are Oxo-Biodegradable (OBD) Polymers? What are the advantages of using nano-composite materials in food packaging? (3+2)
8. What are grease-proof papers? Briefly explain the term 'glassine'. Write the use of kraft paper. (2+2+1)
9. What are the uses of paper-boards as a packaging material for food? What is the function of corrugation in fiber-boards? Why do we laminate papers? (2+2+1)
10. Give some examples of additives in plastics. Why is PET a very good choice for packaging of beverages?What are the stages of performing shrink-wrapping of food? (2+1+2)

GROUP - C

(Long Answer Type Questions)

Answer any ***three*** of the following. $3 \times 15 = 45$

11. What is modified atmosphere packaging (MAP)? What are the packaging films commonly used for MAP? Is there any difference on controlled atmosphere packaging and MAP? Discuss the roles of O_2, N_2 and CO_2 in MAP. Name some equipment used for performing MAP. (3+2+2+6+2)
12. Discuss the difference between tin-plates and tin-free steel (TFS). What are the disadvantages of using TFS? Briefly explain the role of aluminum as a packaging material. How is aluminum foils made? Write some applications of aluminum foils. (3+2+4+2+4)
13. Comment on the advantages of using glass as a food-packaging material. Briefly discuss the methods of forming process for manufacturing glass jars and bottles. (7+8)
14. What type of packaging items will you choose for the following food items –
    a) Milk and Dairy products
    b) Fats and oils
    c) Red Meat

    What are form-fill-seal cartons? How does irradiation help in aseptic packaging? (6+5+4)
15. What are the common sorbants, permeating and migrating substances – generally relevant in interactions between food and packaging materials? Highlight their adverse consequences. How do different factors affect food-packaging interactions? Explain with examples on how we can reduce such problems? (3+3+5+4)
16. Give some examples of different polyolefin used in food packaging industry. Discuss the properties of polypropylene as a food packaging material. What is the major difference between LDPE and LLDPE? What is polystyrene? Give some uses of polystyrene as packaging material. (3+5+2+2+3)
17. What do you mean by intelligent packaging? Give some examples. Discuss the role of radio frequency identification in intelligent packaging of food. How can we improve the printability of a packaging material? (4+3+3+5)
18. What is meant by 'Tetra pack'? Discuss the scalping phenomenon. What are disposable packaging materials? What are the optical tests that are performed for packaging materials? (5+3+2+5)
19. Why is it important to have a good closure to the food container? What are the different types of closures that are in use? What are the different types of heat sealing used in packaging industry? What are the differences between adhesive and cohesive types of peel-able seals usedin food packaging? (2+5+5+3)