INSTITUTE OF AERONAUTICAL ENGINEERING
Dundigal, Hyderabad -500 043
(Autonomous)

INDUSTRIAL WASTE WATER TREATMENT

(A70139) JNTUH-R15

B.Tech IV YEAR I SEM

Prepared By:
Mr. Ch. Balakrishna
Asst. Professor
Department of Civil Engineering

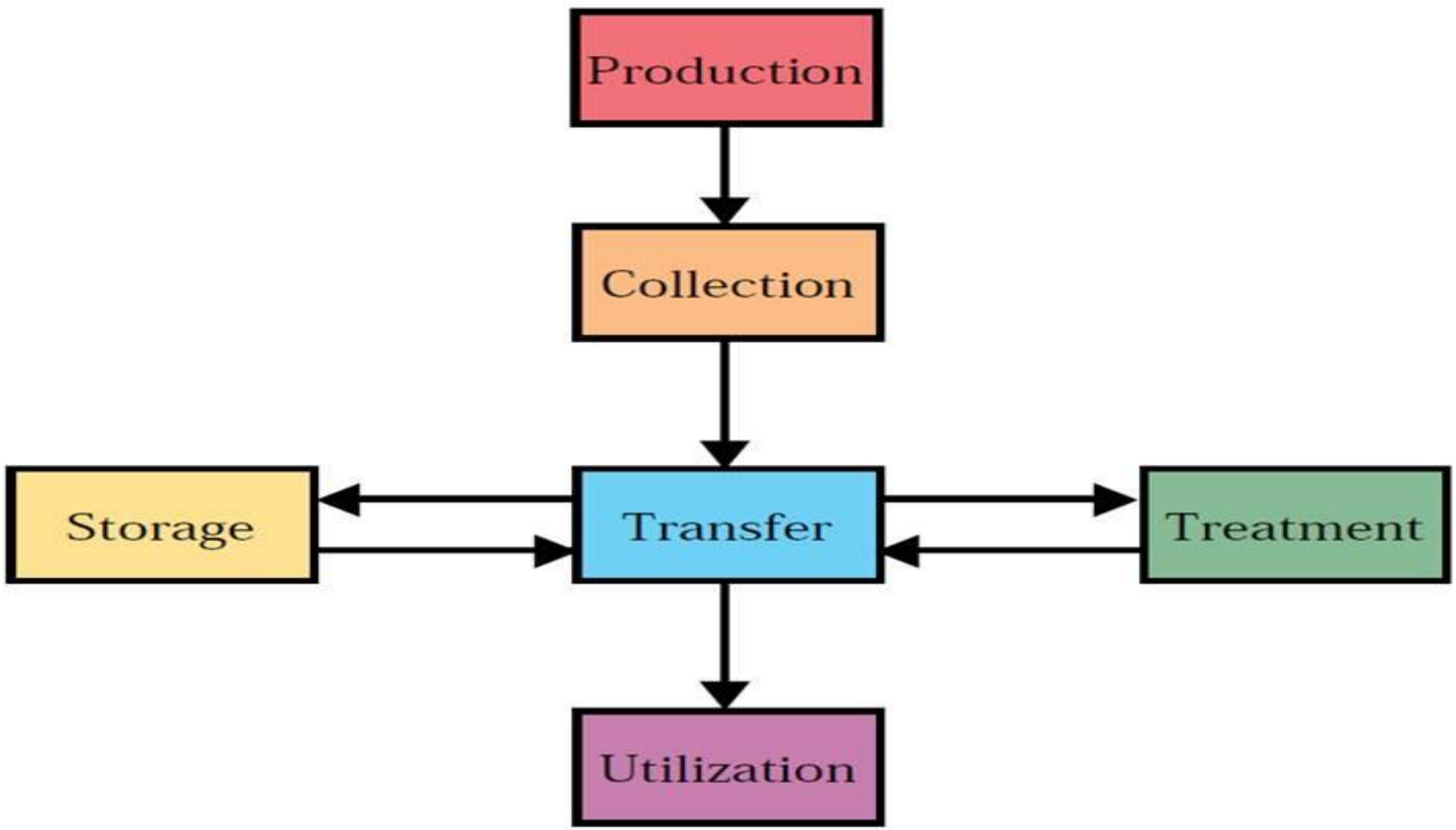
UNIT I
INDUSTRIAL WASTE TREATMENT

Definition

- **Industrial wastewater treatment** covers the mechanisms and processes used to treat waters that have been contaminated in some way by anthropogenic industrial or commercial activities prior to its release into the environment or its re-use.

- Most industries produce some wet waste although recent trends in the developed world have been to minimize such production or recycle such waste within the production process.
- However, many industries remain dependent on processes that produce wastewaters.

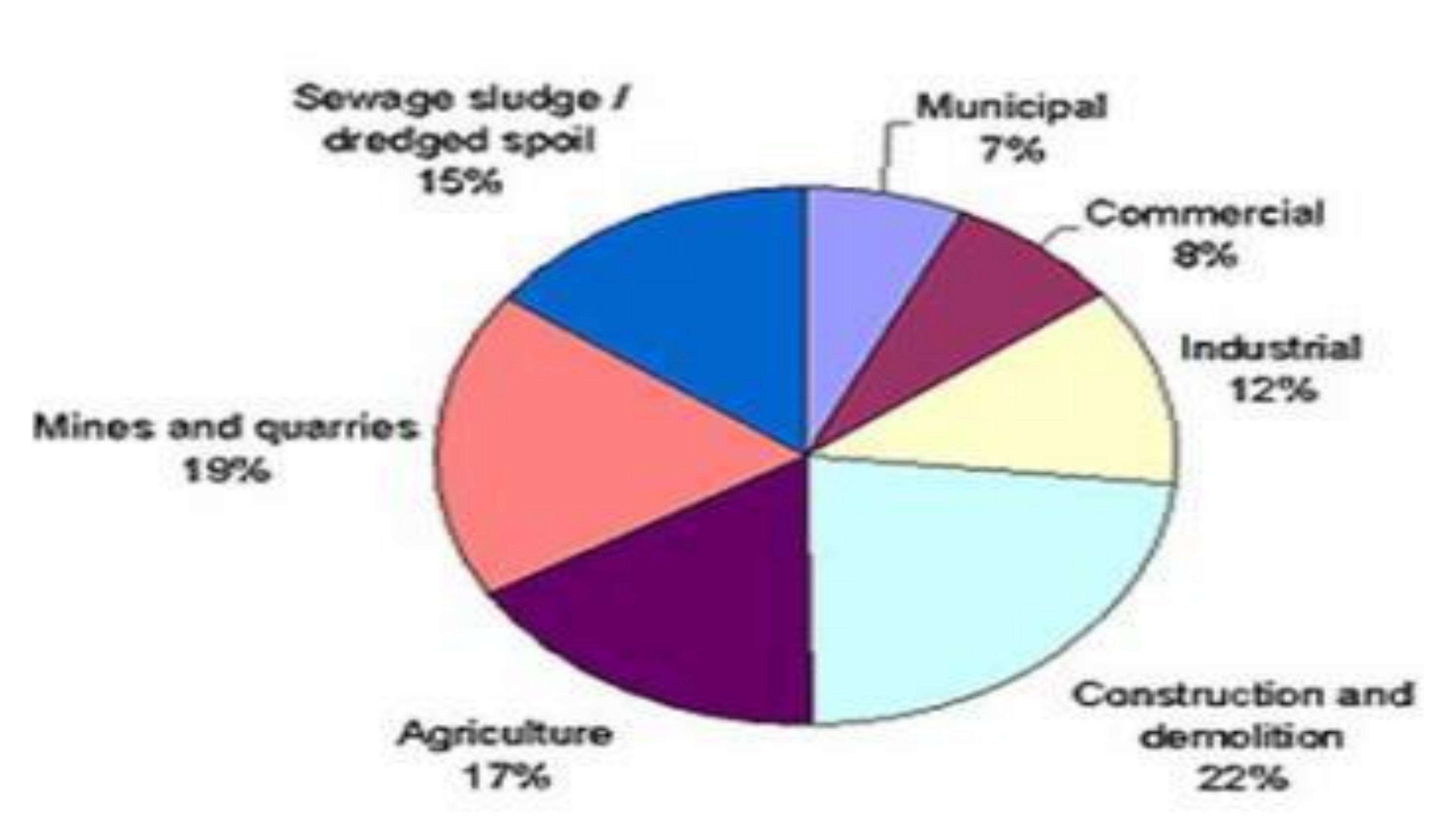
Waste Reduction Principle



Sources of industrial wastewater

- Agricultural waste
- Iron and steel industry
- Mines and quarries
- Food industry
- Complex organic chemicals industry
- Nuclear industry

%Share of Pollutants

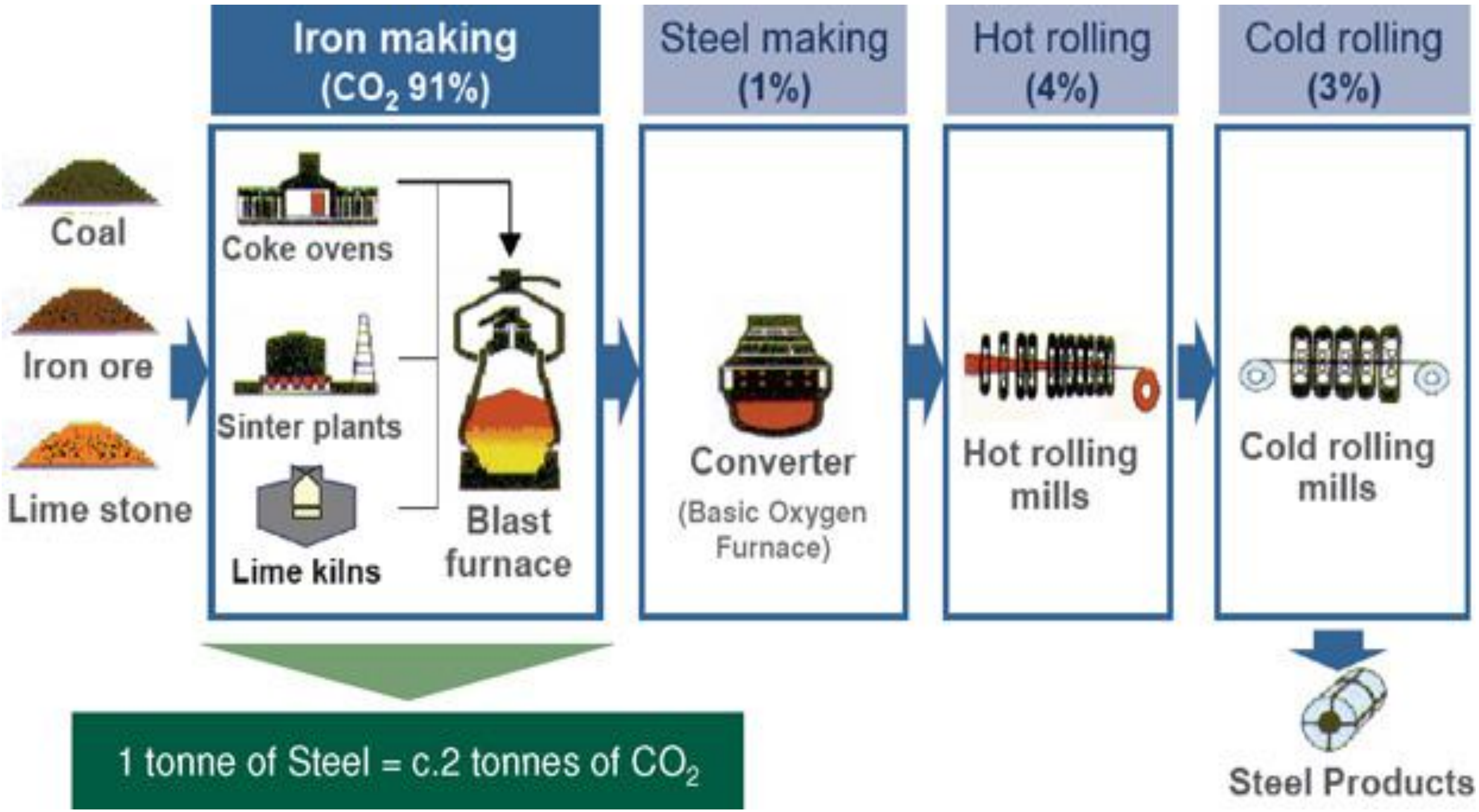


Agricultural waste

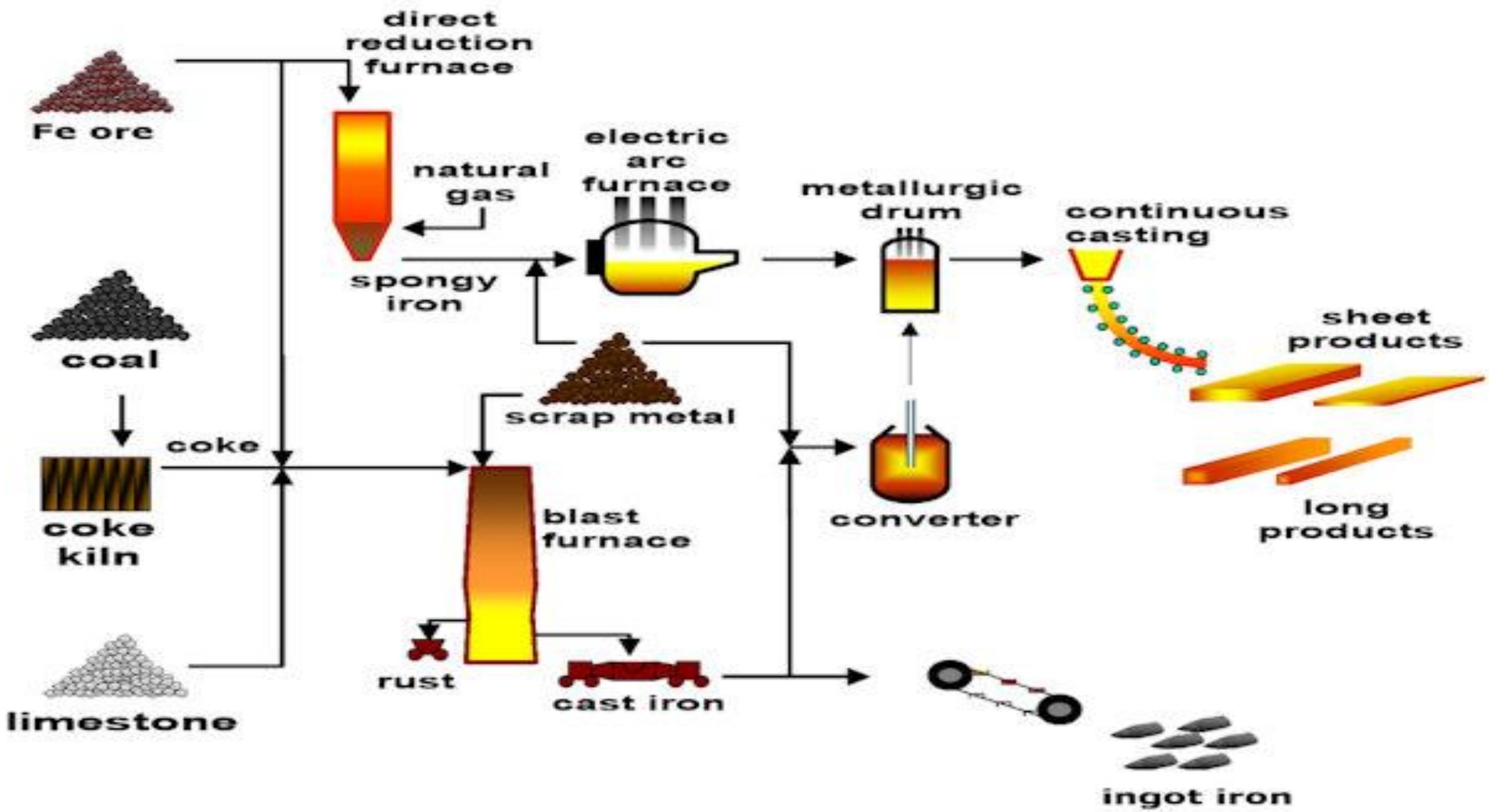
Agricultural waste

- **Agricultural wastewater treatment** relates to the treatment of wastewaters produced in the course of agricultural activities.
- Agriculture is a highly intensified industry in many parts of the world, producing a range of wastewaters requiring a variety of treatment technologies and management practices.

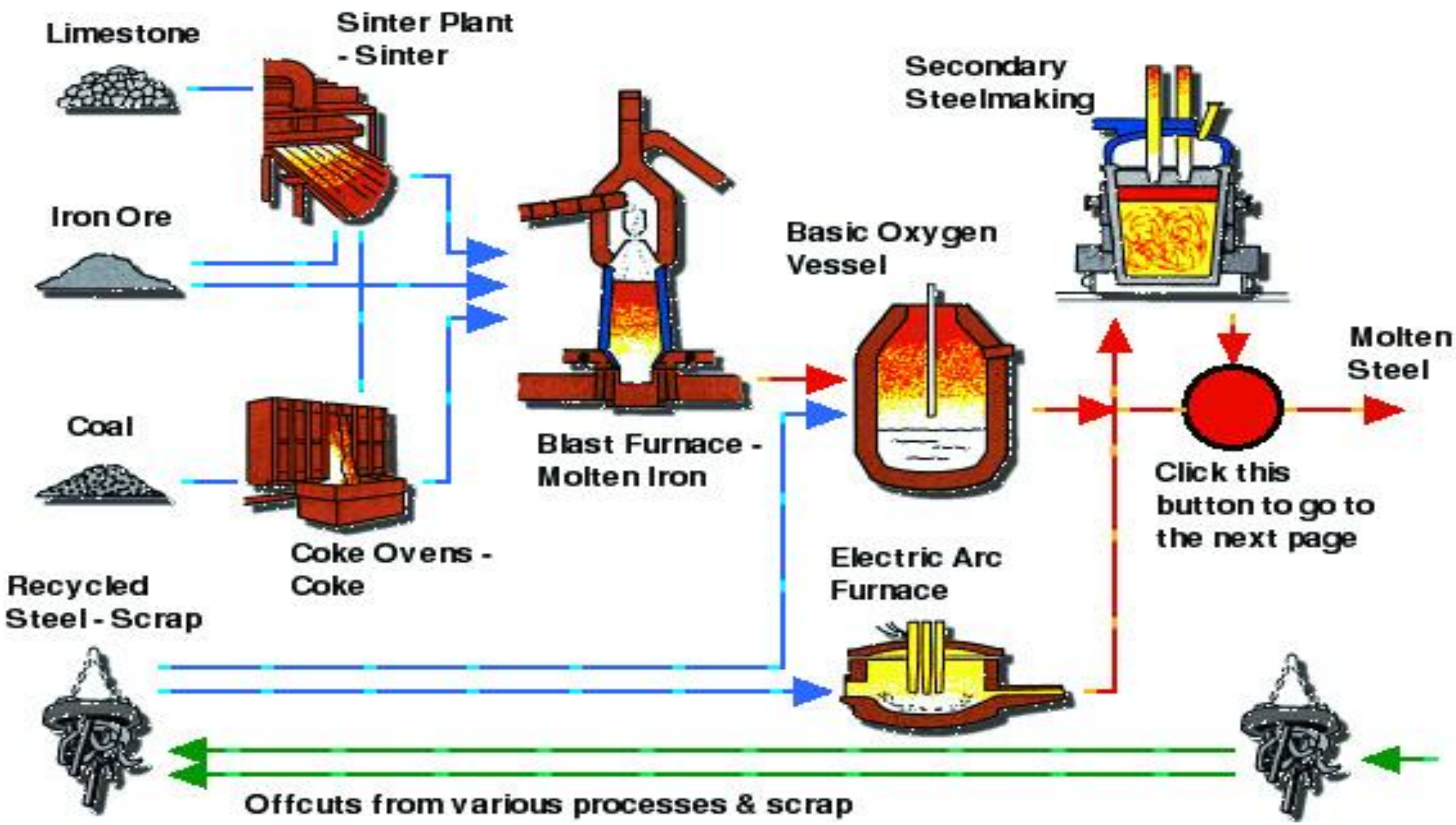
Iron and steel industry



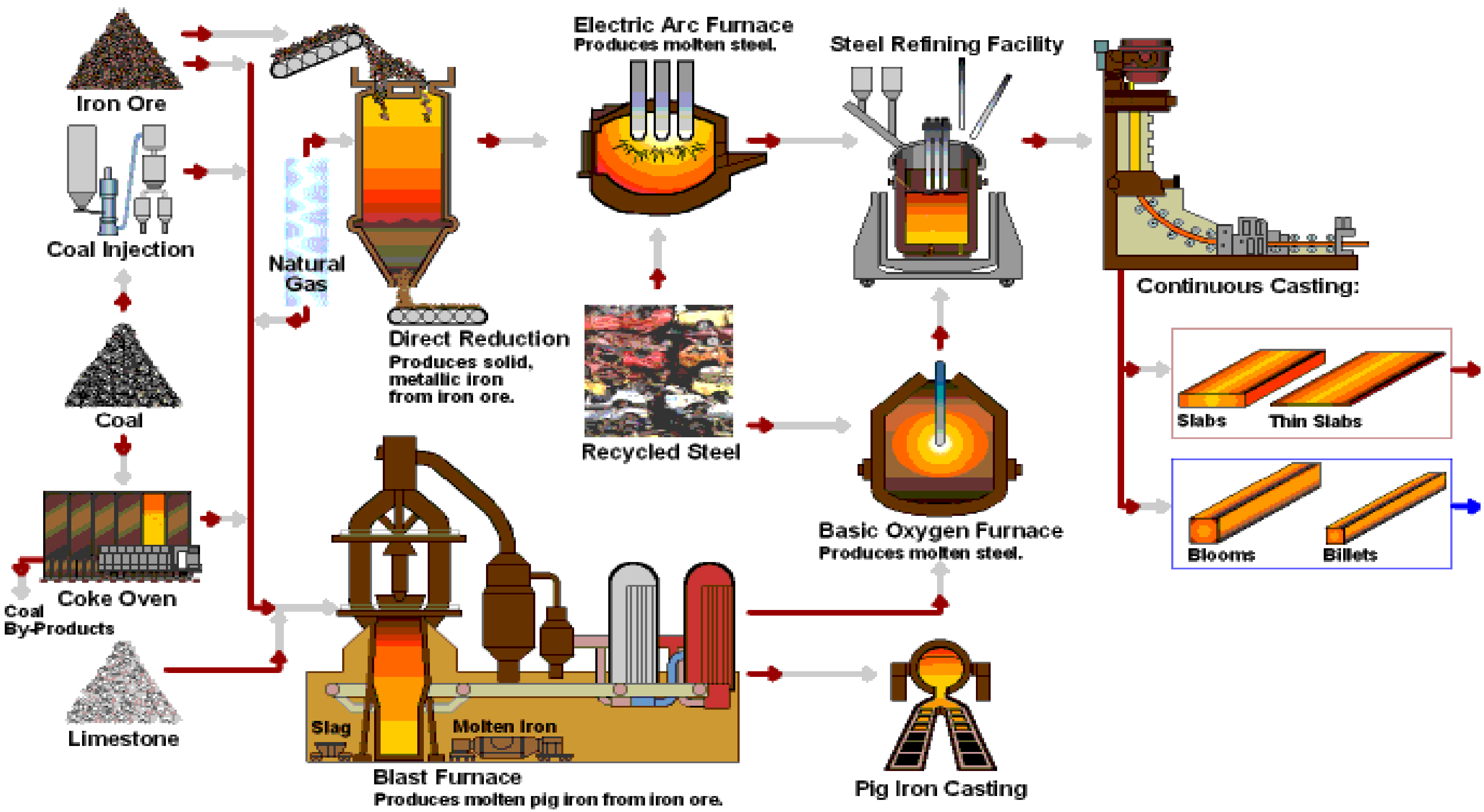
Iron and steel industry



Iron and steel industry



Iron and steel industry



Iron and steel industry

- The production of iron from its ores involves powerful reduction reactions in blast furnaces. Cooling waters are inevitably contaminated with products especially ammonia and cyanide.
- Production of coke from coal in coking plants also requires water cooling and the use of water in by-products separation.
- Contamination of waste streams includes gasification products such as benzene, naphthalene, anthracene, cyanide, ammonia, phenols, cresols together with a range of more complex organic compounds known collectively as polycyclic aromatic hydrocarbons (PAH).

- The conversion of iron or steel into sheet, wire or rods requires hot and cold mechanical transformation stages frequently employing water as a lubricant and coolant.
- Contaminants include hydraulic oils, tallow and particulate solids.
- Final treatment of iron and steel products before onward sale into manufacturing includes *pickling* in strong mineral acid to remove rust and prepare the surface for tin or chromium plating or for other surface treatments such as galvanisation or painting.

- The two acids commonly used are hydrochloric acid and sulfuric acid. Wastewaters include acidic rinse waters together with waste acid.
- Although many plants operate acid recovery plants, (particularly those using Hydrochloric acid), where the mineral acid is boiled away from the iron salts, there remains a large volume of highly acid ferrous sulfate or ferrous chloride to be disposed of.
- Many steel industry wastewaters are contaminated by hydraulic oil also known as *soluble oil.*

Mines and quarries

Mines and quarries

Mines and quarries

Mines and quarries

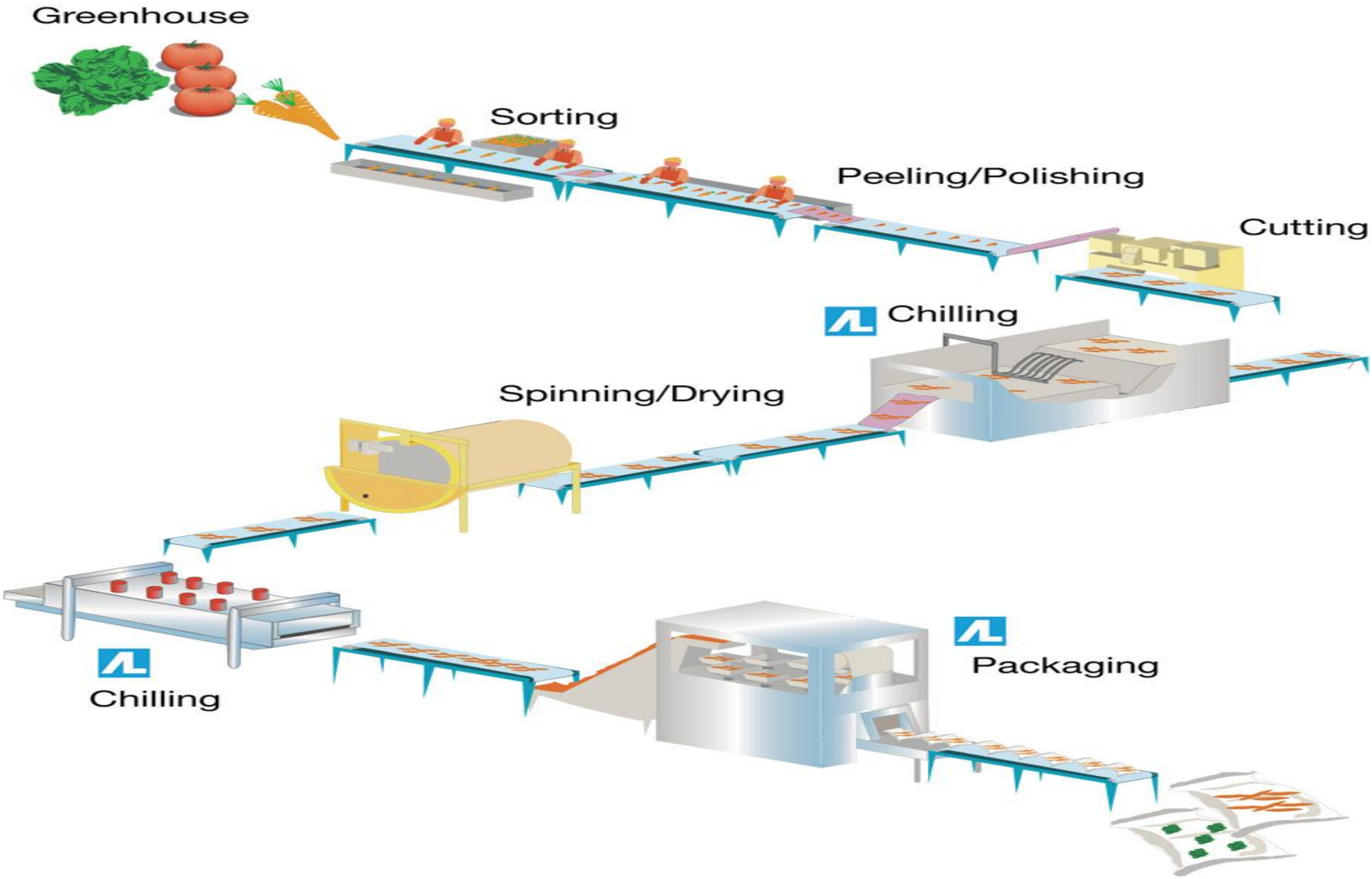
- The principal waste-waters associated with mines and quarries are slurries of rock particles in water.
- These arise from rainfall washing exposed surfaces and haul roads and also from rock washing and grading processes.
- Volumes of water can be very high, especially rainfall related arising on large sites.
- Some specialized separation operations, such as coal washing to separate coal from native rock using density gradients, can produce wastewater contaminated by fine particulate haematite and surfactants.

- Oils and hydraulic oils are also common contaminants.
- Wastewater from metal mines and ore recovery plants are inevitably contaminated by the minerals present in the native rock formations.
- Following crushing and extraction of the desirable materials, undesirable materials may become contaminated in the wastewater.
- For metal mines, this can include unwanted metals such as zinc and other materials such as arsenic.
- Extraction of high value metals such as gold and silver may generate slimes containing very fine particles in where physical removal of contaminants becomes particularly difficult.

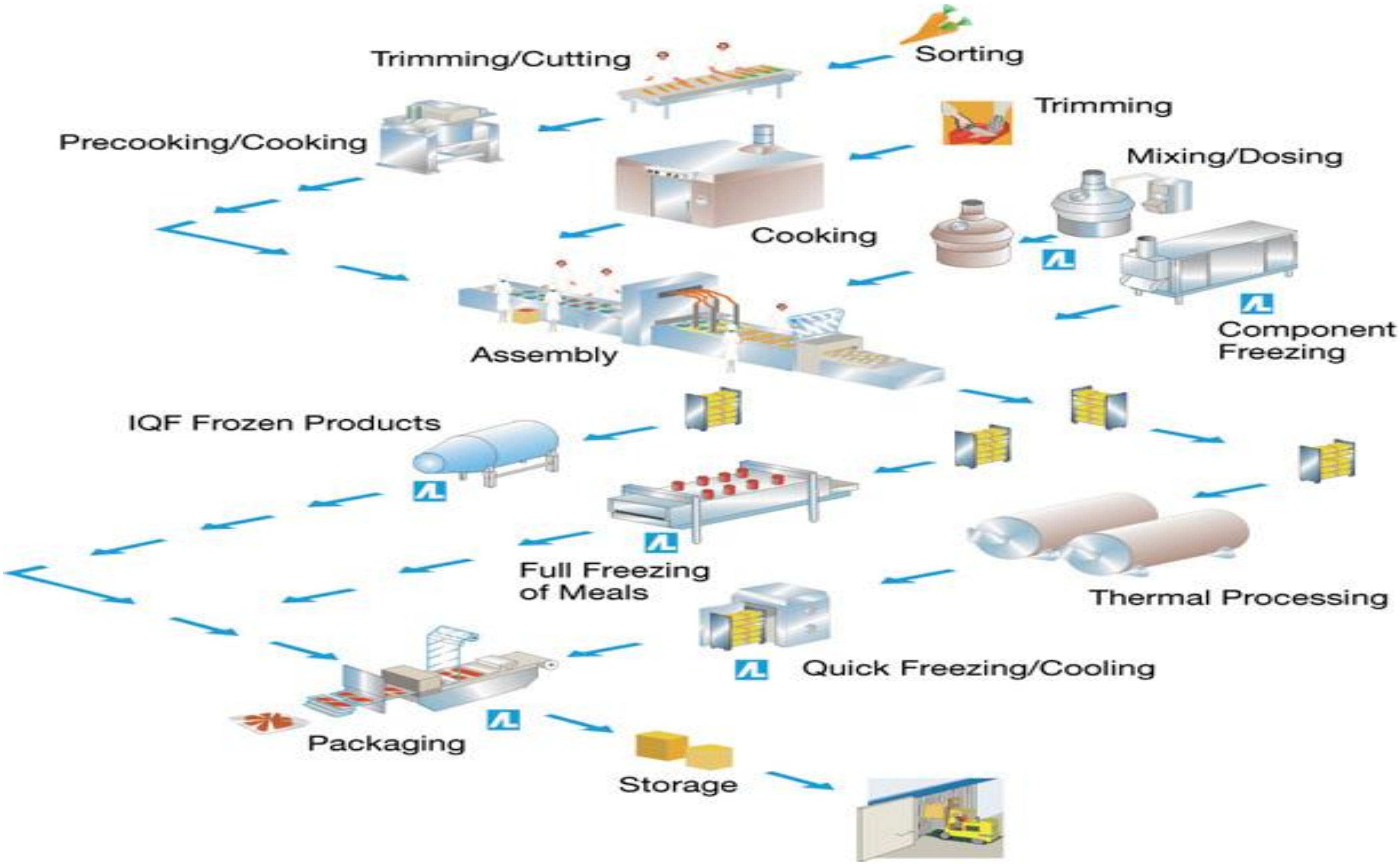
Food industry



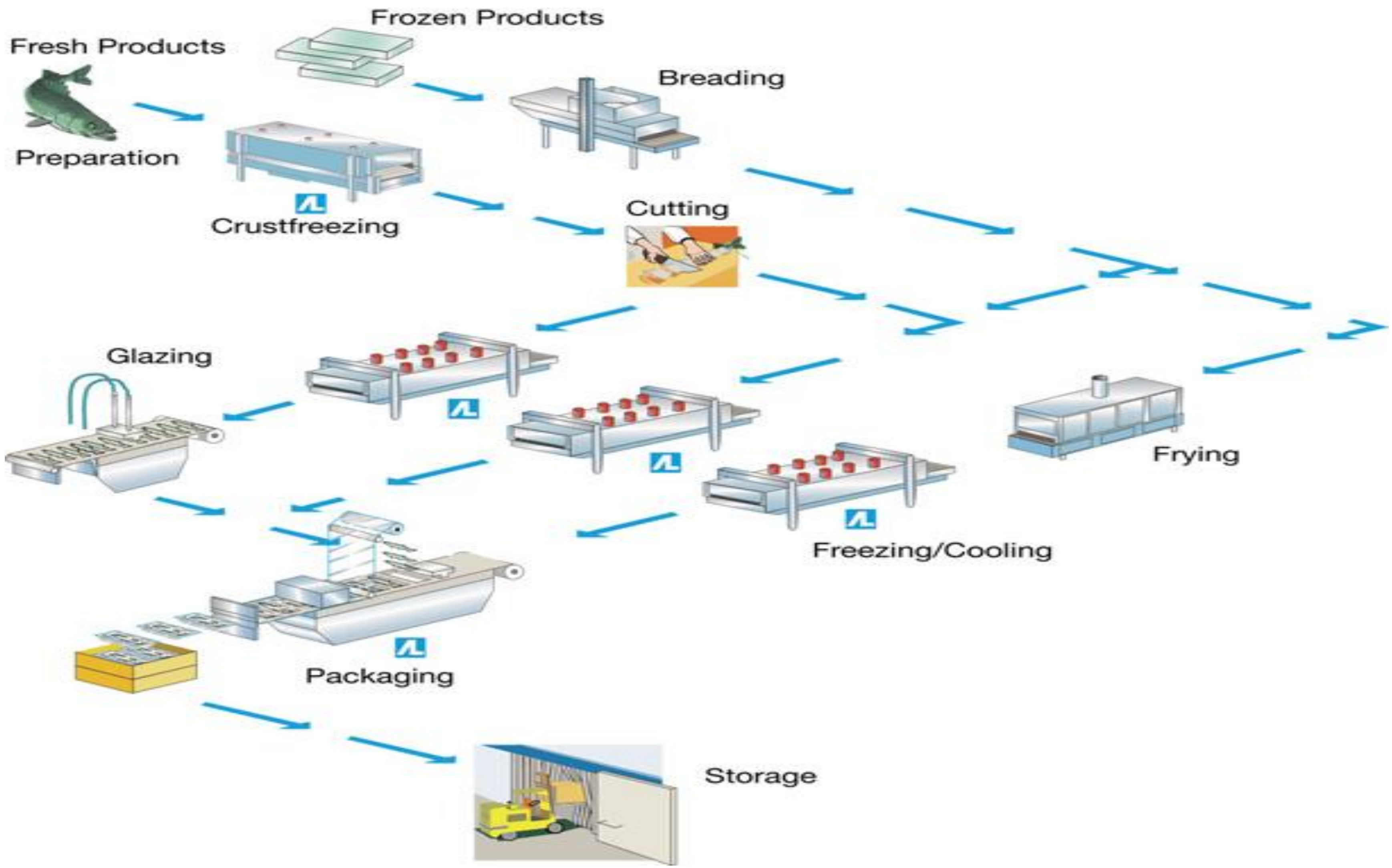
Food industry



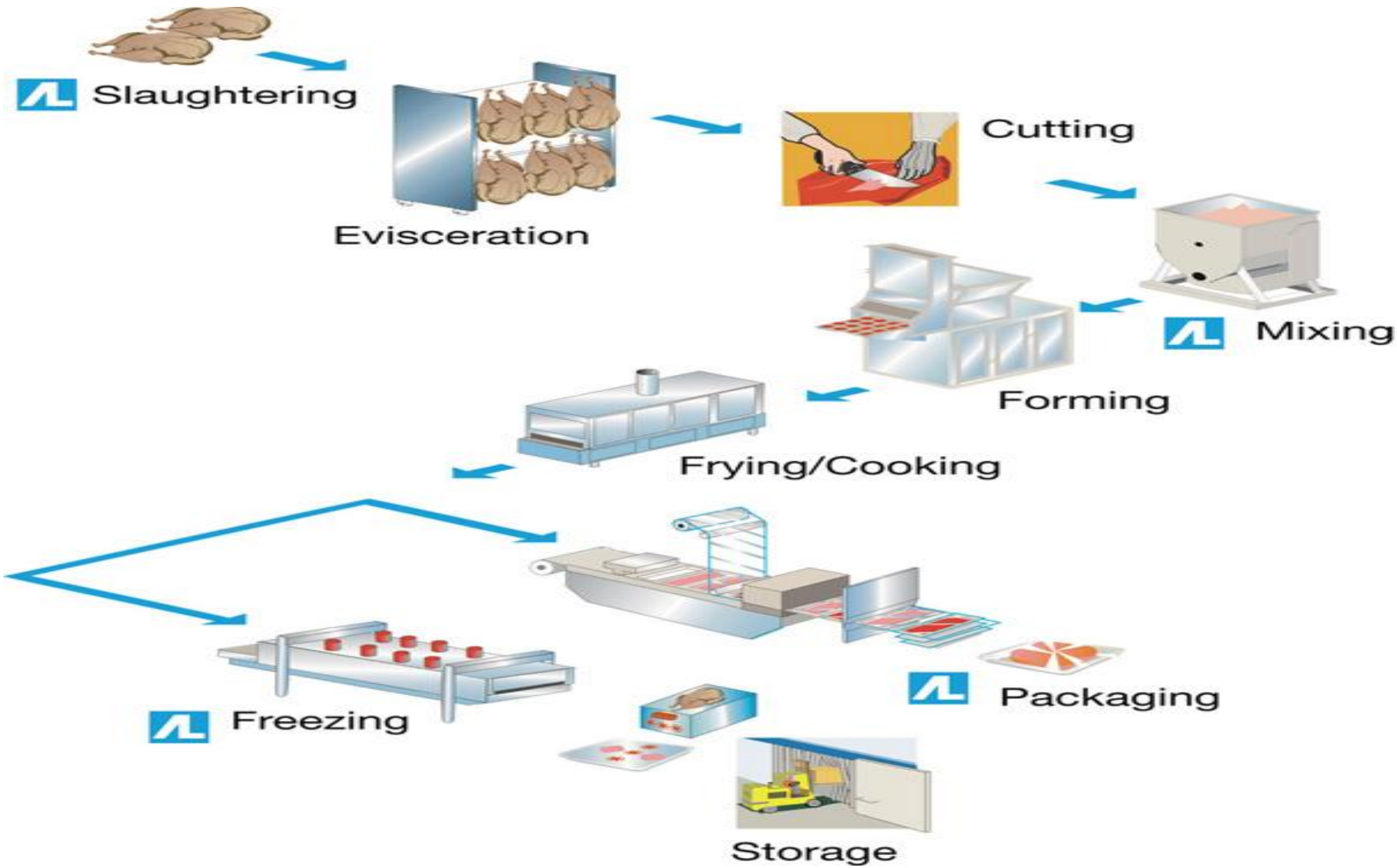
Food industry



Food industry



Food industry



Food industry

- Wastewater generated from agricultural and food operations has distinctive characteristics that set it apart from common municipal wastewater managed by public or private wastewater treatment plants throughout the world: it is biodegradable and nontoxic, but that has high concentrations of biochemical oxygen demand (BOD) and suspended solids (SS).

- The constituents of food and agriculture wastewater are often complex to predict due to the differences in BOD and pH in effluents from vegetable, fruit, and meat products and due to the seasonal nature of food processing and post harvesting.
- Processing of food from raw materials requires large volumes of high grade water.
- Vegetable washing generates waters with high loads of particulate matter and some dissolved organics.
- It may also contain surfactants.

- Animal slaughter and processing produces very strong organic waste from body fluids, such as blood, and gut contents.
- This wastewater is frequently contaminated by significant levels of antibiotics and growth hormones from the animals and by a variety of pesticides used to control external parasites.
- Insecticide residues in fleeces is a particular problem in treating waters generated in wool processing.
- Processing food for sale produces wastes generated from cooking which are often rich in plant organic material and may also contain salt, flavourings, colouring material and acids or alkali. Very significant quantities of oil or fats may also be present.

Complex organic chemicals industry

Complex organic chemicals industry

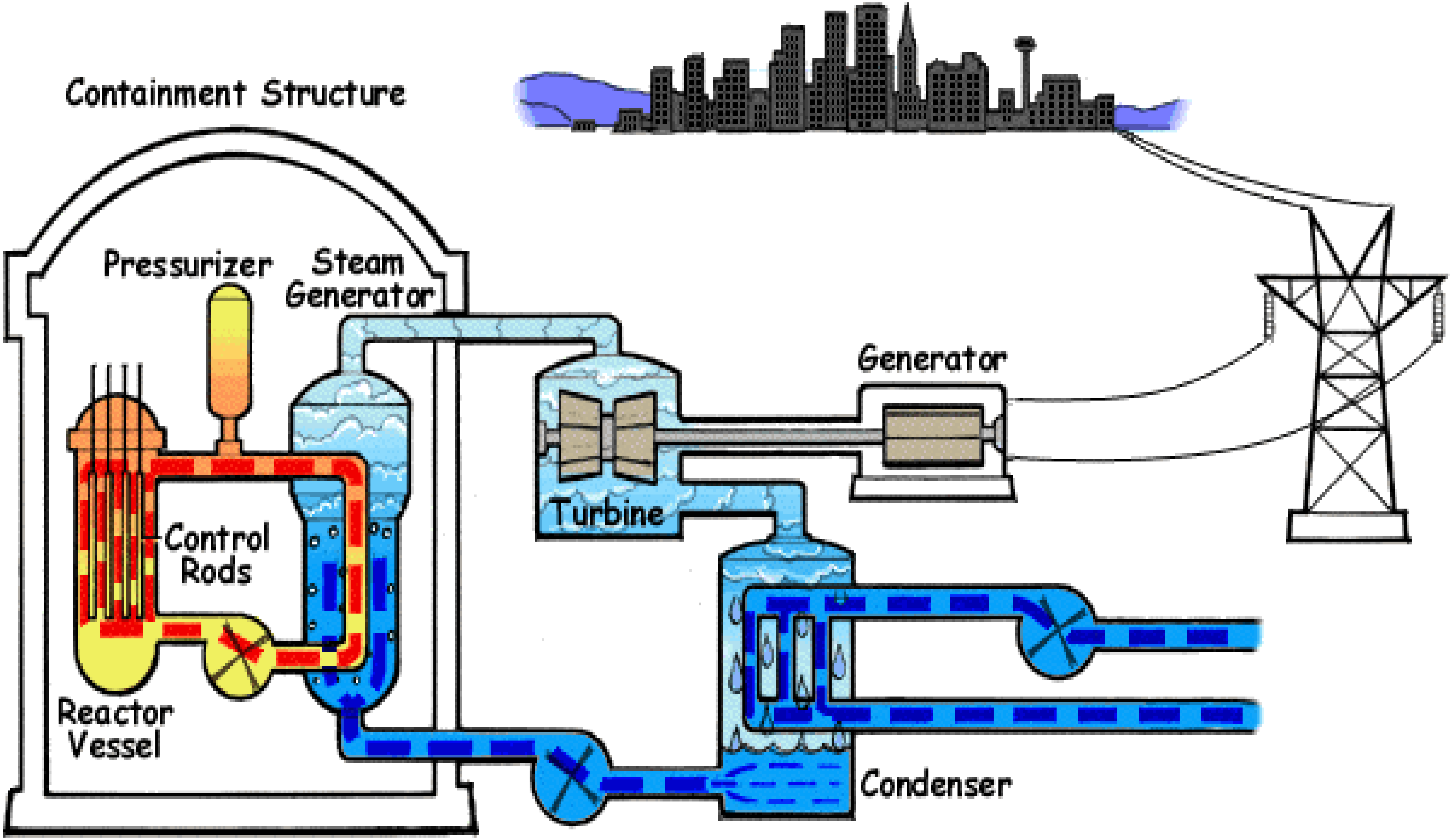
- A range of industries manufacture or use complex organic chemicals. These include pesticides, pharmaceuticals, paints and dyes, petro-chemicals, detergents, plastics, paper pollution, etc.
- Waste waters can be contaminated by feed-stock materials, by-products, product material in soluble or particulate form, washing and cleaning agents, solvents and added value products such as plasticisers.
- Treatment facilities that do not need pH control of their effluent typically opt for a type of aerobic treatment, ie. Aerated Lagoons

Nuclear industry

- **Radioactive waste** is a waste product containing radioactive material. It is usually the product of a nuclear process such as nuclear fission, though industries not directly connected to the nuclear power industry may also produce radioactive waste.
- Radioactivity diminishes over time, so in principle the waste needs to be isolated for a period of time until it no longer poses a hazard
- This can mean hours to years for some common medical or industrial radioactive wastes, or thousands of years for high-level wastes from nuclear power plants and nuclear weapons reprocessing.

Nuclear industry

Nuclear industry



- The majority of radioactive waste is "low-level waste", meaning it has low levels of radioactivity per mass or volume.
- The main approaches to managing radioactive waste to date have been segregation and storage for short-lived wastes, near-surface disposal for low and some intermediate level wastes, and deep burial or transmutation for the long-lived, high-level wastes.

- **Wastewater: is simply that part of the water supply to the community or to the industry which has been used for different purposes and has been mixed with solids either suspended or dissolved**
- **Wastewater is 99.9% water and 0.1% solids. The main task in treating the wastewater is simply to remove most or all of this 0.1% of solids.**

Type of wastewater from household

- **Gray water**

  Washing water from the kitchen, bathroom, laundry (without faeces and urine)
- **Black water**

  Water from flush toilet (faeces and urine with flush water)
- **Yellow water**

  Urine from separated toilets and urinals
- **Brown water**

  Black water without urine or yellow water

Why do we need to treat wastewater ?

- To prevent groundwater pollution
- To prevent sea shore
- To prevent soil
- To prevent marine life
- Protection of public health
- To reuse the treated effluent

  For agriculture, ground water recharge

  For industrial recycle
- Solving social problems caused by the accumulation of wastewater

- **Protecting the public health:**

  Wastewater contains pathogenic microorganisms lead to dangerous diseases to humans and animals

  Hazardous matter such as heavy metals that are toxic

  Produces odorous gases and bad smell

- **Protecting the environment:**
- Raw Wastewater leads to septic conditions in the environment and consequently leads to the deterioration of surface and groundwater quality and pollutes the soil.
- Raw wastewater is rich with nitrogen and phosphorus (N, P) and leads to the phenomena of EUTROPHICATION.
- Raw wastewater is rich with organic matter which consumes oxygen in aquatic environment.
- Raw wastewater may contains toxic gases and volatile organic matter

Physical, chemicals and biological properties of wastewater

Characteristic	Sources
Physical properties: Color	Domestic and industrial wastes, natural decay of organic materials
Odor	Decomposing wastewater, industrial wastes.
Solids	Domestic water supply, domestic and industrial wastes, soil erosion, inflow infiltration
Temperature	Domestic and industrial wastes
Chemical constituents: Organic: Carbohydrates	Domestic, commercial, and industrial wastes
Fats, oils, and grease	Domestic, commercial, and industrial wastes
Pesticides	Agricultural wastes
Phenols	Industrial wastes
Proteins	Domestic, commercial, and industrial wastes
Priority pollutants	Domestic, commercial, and industrial wastes

Physical, chemicals and biological properties of wastewater

Surfactants	Domestic, commercial, and industrial wastes
Volatile organic compounds	Domestic, commercial, and industrial wastes
Other	Natural decay of organic materials
Inorganic: Aikalinity	Domestic wastes, domestic water supply, groundwater infiltration
Chlorides	Domestic wastes, domestic water supply, groundwater infiltration
Heavy metals	Industrial wastes
Nitrogen	Domestic and agricultural wastes
PH	Domestic, commercial, and industrial wastes
Phosphorus	Domestic, commercial, and industrial wastes natural runoff
Priority polluter Sulfur	Domestic water supply; doestic, commercial. And industrial wastes
Gases: Hydrogen sulfide	Decomposition of domestic wastes
Methane	Decomposition of domestic wastes
Oxygen	Domestic water supply , surface- water infiltration
Biological constituents: Animals	Open watercourses and treatment plants
Plants	Open watercourses and treatment plants
Eubacteria	Domestic wastes, surface water infiltration, treatment plants .
Archaebacteria	Domestic wastes, surface-water infiltration, treatment plants
Viruses	Domestic wastes

Physical characteristics-Solids

- Solids are classified into three main types:
- Total Solids (TS): All the matter that remains as residue upon evaporation at 103oC to 105oC.
- Settleable solids: Settleable solids are measured as ml/L, which is an approximate measure of the sludge that can be removed by primary sedimentation.
- Suspended solids (SS) and Filterable solids (FS).

Physical characteristics-Odor

- Odor is produced by gas production due to the decomposition of organic matter or by substances added to the wastewater
- **Detection of odor**: Odor is measured by special instruments such as the Portable H2S meter which is used for measuring the concentration of hydrogen sulfide.

Physical characteristics-Odor

Compound	Chemical Formula	Odor quality
Amines	CH_3NH_2, $(CH_3)\ _3H$	Fishy
Ammonia	NH_3	Ammoniacal
Diamines	$NH_2\ (CH_2)_4\ NH_2$, $(CH_2)_5$ $NH_2\ H_{25}$	Rotten eggs
Mercaptans		
(E. g, methy1 and ethy1)	CH_3SH, $CH_3\ (CH_2)\ SH$	Decayed cabbage
Organic sulfides		Rotten cabbage
Skatole		Fecal matter

Physical characteristics-Temperature

- Temperature of wastewater is commonly higher than that of water supply. Depending on the geographic location the mean annual temperature varies in the range of 10 to 21^{o}C with an average of 16 ^{o}C.
- Affects chemical reactions during the wastewater treatment process. Affects aquatic life
- Oxygen solubility is less in worm water than cold water.

Physical characteristics-Temperature

- 35Aerobic digestion and nitrification stop when the temperature rises to50 oC. When the temperature drops to about 15°c, methane producing bacteria become in active.
- Nitrifying bacteria stop activity at about 5°c.
- Optimum temperature for bacterial activity is in the range of 25°C to 35

Physical characteristics -

- **Density**

  Almost the same density of water when the wastewater doesn't include significant amount of industrial waste.

- **Color**

  Fresh waste water --- **light brownish gray**.

  With time ------**dark gray**

  More time ------**black (septic).**

- Some times **pink** due to algae or due to industrial colors.
- **Turbidity**
- It's a measure of the light –transmitting properties of water.

Chemical characteristics of wastewater

- **Organic matter (CaHbOc).75% SS organic. (Suspended Solids) 40% FS organic. (Filtered Solids)Organic mater is derived from animals & plants and man activities. Proteins (40-60%).Carbohydrates (25-50%). Fats, Oils, and Grease (10%).**

Chemical characteristics of wastewater

- **Measurements of organic matter:-**
- Many parameters have been used to measure the concentration of organic
- matter in wastewater. The following are the most common used methods:
- Biochemical oxygen demand (BOD).
- BOD5is the oxygen equivalent of organic matter. It is determined by measuring the dissolved oxygen used by microorganisms during the biochemical oxidation of organic matter in 5 days at 20oC
- Chemical oxygen demand (COD)
- It is the oxygen equivalent of organic matter. It is determined by measuring
- the dissolved oxygen used during the chemical oxidation of organic matter in 3 hours.

Chemical characteristics of wastewater

- Total organic carbon (TOC)This method measures the organic carbon existing in the wastewater by injecting a sample of the WW in special device in which the carbon is oxidized to carbon dioxide then carbon dioxide is measured and used to quantify the amount of organic matter in the WW. This method is only used for small concentration of organic matter.
- Theoretical oxygen (ThOD)If the chemical formula of the organic matter existing in the WW is known the ThOD may be computed as the amount of oxygen needed to oxidize the organic carbon to carbon dioxide and a other end products.

Inorganic Matter

- The main inorganic materials of concern in wastewater treatment are

1. Chlorides:-

- High concentrations indicate that the water body has been used for waste disposal
- It affects the biological process in high concentrations.

2. Nitrogen

- TKN = Total Kjeldahl nitrogen.

  = Organic Nitrogen + ammonia Nitrogen (120 mg/l)

Inorganic Matter

- The main inorganic materials of concern in wastewater treatment are

3. Phosphorus:-

- Municipal waste contains (4-15 mg/l).

4. Sulfur:-

* Sulfate exists in waste and necessary for synthesis of proteins.

$$\text{Organic matter} + SO_4^{-2} \rightarrow S^{-2} + H_2O + CO_2$$

$$S^{-2} + 2H^+ \rightarrow H_2S$$

5. Toxic inorganic Compounds:-

Copper, lead, silver, chromium, arsenic, boron

Inorganic Matter

- The main inorganic materials of concern in wastewater treatment are

6. Heavy metals:-

- Nickels, Mn, Lead, chromium, cadmium, zinc, copper, iron mercury
- **Gases:-**
- The main gases of concern in wastewater treatment:N_2, O_2, CO_2, H_2S, NH_3, CH_4

PH

- The hydrogen-ion concentration is an important parameter in both natural waters and wastewaters.
- It is a very important factor in the biological and chemical wastewater treatment.
- Water and wastewater can be classified as neutral, alkaline or acidic according to the following ranges:
- **PH = 7 neutral, PH > 7 Alkaline, PH < 7 Acidic.**

Biological Characteristics

- it is a very important characteristics factor in wastewater treatment.
- The EE should know

1. The principal groups of **microorganisms** found in wastewater.
2. The **pathogenic organisms**.
3. **Indicator organisms** (indicate the –presence of pathogens).
4. The methods used to find the **amount of microorganisms.**
5. The methods to **evaluate the toxicity** of treated wastewater

Main groups of Microorganisms

- **Bacteria:-Types: Spheroid, rod curved rod, spiral, filamentous. Some important bacteria**
- Pseudomonas:-reduce NO3to N2, So it is very important in biological nitrate removal in treatment works.
- Zoogloea:-helps through its slime production in the formation of flocs in the aeration tanks.
- Sphaerotilus natuns:Causes sludge bulking in the aeration tanks

Main groups of Microorganisms

- **Bacteria:-Types: Spheroid, rod curved rod, spiral, filamentous. Some important bacteria**
- Bdellovibrio: destroy pathogens in biological treatment.
- Acinetobacter:Store large amounts of phosphate under aerobic conditions and release it under an –anaerobic condition so, they are useful in phosphate removal.
- Nitrosomonas: transform NH4into NO2

Main groups of Microorganisms

- **Bacteria:-Types: Spheroid, rod curved rod, spiral, filamentous. Some important bacteria**
- Nitrobacter: transform NO2-to NO3-
- Coliform bacteria:-The most common type is E-Coli or Echerichia Coli, (indicator for the presence of pathogens).
- E-Coli is measured in (No/100mL)
- **Fungi:**
- Important in decomposing organic matter to simple forms.

Main groups of Microorganisms

- **Algae:**
- **Cause eutrophication phenomena. (negative effect)**
- **Useful in oxidation ponds. (positive effect)**
- **Cause taste and problems when decayed. (negative effect)**
- **Protozoa:**
- Feed on bacteria so they help in the purification of treated waste water
- Some of them are pathogenic.

Main groups of Microorganisms

- **Viruses:**
- Viruses are a major hazard to public health. Some viruses can live as long as 41 days in water and wastewater at 20 oC. They cause lots of dangerous diseases.
- **Pathogenic organisms:**

  The main categories of pathogens are:-
- Bacteria, Viruses, protozoa, helminthes

Typical Wastewater Composition

Concentration				
Contaminants	Unit	Weak	Medium	Strong
Solids, total (TS)	mg/L	350	720	1200
Dissolved, total (TDS)	mg/L	250	500	850
Fixed	mg/L	145	300	525
Volatile	mg/L	105	200	325
Settle able solids (SS)	mg/L	100	220	350
Fixed	mg/L	20	55	75
Volatile	mg/L	80	165	275
Settle able Solids	mg/L	5	10	20
Biochemical oxygen demand, mg/l:				
C) ◦ C (BOD_5,20◦5-day, 20	mg/L	110	220	400
Total organic carbon (TOC)		80	160	290
Chemical oxygen demand (COD)	mg/L	250	500	1000

Typical Wastewater Composition

Nitrogen (total as N)	mg/L	20	40	85
Organic	mg/L	8	15	35
Free ammonia	mg/L	12	25	50
Nitrites	mg/L	0	0	0
Nitrites	mg/L	0	0	0
Phosphorus (total as P)	mg/L	4	8	15
Organic	mg/L	1	3	5
Inorganic	mg/L	3	5	10
Chlorides[a]	mg/L	30	50	100
Sulfate[a]	mg/L	20	30	50
Alkalinity (as $CaCO_3$)	mg/L	50	100	200
Grease	mg/L	50	100	150
Total coliform[b]	no/100 ml	10^6 - 10^7	10^7 – 10^8	10^7 – 10^9
Volatile organic compounds (VOC_s)	Mg/L	<100	100 - 400	> 400

Wastewater treatment standards

- The most common WWT standards are set for the secondary treatment effluent. The main effluent parameter are: BOD5, TSS,pH and CBOD5.

"secondary treatment"standards

Characteristic of discharge	unit	Average 30-day concentration	Average 7-day concentration
BOD_5	mg/L	30	45
TSS	mg/L	30	45
pH	pH units	Within the range 6-9 always	
$CBOD_5$*	mg/L	25	40

Wastewater treatment standards

- CBOD: (Carbonaceous BOD, from organic compounds and oxidation of inorganic compounds such as ferrous iron)
- The standards for **the removal of nitrogen and phosphorus (N,P) need tertiary treatment**
- Removal of the coliform bacteria is also regulated according to reuse purpose
- Fecal coliforms < 500/100 ml (disposed into recreational waters)
- Fecal coliforms <1000/100 ml (for irrigations)

Treatment of industrial wastewater

- The different types of contamination of wastewater require a variety of strategies to remove the contamination.
- Solids removal
- Oils and grease removal
- Removal of biodegradable organics
- Treatment of other organics
- Treatment of acids and alkalis
- Treatment of toxic materials

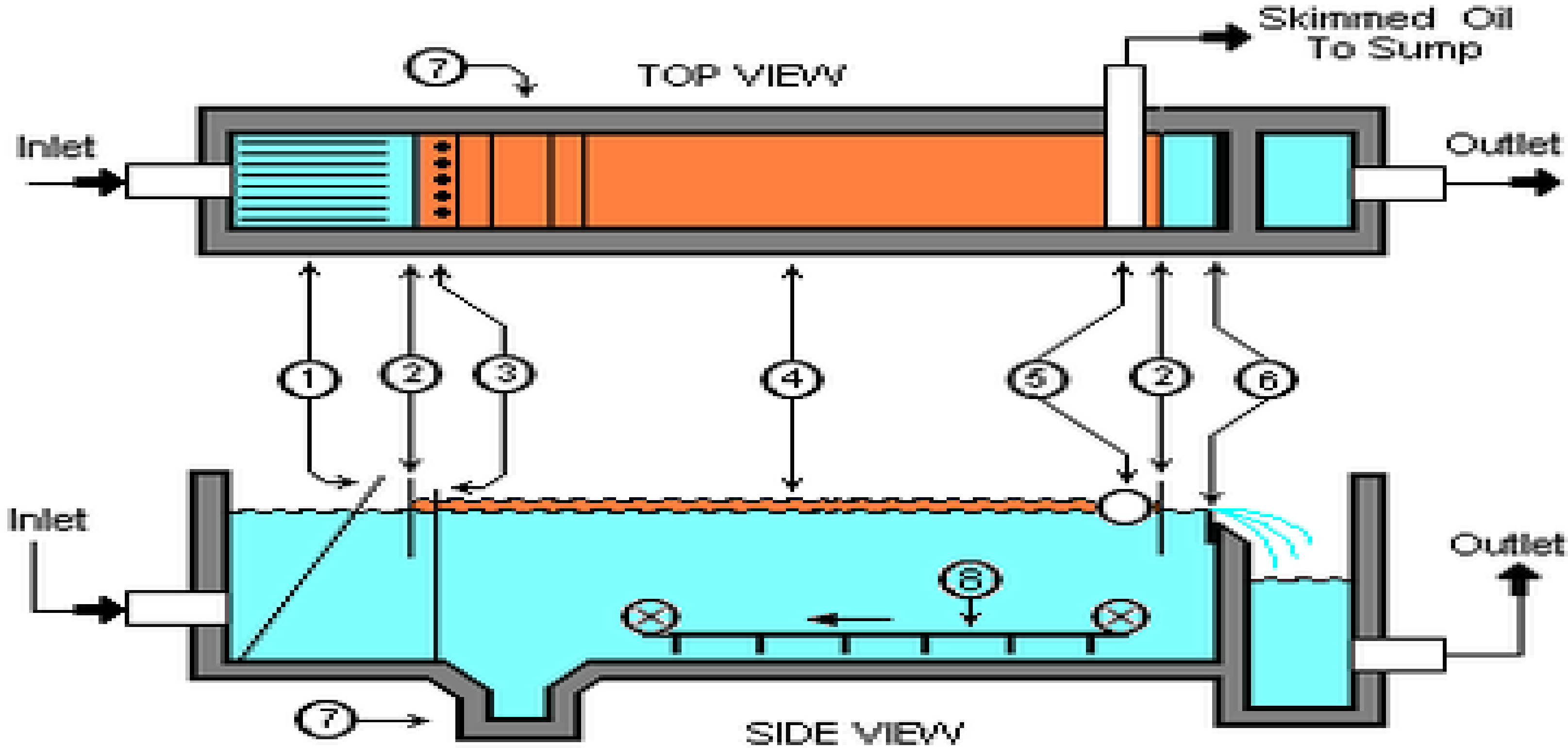
Solids removal

- Most solids can be removed using simple sedimentation techniques with the solids recovered as slurry or sludge.
- Very fine solids and solids with densities close to the density of water pose special problems.
- In such case filtration or ultrafiltration may be required. Although, flocculation may be used, using alum salts or the addition of polyelectrolytes.

Oils and grease removal

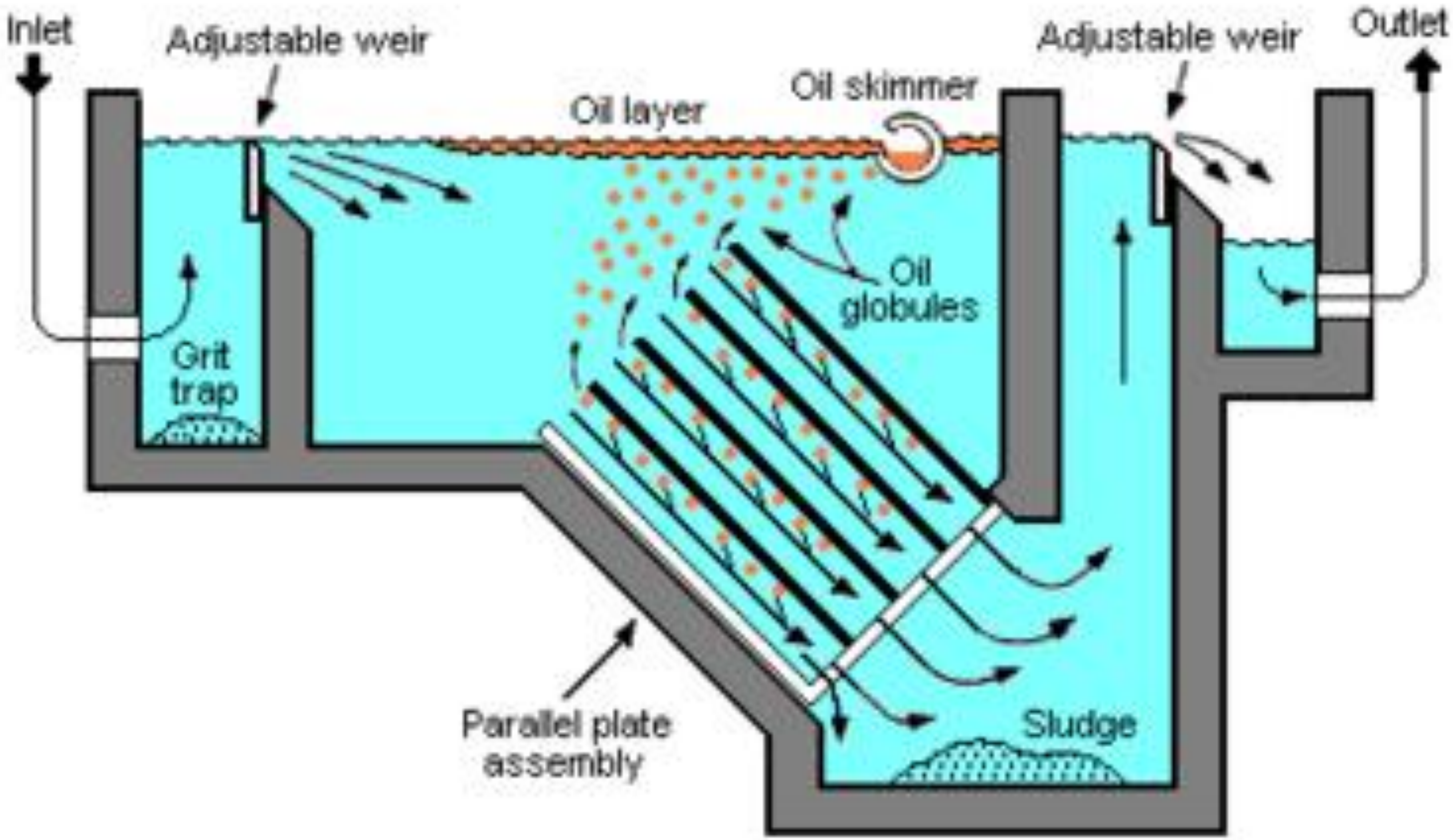
- Many oils can be recovered from open water surfaces by skimming devices.
- Considered a dependable and cheap way to remove oil, grease and other hydrocarbons from water, oil skimmers can sometimes achieve the desired level of water purity.
- At other times, skimming is also a cost-efficient method to remove most of the oil before using membrane filters and chemical processes.
- Skimmers will prevent filters from blinding prematurely and keep chemical costs down because there is less oil to process.

- The wastewaters from large-scale industries such as oil refineries, petrochemical plants, chemical plants, and natural gas processing plants commonly contain gross amounts of oil and suspended solids.
- Those industries use a device known as an API oil-water separator which is designed to separate the oil and suspended solids from their wastewater effluents.
- The name is derived from the fact that such separators are designed according to standards published by the American Petroleum Institute



1 Trash trap (inclined rods)
2 Oil retention baffles
3 Flow distributors (vertical rods)
4 Oil layer
5 Slotted pipe skimmer
6 Adjustable overflow weir
7 Sludge sump
8 Chain and flight scraper

A typical API oil-water separator used in many industries



A typical parallel plate separator

Removal of biodegradable organics

- Biodegradable organic material of plant or animal origin is usually possible to treat using extended conventional wastewater treatment processes such as activated sludge or trickling filter.
- Problems can arise if the wastewater is excessively diluted with washing water or is highly concentrated such as neat blood or milk. The presence of cleaning agents, disinfectants, pesticides, or antibiotics can have detrimental impacts on treatment processes.

Treatment of other organics

- Synthetic organic materials including solvents, paints, pharmaceuticals, pesticides, coking products and so forth can be very difficult to treat.
- Treatment methods are often specific to the material being treated.
- Methods include Advanced Oxidation Processing, distillation, adsorption, vitrification, incineration, chemical immobilisation or landfill disposal.
- Some materials such as some detergents may be capable of biological degradation and in such cases, a modified form of wastewater treatment can be used.

Treatment of acids and alkalis

- Acids and alkalis can usually be neutralised under controlled conditions. Neutralisation frequently produces a precipitate that will require treatment as a solid residue that may also be toxic.
- In some cases, gasses may be evolved requiring treatment for the gas stream.
- Some other forms of treatment are usually required following neutralisation.

Treatment of toxic materials

- Toxic materials including many organic materials, metals (such as zinc, silver, cadmium, thallium, etc.) acids, alkalis, non-metallic elements (such as arsenic or selenium) are generally resistant to biological processes unless very dilute.
- Metals can often be precipitated out by changing the pH or by treatment with other chemicals.
- Many, however, are resistant to treatment or mitigation and may require concentration followed by landfilling or recycling.
- Disolved organics can be *incinerated* within the wastewater by Advanced Oxidation Processes.

Wastewater Treatment Methods

- **Physical**
- **Chemical**
- **Biological**

Physical

Sedimentation (Clarification)

Screening

Aeration

Filtration

Flotation and Skimming

Degassification

Equalization

Chemical

Chlorination
Ozonation
Neutralization
Coagulation
Adsorption
Ion Exchange

Biological

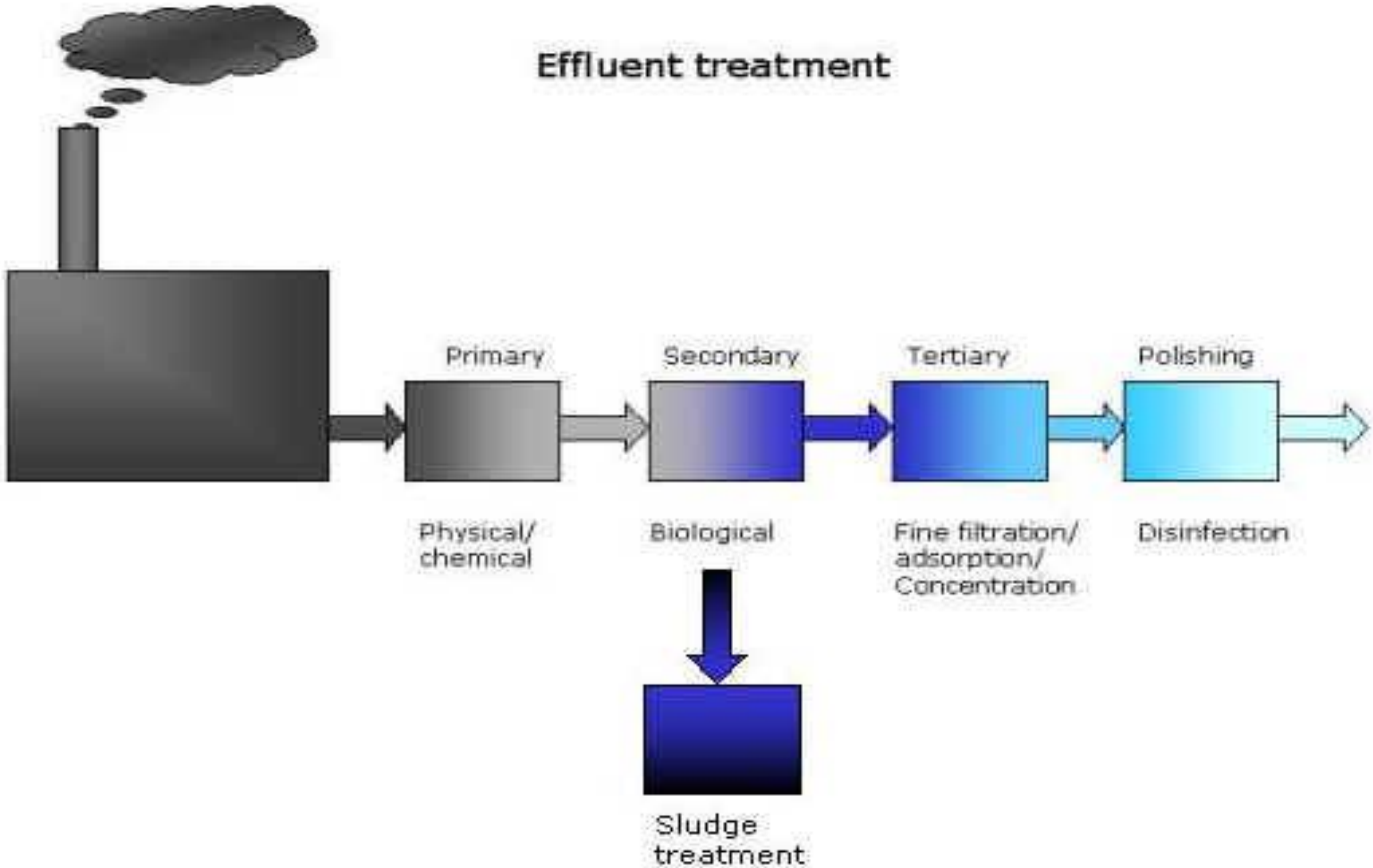
- *Aerobic*
  Activated Sludge Treatment Methods
  Trickling Filtration
  Oxidation Ponds
  Lagoons
  Aerobic Digestion
- *Anaerobic*
  Anaerobic Digestion
  Septic Tanks
  Lagoons

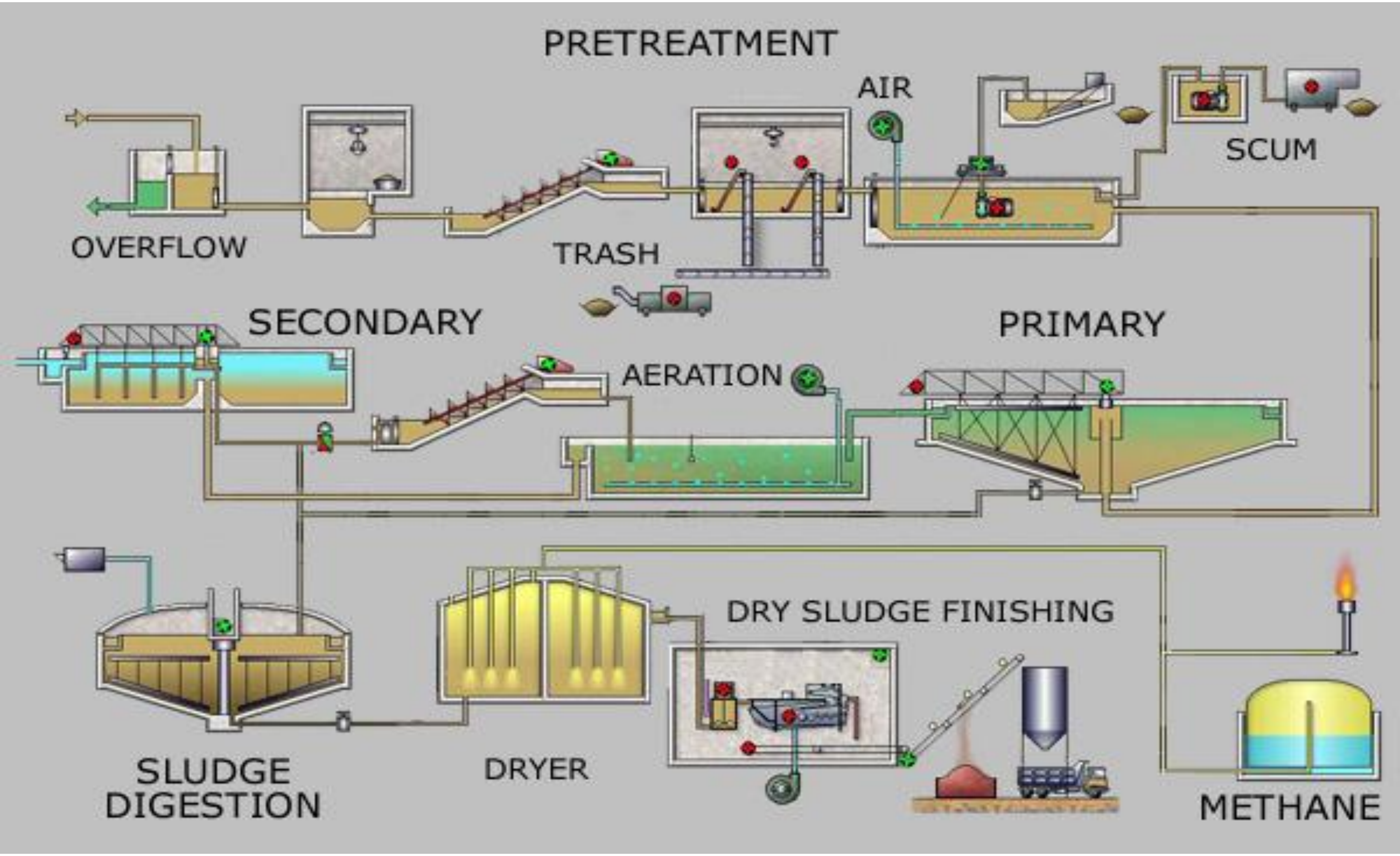
UNIT II
PRE AND PRIMARY TREATMENT

Common set of processes **Wastewater Treatment**

- **Preliminary treatment**
- **Primary treatment**
- **Secondary treatment**
- **Tertiary treatment**
- **Polishing treatment**

Effluent treatment




PRETREATMENT
AIR
SCUM
OVERFLOW
TRASH
SECONDARY
AERATION
PRIMARY
DRY SLUDGE FINISHING
SLUDGE
DIGESTION
DRYER
METHANE

Preliminary treatment

- At most plants preliminary treatment is used to protect pumping equipment and facilitate subsequent treatment processes. Preliminary devices are designed to remove or cut up the larger suspended and floating solids, to remove the heavy inorganic solids, and to remove excessive amounts of oils or greases.
- To effect the objectives of preliminary treatment, the following devices are commonly used:
- Screens -- rack, bar or fine
- Comminuting devices -- grinders, cutters, shredders
- Grit chambers
- Pre-aeration tanks

- In addition to the above, chlorination may be used in preliminary treatment.
- Since chlorination may be used at all stages in treatment, it is considered to be a method by itself.
- Preliminary treatment devices require careful design and operation.

Primary treatment

In this treatment, most of the settleable solids are separated or removed from the wastewater by the physical process of sedimentation.

When certain chemicals are used with primary sedimentation tanks, some of the colloidal solids are also removed.

Biological activity of the wastewater in primary treatment is of negligible importance.

- The purpose of primary treatment is to reduce the velocity of the wastewater sufficiently to permit solids to settle and floatable material to surface.
- Therefore, primary devices may consist of settling tanks, clarifiers or sedimentation tanks.
- Because of variations in design, operation, and application, settling tanks can be divided into four general groups:

- Septic tanks
- Two story tanks -- Imhoff and several proprietary or patented units
- Plain sedimentation tank with mechanical sludge removal
- Upward flow clarifiers with mechanical sludge removal

When chemicals are used, other auxiliary units are employed. They are:

- Chemical feed units
- Mixing devices
- Flocculators

Secondary treatment

Secondary treatment depends primarily upon aerobic organisms which biochemically decompose the organic solids to inorganic or stable organic solids.

It is comparable to the zone of recovery in the self-purification of a stream.

The devices used in secondary treatment may be divided into four groups:

- Trickling filters with secondary settling tanks
- Activated sludge and modifications with final settling tanks
- Intermittent sand filters
- Stabilization ponds

Attached growth process

- In an attached growth process, the microorganisms grow on a surface, such as rock or plastic.

Examples are

- Open *trickling filters,* where the water is distributed over rocks and trickles down to underdrains, with air being supplied through vent pipes,
- Enclosed *biotowers*, which are similar, but more likely to use shaped, plastic media instead of rocks, and
- *Rotating biological contacters*, or RBC's, which consist of large, partially submerged discs which rotate continuously, so that the microorganisms growing on the disc's surface are repeatedly being exposed alternately to the wastewater and to the air.

Suspended growth process

- suspended growth process is the so-called *activated sludge* system .
- This type of system consists of two parts, an *aeration tank* and a settling tank, or *clarifier*.
- The aeration tank contains a "sludge" which is what could be best described as a "mixed microbial culture", containing mostly bacteria, as well as protozoa, fungi, algae, etc.
- This sludge is constantly mixed and aerated either by compressed air bubblers located along the bottom, or by mechanical aerators on the surface.
- The wastewater to be treated enters the tank and mixes with the culture, which uses the organic compounds for *growth*-- producing more microorganisms-- and for *respiration,* which results mostly in the formation of carbon dioxide and water. The process can also be set up to provide biological removal of the nutrients nitrogen and phosphorus

Tertiary treatment

- Since the early 1970's "tertiary" treatment has come into use to describe additional treatment following secondary treatment.
- Quite often this merely indicates the use of intermittent sand filters for increased removal of suspended solids from the wastewater.
- In other cases, tertiary treatment has been used to describe processes which remove plant nutrients, primarily nitrogen and phosphorous, from wastewater.
- Improvement and upgrading of wastewater treatment units as well as the need to minimize environmental effects has led to the increased use of tertiary treatment.

Polishing treatment

- Disinfection is the commonly used treatment as a polishing treatment
- It involves the application of chlorine to the wastewater for the following purposes:
- Disinfection or destruction of pathogenic organisms
- Prevention of wastewater decomposition --

(a) odor control, and
(b) protection of plant structures

Characteristics of wastewater

	Strong	Medium	Weak
Total solids	1200	700	350
Dissolved solids (TDS)[1]	850	500	250
Suspended solids	350	200	100
Nitrogen (as N)	85	40	20
Phosphorus (as P)	20	10	6
Chloride[1]	100	50	30
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50
BOD_5	300	200	100

Basic theories

- Strength reduction
- Volume reduction
- Neutralization
- Equalization
- Proportioning

Strength reduction

- Reducing the concentration of waste for better treatment
- The strength of waste may be reduced by
- Process changes
- Equipment modifications
- Segregation of wastes
- Equalization of wastes
- By-product recovery
- Proportioning wastes
- Monitoring waste streams

Process changes

- In reducing the strength of waste through process changes, the sanitary engineer is concerned with wastes that are more troublesome from a pollution stand point.
- His problems and his approach differ from those of the plant engineer.
- Sometimes tremendous resistance by a plant engineer must be overcome in order to effect a change in process.
- Many industries resolve their waste problems through process changes.
- Ex. Textile and metal fabricating industries.

Equipment modifications

- Changes in equipment can effect a reduction in the strength of the waste, usually by reducing the amounts of contaminants entering the waste stream,
- Often quite slight changes can be made in present equipment to reduce the waste.
- For example in pickle industry, screens placed over drain lines in cucumber tanks prevent the escape of seeds and pieces of cucumber which add to the strength and density of the waste.
- Similarly , traps on the discharge pipe line in poultry plants prevent emission of feathers and pieces of fat.

- Another example of waste strength reduction (with a more extensive modification of equipment) occurred in the dairy industry.
- The new cans were constructed with smooth necks so that they could be drained faster and more completely.
- This prevented a large amount of milk waste from entering streams and sewage plants.

Segregation of wastes

- Segregating a strong waste from a less potent ones will reduce the strength of the main volume and the small volume strong wastes can be handled with methods specific to the problems it present.
- Another type of segregation is the removal of one particular process waste from the other process wastes of an industrial plant which renders the major part of the waste more amenable to treatment.

- In some industries process, cooling and sanitary wastewaters are mixed and then treated.
- Modern industrial treatment suggests segregation of these waste streams for separate disposal, treatment or controlled mixing.
- For example, cooling water which generally contains no organic pollution can be disposed of directly into a storm sewer or a stream.
- Similarly waste streams containing coarser materials like corn, vegetable peelings, feather and hair must be screened through before mixing with other wastes.

Equalization of waste

- Certain industries having diversified activities and products using different processes prefer to equalize these wastes.
- Flow and quality of sewage are equalized during equalization.
- This is done by holding the wastes for certain period depending on process.
- Sometimes, considerably greater neutralizing power would be required for the acid waste if it is not equalized to even out the peaks prior to neutralization.

By product recovery

- Any use of waste materials eliminates at least some tons of the waste which eventually must be disposed of.
- For example metal plating industry use ion exchangers to recover phosphoric acid, copper, nickel and chromium from plating solutions.
- The deionized water without any further treatment is ideal for boiler feed requirements.

Proportioning wastes

- By proportioning its discharge of concentrated wastes into the main sewer a plant can often reduce the strength of its total waste to the point where it will need a minimum of final treatment or will cause the least damage to the stream or treatment plant.
- It may prove less costly to proportion one small but concentrated waste into the main flow, according to the rate of main flow, then to equalize the entire waste of the plant in order to reduce the strength.

Monitoring of waste streams

- Sophistication in plant control should include that of wastewater controls.
- Remote sensing devises that control the operator to stop, reduce or redirect the flow from any process when its concentration of contaminants exceeds certain limits are an excellent method of reducing waste strengths.
- In fact accidental spills are often the sole cause of stream pollution or malfunctioning of treatment plants and these can be controlled and often eliminated completely, if all significant sources of wastes are monitored.

Volume reduction

- Reducing the volume of wastewater by reusing and recycling of water
- This may be accomplished by
- Classification of wastes
- Conservation of water
- Changing production to decrease waste
- Reusing both industrial and municipal effluents as raw water supplies
- Elimination of batch or slug discharges of process wastewater.

Classification of wastes

- If wastes are classified so that manufacturing wastes are separated from cooling wastes , the volume of waste reduces considerably.
- Sometimes it is possible to classify and separate process wastes themselves, so that only the most polluted ones are treated and relatively uncontaminated are discharged without treatment.
- The three main classes of wastes are
- Wastes from manufacturing processes.
- Wastes used as cooling agents in industrial processes.
- Wastes from sanitary uses.

Wastes from manufacturing processes

- These wastes include in forming paper on traveling wire machines, expected from plating solutions in metal fabrication, discharged from wasting of milk cans in dairy industry.

Wastes used as cooling agents in industrial processes.

- The volume of these wastes from one industry to another depending on the total temperatures to be removed the process waters.
- One large refinery discharges a total of 680 million litres/day of which only 23 million litres/day is process water, the remaining 655 million litres/day is only slightly contaminated cooling water waste.
- Although cooling water can become contaminated by small leaks, corrosion products, or the effects of heat, these wastes contain little, if any organic matter and are classed as non pollutional from the stand point.

Wastes from sanitary uses.

- These will normally range from 100 to 200 litres per employee per day.
- The volume depends on many factors, including size of the plant, amount of waste product materials wasted from floors and the degree of contamination required of weakness in the process operation.
- Unfortunately, in most older plants, process, cooling and sanitary waste waters are mixed in one pipe line.
- Before 1930, industry paid little attention to segregating wastes to avoid stream pollution.

Conservation of water

- Water conserved is waste saved.
- Contamination begins when an industry changes from an open System to closed system.
- For example a paper mill which recycles white water and then reduces the volume of waste waters, it uses in practicing water conservation.
- Concentrated waste recycled waste waters are often treated at the end of period of usefulness, since usually it is impractical and uneconomical to treat the wastewaters as they complete each cycle.

- The savings are two fold both waste costs and water treatment costs are lower.
- How Ever many to effect conservation are quite costly and their benefits must be balanced against the costs.
- If the net result is deemed economical then, then new conservation practices can be installed with assurance.

Changing production to decrease waste

- This is an effective method of controlling the volume of wastes but is difficult to put into practice.
- It is hard to persuade production man to change their operations just to eliminate wastes normally, the operational phase of engineering is planned by the chemical, mechanical or industrial engineers where primary objective is cost savings.

- The sanitary engineer on the other hand has to protect the public health and the conservation of natural resource as his main consideration, yet there is no reason why both objectives can not be achieved.
- Waste treatment at the source should be considered AS AN INTEGRAL PART OF PRODUCTION.
- If the chemical engineer argues that it would cost the company to change its methods of manufacture in order to reduce pollution at the source, the sanitary engineer can do more than simply enter a plea for the improvement of man kinds environment.

- He can point out for instance that reduction in the amount of sodium sulphate used in dyeing, of sodium cyanide used in plating and of other chemicals used directly in production has resulted in both lessening of water and saving of money.
- He can also mention the fact that balancing the quantities of acids and alkalis used in a plant often results in a neutral waste with a saving of chemicals money and time spent in waste treatment.

Reusing both industrial and municipal effluents as raw water supplies

- Practiced mainly in areas where water is scarce and/or expensive, this is proving a popular and economical method of conservation, of all the sources of water available to industry.
- Sewage plant effluent is the most reliable at all seasons of the year and the only one that is actually increasing in quantity and improving in quality.

- Though there are many problems involved in the reuse of effluents for raw water supply, it must be remembered that any water supply poses problems to cities and industries.
- Many industries and cities hesitate to reuse effluents for raw water supply.
- The reasons are
- Lack of adequate information on the part of industrial managers
- Difficulty of negotiating contracts satisfactory to both municipalities and industrial users
- Certain technical problems such as hardness, colour and so froth
- Aesthetic reluctance to accept effluents as a Potential source of water for any Purpose.

Elimination of batch or slug discharges of process wastewater

- In wet manufacturing of a Product One or more steps are sometimes repeated, which results in production of a significantly higher volume and strength of waste during that period.
- If this waste is discharged in a short period of time, it is usually referred to as a slug discharge.
- This type of waste, because of its concentrated contaminants and/or surge in volume, can be troublesome to both treatment plants and receiving streams.

- There are at least two methods of reducing the effects of these streams
- The manufacturing firm alters its Practice so as to increase the frequency and lessen the magnitude of batch discharges.
- Slug wastes are retained in holding basins from which they are allowed to flow continuously and uniformly over an extended (usually 24-hour) period.

Neutralization

- Some of the wastes are acidic and some are alkaline-hence mixing them to make neutral
- They are several acceptable methods for neutralizing over acidity or over alkalinity of waste waters such as
- Mixing wastes so that the net effect is a near neutral
- Passing acid wastes through beds of lime stone
- Mixing acid wastes with lime slurries of dolomite lime slurries

- Adding the proper portion of concentrated solutions of caustic soda (NaoH) or soda ash (Na_2Co_3)
- Blowing waste boiler flue gas through alkaline wastes
- Adding compressed Co_2 to alkaline wastes
- Producing Co_2 in alkaline wastes
- Adding sulphuric acid to alkaline wastes.

Mixing wastes so that the net effect is a near neutral

- Mixing of wastes can be accomplished within a single plant operation or between neighboring industrial plants.
- Acid and alkaline waste may be produced individually within one plant and proper mixing of these wastes at appropriate times can accomplish neutralization, although this usually requires some storage of each waste to avoid slugs of either acidic or alkaline.

Lime stone treatment for acid wastes

- Passing acid wastes through beds of limestone was one of the original methods of neutralizing them.
- The wastes can be pumped up of down through the bed, depending on the head available and the cost involved, at a rate of 4.5 litres per minute per square foot or less.
- Neutralization proceeds chemically according to the following typical reaction
- $CaCo_3 + H_2So_4 \rightarrow Caso_4 + H_2Co_3$

Lime slurry treatment for Acid wastes

- Mixing acid wastes with lime slurries is an effective procedure for neutralization.
- The reaction is similar to that obtained with limestone beds.
- In this case lime is used up continuously because it is converted to calcium sulphate and carried out in the waste.
- Though slow acting, lime possesses a high neutralizing power and its action can be hastened by heating or oxygenating the mixture.

- It is relatively in expensive, but in large quantities the cost can be an important item.
- Hydrated lime is sometimes difficult to handle, since it has a tendency to arch, or bridge, over the outlet in storage bins and possess poor flow properties, but it is particularly adaptable to neutralization problems involving small quantities of acid waste, as it can be stored in bags without the erection of special storage facilities.

Caustic soda treatment for acid wastes

- Adding concentrated solutions of caustic soda or sodium carbonate to acid wastes in the proper proportions results in faster, but more costly, neutralization of smaller volumes of the agent are required, since these neutralizers are more powerful than lime or limestone.
- Another advantage is that the reaction products are soluble and do not increase the hardness of receiving waters.
- Caustic soda is normally bled in to the suction side of the pump discharging acid wastes.

- This method is suitable for small volumes, but for neutralizing large volumes of acid waste water, special proportioning equipment should be provided, as well as suitably sized storage tank for the caustic soda, with a multiple speed pump for direct addition of the alkali to the flow of acid wastes.
- $2NaoH+H_2So_4 \rightarrow Na_2So_4+2H_2o$
- $Na_2CO_3+H2So_4 \rightarrow Na_2So_4+H_2Co_3$

Using waste boiler flue gas

- Blowing waste boiler flue gas through alkaline wastes is a relatively new and economical method for neutralizing them.
- Most of the experimental works have been carried out on textile wastes.
- Well burned stack gases contain approximately 14 percent carbon dioxide dissolved in wastewater, will form carbonic acid (a weak acid) which in turn reacts with caustic wastes to neutralize the excess alkalinity.

Carbon dioxide treatment for alkaline wastes

- Bottled carbon dioxide is applied to wastewaters in much the same as compressed air is applied to activated sludge basins.
- It neutralizes alkaline wastes on the same principle as boiler feed gases (i.e it forms a weak acid when dissolved in water) but with less operating difficulty.
- The cost may be prohibitive, however, when the quantity of alkaline wastes is large.

Producing carbon dioxide in alkaline wastes

- Another way to produce carbon dioxide is to burn gas under water.
- This process is called submerged combustion and has been used in the disposal of nylon wastes to neutralize the waste prior to biological treatment.
- In pilot-plant studies, the researchers investigated submerged combustion on a continuous basis, using an evaporation vessel, a burner with flame jets submerged below the waste surface in the vessel, a bustle where air and natural gas were mixed to form a combustible mixture.

Sulphuric acid treatment for alkaline wastes

- The addition of sulphuric acid to alkaline wastes is a fairly common, but rather expensive, means of neutralization.
- Sulphuric acid can cost as much as two three cents per found; although it may be as low as one cent per found in large quantities.
- Storage and feeding requirements are low as a result of great acidity but it is difficult to handle because of its corrosiveness.

Acid waste utilization in industrial processes

- In some situations it may be possible to use acid wastes to effect a desired result in industrial processing to wash, cool, or neutralize products.
- Mine waste waters occurs in large quantities in the coal industry.
- These wastes are usually acid contain sulphates of iron and alumina, if they are used to wash raw coal, neutralization results, since coal contains calcium and magnesium carbonates.

Equalization

- Equalization is a method of retaining wastes in a basin so that the effluent discharged is fairly uniform in its sanitary characteristics(ph, colour, turbidity, alkalinity, BOD and so forth)
- A secondary but significant effect is that of lowering the concentration of effluent contaminants.
- This is accomplished not only by ironing out the slugs of high concentration of contaminants but also by physical, chemical and biological reactions which may occur during retention in equalization basins.

- A retention pond serves to level out the effects of peak loadings on the plant while substantially lowering the BOD and suspended solids lead to the aeration unit.
- Air is sometimes injected into these basins to provide (1) better mixing (2) chemical oxidation of reducing compounds (3)some degree of biological oxidation (4) agitation to prevent suspended solids from settling

- The size and shape of the basins vary with the quantity of waste and the pattern of its discharge from the factory.
- Most basins are rectangular or square, but triangular tanks produce satisfactory flow distribution.
- The capacity should be adequate to hold and render homogeneous, all the wastes from the plant.
- Almost all industrial operate on a cycle basis; thus, if the cycle of operations is repeated every two hours, an equalization tank which can hold a two hour flow will usually be sufficient.

- The mere holding of waste, however is not sufficient to equalize it.
- Each unit volume of waste discharged must be adequately mixed with other unit volumes of waste discharged many hours previously.
- This mixing may be brought about in the following ways (1) proper distribution and baffling (2) mechanical agitators (3) aeration and (4) combination of all three.

Proportioning

- Proportioning means the discharge of industrial wastes in proportion to the flow of municipal sewage in the sewers or to the stream flow in the receiving river.
- In most cases it is possible to combine equalization and proportioning in the same basin.
- The effluent from the equalization basin in metered into the sewer or stream according to a predetermined schedule.

- The objective of proportioning in sewers is to keep constant the percentage of industrial wastes to domestic sewage flow entering the municipal sewage plant.
- This procedure has several purposes (a) to protect municipal sewage treatment using being impaired by a sudden overdose of chemicals contained in the industrial waste
- (b) to protect biological treatment devices from shock leads of industrial wastes, which may inactivate the bacteria
- (c) to minimize fluctuations of sanitary in the treatment effluent.

- There are two general methods of discharging industrial waste in proportion to the flow of domestic sewage at the municipal plant
- (a) manual control, related to a well defined domestic sewage flow pattern and (b) automatic control by electronics.

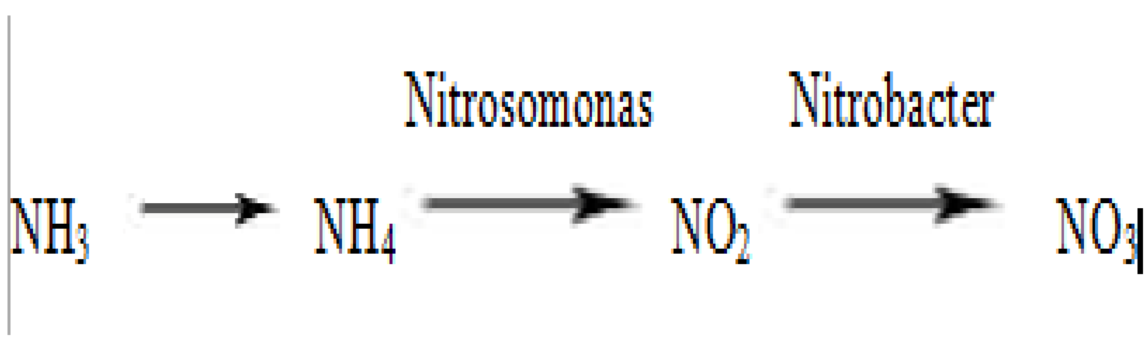
UNIT III
WASTE TREATMENT METHODS

Nitrification-Denitrification

- A certain amount of nitrogen removal (20-30%) occurs in conventional activated sludge systems.
- Nitrogen removal ranging from 70 to 90 % can be obtained by use of nitrification-denitrification method in plants based on activated sludge and other suspended growth systems.
- Biological denitrification requires prior nitrification of all ammonia and organic nitrogen in the incoming waste.

Nitrification

- There are two groups of chemoautotrophic bacteria that can be associated with the process of nitrification.
- One group (*Nitrosomonas*) derives its energy through the oxidation of ammonium to nitrite, whereas the other group (*Nitrobacter*) obtains energy through the oxidation of nitrite to nitrate. Both the groups, collectively called *Nitrifiers*, obtain carbon required, from inorganic carbon forms.
- Nitrification of ammonia to nitrate is a two step process:
-



- Stoichiometrically, 4.6 kg of oxygen is required for nitrifying 1 kg of nitrogen.
- Under steady state conditions, experimental evidence has shown nitrite accumulation to be insignificant.
- This suggests that the rate-limiting step for the conversion of ammonium to nitrate is the oxidation of ammonium to nitrite by the genus Nitrosomonas.

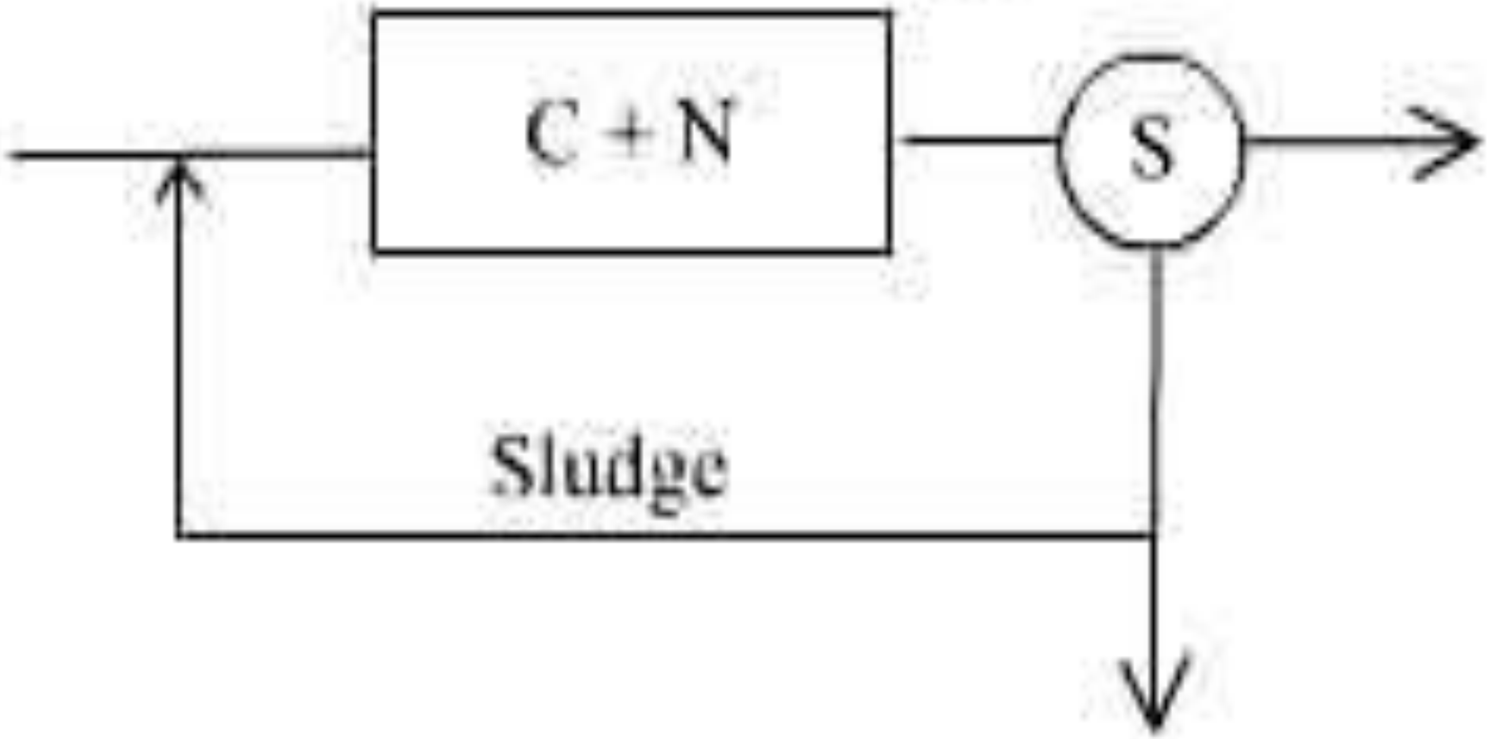
  $$qc = \frac{1}{m}$$

  where m is the growth rate of nitrosomonas at the worst operating temperature.
- Sludge age (or mean cell residence time), qc in a treatment plant must be sufficiently high if nitrification is desired.

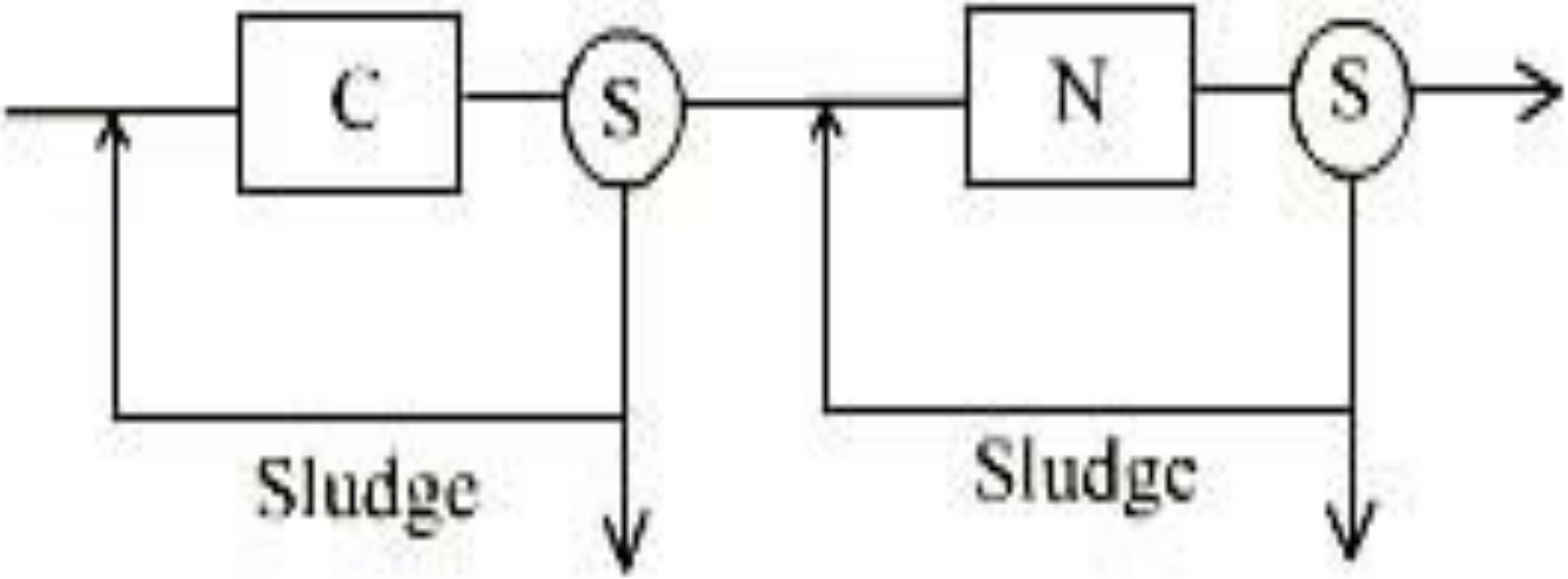
Combined and Separate Systems of Biological Oxidation & Nitrification

- Following figure shows flow sheets for combined and separate systems for biological oxidation and nitrification.

Flow sheet of Combined Nitrification system



Flow sheet of Separate Nitrification system



Combined system

- ***Combined system*** is favoured method of operation as it is less sensitive to load variations - owing to larger sized aeration tank - generally produces a smaller volume of surplus sludge owing to higher values of qc adopted, and better sludge settleability.
- Care should be taken to ensure that the oxygenation capacity of aeration tank is sufficient to meet oxygen uptake due to carbonaceous demand and nitrification.
- Recycling of sludge must be rapid enough to prevent denitrification (and rising sludge) owing to anoxic conditions in the settling tank.

separate system

- In ***separate system***, the first tank can be smaller in size since a higher F/M ratio can be used, but this makes the system somewhat more sensitive to load variations and also tends to produce more sludge for disposal.
- An additional settling tank is also necessary between the two aeration tanks to keep the two sludges separate.
- A principal advantage of this system is its higher efficiency of nitrification and its better performance when toxic substances are feared to be in the inflow.

Biological Denitrification

- When a treatment plant discharges into receivingstream with low available nitrogen concentration and with a flow much larger than the effluent, the presence of nitrate in the effluent generally does not adversely affect stream quality.
- However,if the nitrate concentration in the stream is significant, it may be desirable to control the nitrogen contentof the effluent, as highly nitrified effluents can stillaccelarate algal blooms.

- Even more critical is the case where treatment plant effluent is discharged directly into relatively still bodies of water such as lakes or reservoirs.
- Another argument for the control of nitrogen in the aquatic environment is the occurence of infantile methemoglobinemia, which results from high concentration of nitrates in drinking water.

- The four basic processes that are used are: (1) ammonia stripping,
  (2) selective ion exchange, (3) break point chlorination, and (4) biological nitrification/denitrification.
- ***Biological nitrification/denitrification*** is a two step process.
- The first step is nitrification, which is conversion of ammonia to nitrate through the action of nitrifying bacteria.
- The second step is nitrate conversion (denitrification), which is carried out by facultative heterotrophic bacteria under anoxic conditions.

Microbiological Aspects of Denitrification

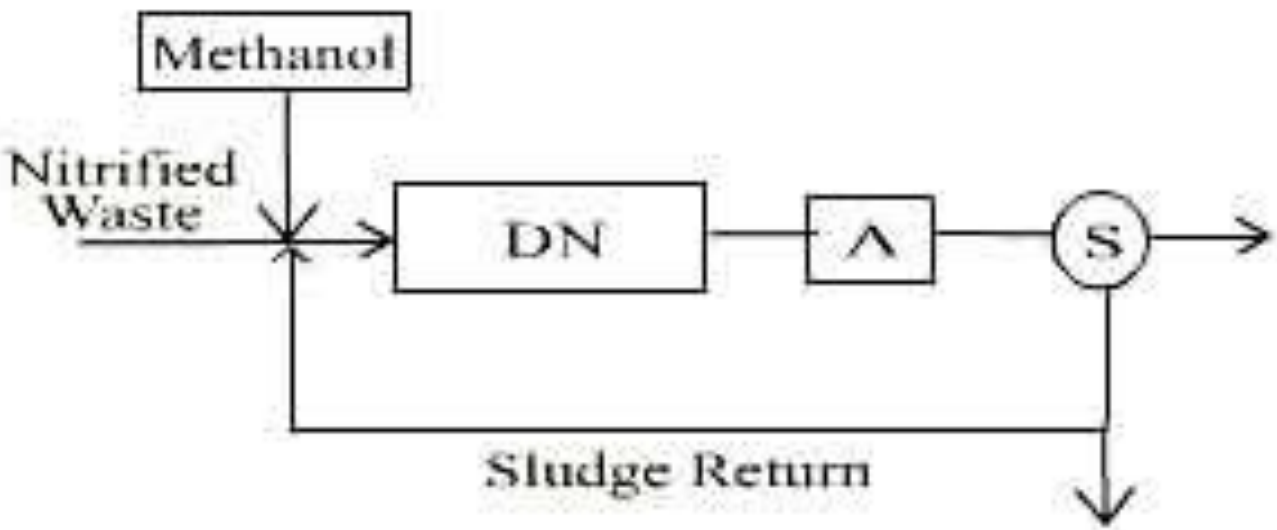
- Nitrate conversion takes place through both assimilatory and dissimilatory cellular functions. In ***assimilatory denitrification***, nitrate is reduced to ammonia, which then serves as a nitrogen source for cell synthesis. Thus, nitrogen is removed from the liquid stream by incorporating it into cytoplasmic material.
- In ***dissimilatory denitrification***, nitrate serves as the electron acceptor in energy metabolism and is converted to various gaseous end products but principally molecular nitrogen, N2, which is then stripped from the liquid stream.

- Because the microbial yield under anoxic conditions is considerably lower than under aerobic conditions, a relatively small fraction of the nitrogen is removed through assimilation. Dissimilatory denitrification is, therfore, the primary means by which nitrogen removal is achieved.
- A carbon source is also essential as electron donor for denitrification to take place. This source may be in the form of carbon internally available in sewage or artificially added (eg. as methanol). Since most community wastewaters have a higher ratio of BOD:N, the internally available carbon becomes attractive and economical for denitrification.

- Denitrification releases nitrogen which escapes as an inert gas to the atmosphere while oxygen released stays dissolved in the liquid and thus reduces the oxygen input needed into the system. Each molecule of nitrogen needs 4 molecules of oxygen during nitrification but releases back 2.5 molecules in denitrification. Thus, theoretically, 62.5% of the oxygen used is released back in denitrification.

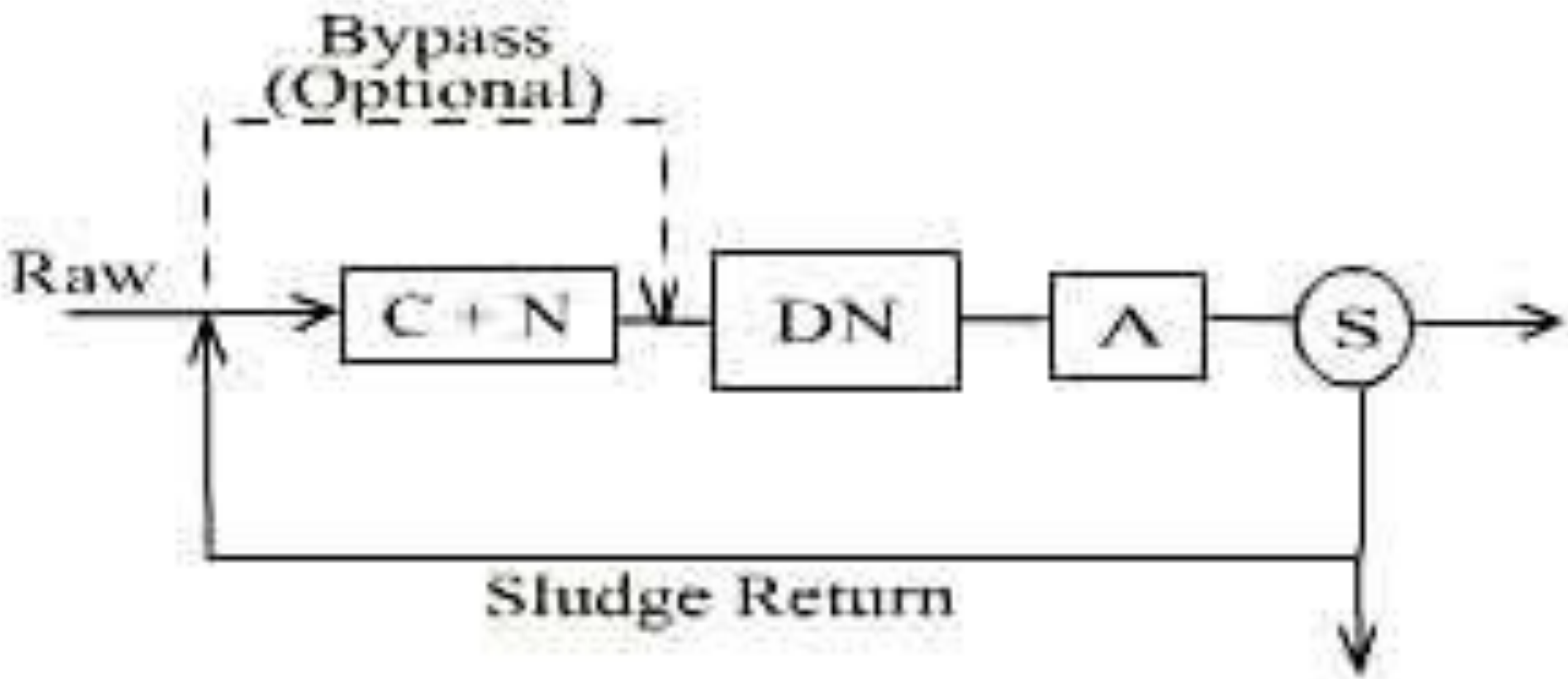
Typical Flowsheets for Denitrification

Flow sheet for Separate Denitrification of Nitrified Wastewater Using Methanol



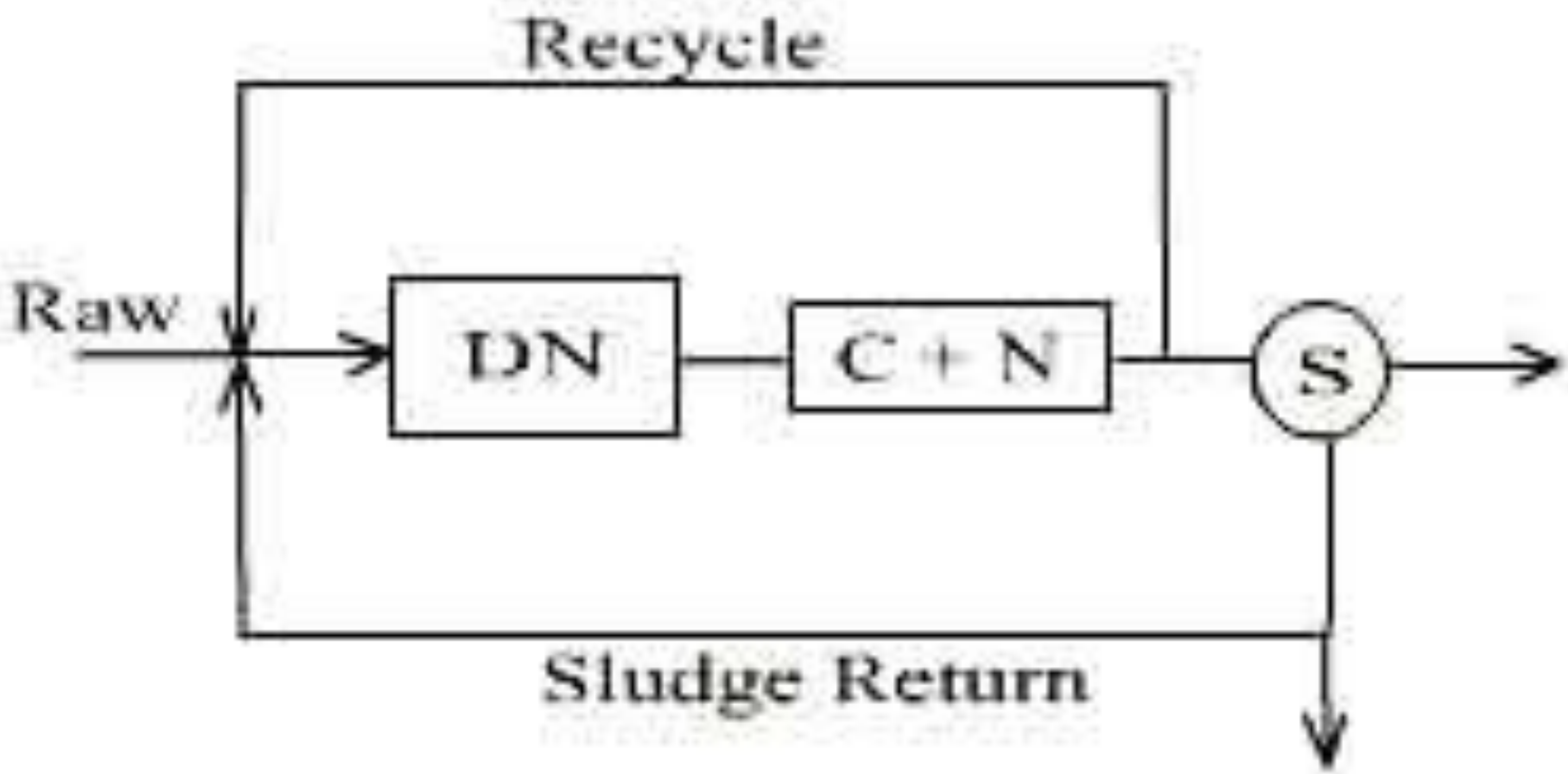
- The use of methanol or any other artificial carbon source should be avoided as far as possible since it adds to the cost of treatment and also some operating difficulties may arise fro dosing rate of methanol.
- Too much would introduce an unnecessary BOD in the effluent while too little would leave some nitrates under nitrified.

Separate Denitrification of Nitrified Wastewater Using Methanol



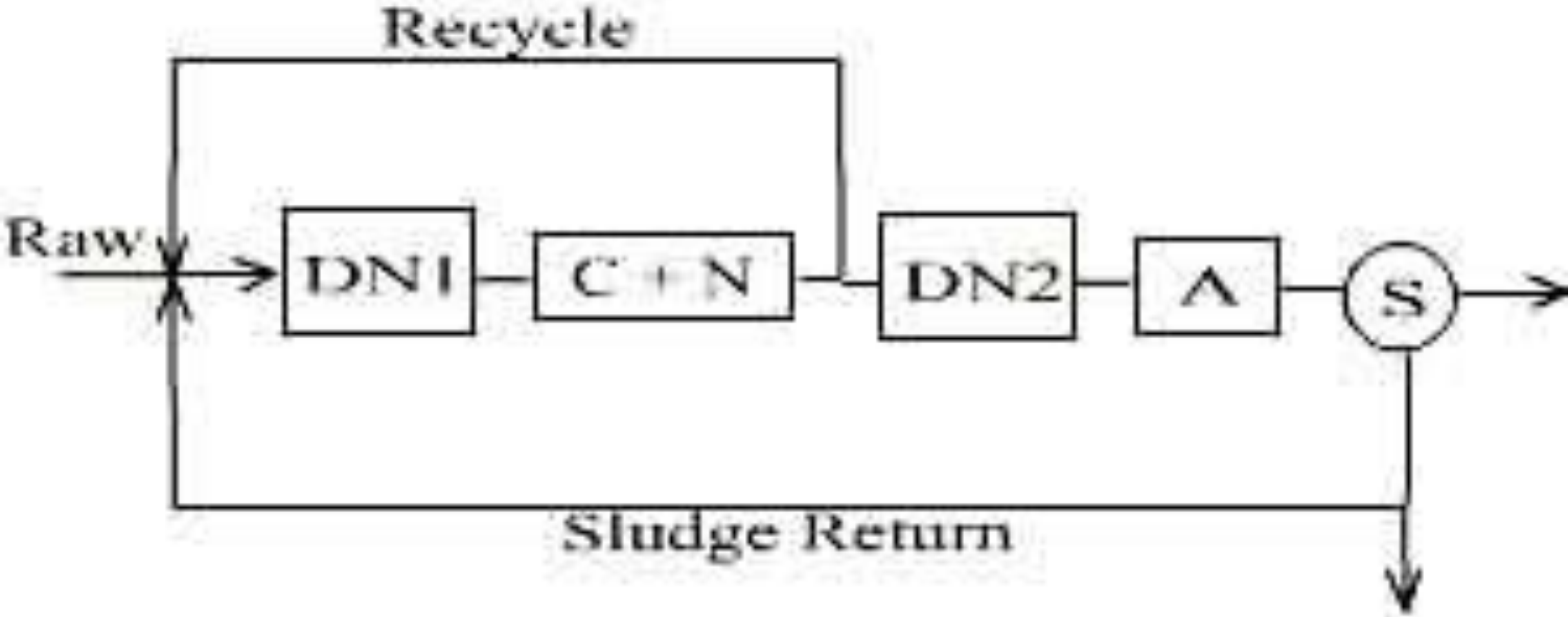
- A more satisfactory arrangement would be to use the carbon contained in the waste itself.
- However, the anoxic tank has to be of sufficient detention time for denitrification to occur which, has a slower rate; since the corresponding oxygen uptake rate of the mixed liquor is mainly due to endogenous respiration and is thus low.
- The denitrification rate, therefore, in a way also depends on the F/M ratio in the prior aeration tank.

Pre-denitrification with Recycle of Nitrified Effluent to Anoxic Tank



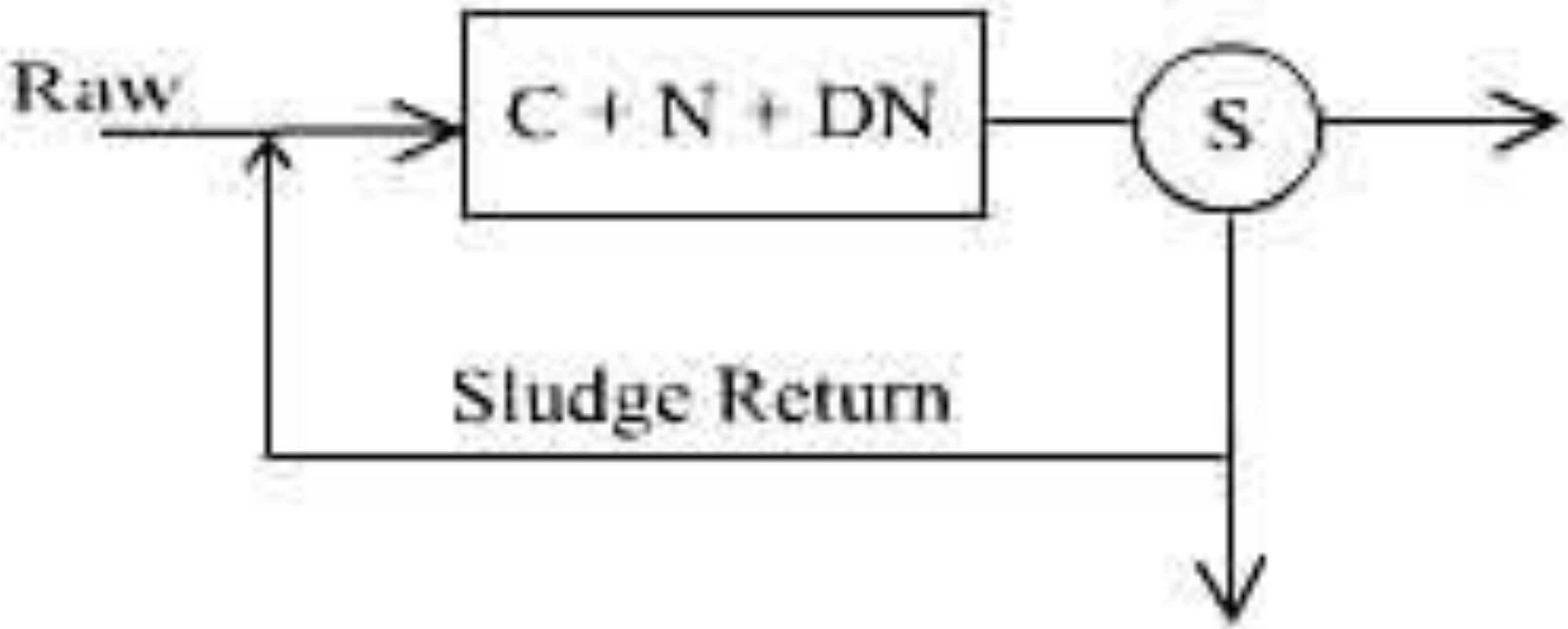
- Consequently, if desired, a portion of the raw waste may be bypassed to enter directly into the anoxic tank and thus contribute to an increased respiration rate.
- This reduces the sizes of both the anoxic and aeration tanks, but the denitrification efficiency is reduced as the bypassed unnitrified ammonia can not be denitrified.

"Bardenpho" Arrangement With two Anoxic Tanks to Give Higher Degree of Denitrification



- By reversing the relative positions of anoxic and aerobic tanks, the oxygen requirement of the waste in its anoxic state is met by the release of oxygen from nitrates in the recycled flow taken from the end of nitrification tank.
- Primary settling of the raw waste may be omitted so as to bring more carbon into the anoxic tank.

Simultaneous Nitrification-denitrificationin the same Tank



- More complete nitrification-denitrification can be achieved by Bardenpho arrangement.
- The first anoxic tank has the advantage of higher denitrification rate while the nitrates remaining in the liquor passing out of the tank can be denitrified further in a second anoxic tank through endogenous respiration.
- The flow from anoxic tank is desirable to reaerate for 10-15 minutes to drive off nitrogen gas bubbles and add oxygen prior to sedimentation.

Phosphorus Removal

Introduction

- Controlling phosphorous discharged from municipal and industrial wastewater treatment plants is a key factor in preventing eutrophication of surface waters.
- Phosphorous is one of the major nutrients contributing in the increased eutrophication of lakes and natural waters.
- Its presence causes many water quality problems including increased purification costs, decreased recreational and conservation value of an impoundments, loss of livestock and the possible lethal effect of algal toxins on drinking water.
- Phosphate removal is currently achieved largely by chemical precipitation, which is expensive and causes an increase of sludge volume by up to 40%.
- An alternative is the biological phosphate removal

Phosphorous in wastewater

- Municipal wastewaters may contain from 5 to 20 mg/l of total phosphorous, of which 1-5 mg/l is organic and the rest in inorganic.
- The individual contribution tend to increase, because phosphorous is one of the main constituent of synthetic detergents.
- The individual phosphorous contribution varies between 0.65 and 4.80 g/inhabitant per day with an average of about 2.18 g.
- The usual forms of phosphorous found in aqueous solutions include:

- Orthophosphates: available for biological metabolism without further breakdown
- Polyphosphates: molecules with 2 or more phosphorous atoms, oxygen and in some cases hydrogen atoms combine in a complex molecule.
- Usually polyphosphates undergo hydrolysis and revert to the orthophosphate forms.
- This process is usually quite slow.
- Normally secondary treatment can only remove 1-2 mg/l, so a large excess of phosphorous is discharged in the final effluent, causing eutrophication in surface waters.
- New legislation requires a maximum concentration of P discharges into sensitive water of 2 mg/l.

Phosphorous removal processes

- Treatment technologies presently available for phosphorus removal include:
- Physical:
- filtration for particulate phosphorus
- membrane technologies
- Chemical:
- precipitation
- other (mainly physical-chemical adsorption)
- Biological
- assimilation
- enhanced biological phosphorus removal (EBPR)

- The greatest interest and most recent progress has been made in EBPR, which has the potential to remove P down to very low levels at relatively lower costs.
- Membrane technologies are also receiving increased attention, although their use for P removal has been more limited to date.
- The question of sludge handling and treatment of P in side streams is also being addressed.

Physical Treatment

- **Filtration for particulate Phosporous**
- Assuming that 2-3% of organic solids is P, then an effluent total suspended solids (TSS) of 20 mg/L represents 0.4-0.6 mg/L of effluent P .
- In plants with EBPR the P content is even higher.
- Thus sand filtration or other method of TSS removal (e.g., membrane, chemical precipitation) is likely necessary for plants with low effluent TP permits

Membrane technologies

- Membrane technologies have been of growing interest for wastewater treatment in general, and most recently, for P removal in particular.
- In addition to removing the P in the TSS, membranes also can remove dissolved P.
- Membrane bioreactors (MBRs, which incorporate membrane technology in a suspended growth secondary treatment process), tertiary membrane filtration (after secondary treatment), and reverse osmosis (RO) systems have all been used in full-scale plants with good results.

Chemical Treatment

- **Precipitation**
- Chemical precipitation has long been used for P removal. The chemicals most often employed are compounds of calcium, aluminum, and iron .
- Chemical addition points include prior to primary settling, during secondary treatment, or as part of a tertiary treatment process
- However, that the process is more complex than predicted by laboratory pure chemical experiments, and that formation of and sorption to carbonates or hydroxides are important factors.

- Gas concrete (produced from mixtures of silica, sand, cement, lime, water, and aluminum cake) waste was used to remove phosphate from pure aqueous solutions .
- High phosphate removal (> 95% in 10 min, batch system) was obtained from a 33 mg/L P solution, but direct applicability to wastewater treatment (lower concentrations, possible interferences) was not investigated.
- The gas concrete's removal efficiency can be regenerated at low pH, with the resulting concentrated phosphate solution potentially a source of recycled phosphate.
- Similarly, iron oxide tailings were found to be effective for phosphorus removal from both pure solutions and liquid hog manure

Biological Treatment

- **Assimilation**
- Phosphorus removal from wastewater has long been achieved through biological assimilation – incorporation of the P as an essential element in biomass, particularly through growth of photosynthetic organisms (plants, algae, and some bacteria, such ascyanobacteria).
- Traditionally, this was achieved through treatment ponds containing planktonic or attached algae, rooted plants, or even floating plants (e.g., water hyacinths, duckweed).

EBPR

- As indicated in the introduction, the greatest recent and present interest has been in enhanced biological phosphorus removal.
- This is because of its potential to achieve low or even very low (<0.1 mg/L) effluent P levels at modest cost and with minimal additional sludge production.
- Removal of traditional carbonaceous contaminants (BOD), nitrogen, and phosphorus can all be achieved in a single system, although it can be challenging to achieve very low concentrations of both total N and P in such systems.

Joint Treatment of Industrial Waste and Domestic Sewage

- Industrial discharges often significantly alter the total flow and concentrations of various wastewater constituents, such as biochemical oxygen demand (BOD), suspended solids, and heavy metals, to be treated by municipal treatment facilities.
- These factors are important in determining the size and type of treatment processes required to meet the increasingly stringent standards being imposed on communities.

- Planning for the joint treatment of domestic and industrial wastewater is a crucial element in the design of cost-effective treatment systems.
- The impact of joint treatment on the various participants and their corresponding responses will be important in determining the type and size of facilities required.

Advantages

- The municipality is required to provide joint treatment when certain conditions are met, but it has considerable flexibility in making use of such policy instruments as pricing strategies and pretreatment requirements to encourage or discourage joint treatment.
- The municipality will compare the additional benefits and costs of joint treatment in order to determine its policies.

- EPA describes several benefits a municipality may anticipate from joint treatment.
- One such benefit is the potential economies of size associated with small-scale treatment facilities which serve rural communities.
- The increased flow from industrial participation is expected to result in lower average treatment costs.
- The increased flow may also result in a reduced peak-to average flow ratio, thereby increasing capacity utilization.
- Treatment of combined wastes also allows the use of nutrients available in domestic wastes for biological treatment of industrial wastes that may be nutrient deficient.

Disadvantages

- Inclusion of industrial wastes in municipal wastewater treatment systems can, however, lead to additional system costs.
- Many industrial wastewaters, while compatible with common treatment processes, are more highly concentrated, in terms of constituents such as BOD and suspended solids, than normal domestic sewage.
- The inclusion of these wastes, therefore, may require longer detention times and/or equipment with larger capacities, resulting in higher per unit treatment costs.

- Industrial wastes often contain high levels of pollutants, such as heavy metals, grease, cyanide, and many organic compounds, which are incompatible with certain biological treatment technologies.
- The efficiency of biological processes may be lowered with the presence of certain pollutants, thereby creating the potential for increased pass-through of pollutants and possible violation of the municipality's National Pollutant Discharge Elimination System (NPDES) permit for direct discharge.

- Sufficient levels of some pollutants may even cause a complete breakdown.
- To prevent such a breakdown, the treatment facility may have to substitute higher cost treatment alternatives or require additional treatment processes not otherwise necessary for treatment of the municipal wastes, and therefore, not subject to Federal subsidies.

- In addition, industrial pollutants are likely to become concentrated in the wastewater sludges.
- This may lower the quality of resultant sludges, making them unsuitable for certain disposal methods and possibly increasing disposal costs.
- Finally, incompatible wastes from industrial sources may simply pass through the treatment plant without affecting its operations and associated costs, but may cause the plant to violate its NPDES permit with respect to the corresponding pollutants.

WASTE WATER DISPOSAL METHODS

Introduction

- The disposal of sewage effluent is the last stage of getting rid of sewage after subjecting it to various steps of processes (i.e.) treatment of transforming the sewage into the harmless liquid which fulfils the minimum standard of health and sanitation.
- The main object of controlling disposal of sewage are
- To render the sewage inoffensive
- To save the aquatic life in streams

- To eliminate the danger of contamination of water supplies.
- The amount or degree of treatment that should be given to the sewage depends upon the source of its disposal as well as its capacity to assimilate the impurities present in the sewage without itself getting polluted or less useful.
- So before designing the treatment plant first the source of disposal has to be selected.

Methods of Wastewater Disposal

- Natural Methods
- Artificial Methods
- Combined Methods

Natural Methods

- **(i) Dilution or disposal into water i.e. into sea, lakes or rivers**
- **(ii) Disposal on land or land treatment i.e. sewage farming and irrigation.**

Natural Methods

Disposal on land

Dilution or Disposal into Water

Artificial Methods

- Artificial method is by which the sewage is disposed off only after subjecting it to various treatments (primary and secondary) such as:
- Screening and detritus removal
- Sedimentation with or without chemicals
- Biological treatment (trickling filter, oxidation pond or activated sludge process)
- Now a days the actual practice is to use both the methods, the sewage is first given the treatment and then it is disposed off by any of the natural method. If full treatment is not given at least the primary treatment is given before disposal.

Dilution

- Dilution is a prominent method of natural disposal, consists of discharging the wastewater into receiving water body (Such as river, sea, lake etc.)
- This is done on the assumption that the sufficient dissolved oxygen is available in the water body so that biochemical oxygen demand is satisfied.

- If however, the diluting water is not sufficient to supply the biological(or biochemical) oxygen demand to oxidise the entire matter present, there will be nuisance of foul odour and unsighty islands of half digested floating, putrefying matter at the surface.
- In addition to this problem, the depletion of oxygen would kill the aquatic life, and if this dilution water is used at the downstream side for drinking purpose, it will cause danger to the public health.

- The discharged wastewater or effluent is purified, in due course of time, by the so called self purification process of natural streams.
- The limit of effluent discharge and the degree of treatment of wastewater depend upon the self purification capacity of natural waters as well as the intended use of the water body at the downstream side.

Disposal By Dilution

Conditions Favoring Disposal

- The Dilution method for disposing of the sewage canfavorable by adopted under the following conditions:
- When the sewage is comparatively fresh i.e. it is discharged within 3-4 hours of its collection.
- When the floating matter and settlable solids have been removed by primary treatment.
- When the diluting water has high DO content, so that not only the BOD is satisfied, but sufficient DO remains available for the aquatic life.

- Where the dilution waters are not used for the purpose of navigation or water supply for at-least some reasonable distance on the downstream from the point of sewage disposal.
- Where flow current of the diluting waters are favorable, causing no deposition or destruction to aquatic life. Its means that swift forward currents are helpful, as they easily carry away the sewage to the point of unlimited dilution. On the other hand, slow back currents tend to cause sedimentation, resulting in large sludge deposits.
- Where the wastewater does not contain industrial wastewater having toxic substances.
- When the outfall sewer of the city or the treatment plant is situated near some natural waters.

Standards Of Dilution For Discharge Of Wastewater Into Rivers

- The ratio of the quantity of the diluting water to that of sewage is known as the diluting factor; and depending upon this factors the ‘ Royal Commission Report of Sewage Disposal’ has laid down the following standards and degree of treatment required to be given to a particular sewage.

Standard of Dilution

Table 3.15 Standards of Dilution Based on Royal Commission Report

Dilution factor	Standards of purification required
Above 500	No treatment is required. Raw sewage can be directly discharged into the volume of dilution water.
Between 300 to 500	Primary treatment such as plain sedimentation should be given to sewage, and the effluents should not contain suspended solids more than 150 ppm.
Between 150 to 300	Treatments such as sedimentation, screening and essentially chemical precipitation are required. The sewage effluent should not contain suspended solids more than 60 ppm.
Less than 150	Complete thorough treatment should be given to sewage. The sewage effluent should not contain suspended solids more than 30 ppm., and its 5 days B.O.D. at 18.3°C should not exceed 20 ppm.

- The above mentioned standards have been operative in England since 1912, and had also been following in India without much change.

1. But with the increase in the pollution by indiscriminating disposal of domestic as well as industrial waste into rivers without the considerations of various pollutants being discharge in the surface water.
2. For this purpose countries have prescribed their own standards including India.

- The bureau of Indian standards has therefore laid down its guiding standards for sewage effluents, vide 4764-1973 and for industrial effluents vide IS 2490 – 1974
- • These standards are the national guide lines for each state pollution control board, using which they prescribed their legally enforceable standards depending upon the water quality and dilution available in their respective surface water sources.
- • When the industrial waste water are disposed of in to public sewers, their quality should be control by using the standards IS 3306-1974

Types Of Receiving Waters For Dilution

- The following are the types of receiving waters into which wastewater or effluent can be discharged for dilution:
- Perennial rivers and streams
- Lakes
- Oceans or Sea
- Estuaries
- Creeks

Types Of Receiving Waters For Dilution

Perennial rivers and streams

- Perennial rivers or streams are probably the best type of receiving waters, since the water is in continuous motion.
- Also in the natural streams there is balance between plant and animal life, with considerable interaction among the various life forms.
- However the discharge flowing during summer and during winter varies.
- During summer, there may be minimum flow in the stream, so the dilution factor may be low, and also high temperature of water may result in low solubility of oxygen, necessitating proper treatment before dilution

Lakes

- Sometimes, especially when the perennial streams are not available lakes may be used for dilution.
- Various characteristics of lakes, such as its size, shape, volume of fresh water flowing into it etc.. should be critically examined before deciding the self purifying capacity.

Ocean

Ocean has abundant water so that the dilution factor is unlimited. However, sea water has about 20 % less DO than river or stream.

The water is turbid due to dissolved impurities and penetration of sun rays is less.

Due to this proper care has to be taken in dilution by sea otherwise anaerobic conditions would occur resulting in forming of sludge banks and emission of foul odour.

Creek

- A creek is in the form of an inlet on sea coast, which may not have dry weather flow during some part of the year.
- Due to this, great care should be taken in disposal of effluent in to it.

Estuary

- Estuary is wide lower tidal part of the river.
- Hence dilution in an estuary is affected both by ocean water as well as river water.
- However, the process of dilution is generally satisfactory in estuaries.

UNIT IV
CHARACTERISTICS AND COMPOSITION OF WASTE WATER

Introduction

- When the wastewater or the effluent is discharged into a natural stream, the organic matter is broken down by bacteria to ammonia, nitrates, sulphates, carbon dioxide etc.
- In this process of oxidation, the dissolved oxygen content of natural water is utilized. Due to this, deficiency of dissolved oxygen is created.
- As the excess organic matter is stabilized, the normal cycle will be reestablished in a process known as self purification where in the oxygen is replenished by its aeration by wind.

Actions involved in Self-purification

- Dilution
- Dispersion due to currents
- Sedimentation
- Oxidation
- Reduction
- Temperature
- Sun light

Dilution

- When wastewater is discharged into the receiving water, dilution takes place due to which the concentration of organic matter is reduced and the potential nuisance of sewage is also reduced.
- If Cs and Cr are the concentrations of any impurity such as organic content, BOD, Suspended solids in the sewage and the river having discharge rates Qs and Qr respectively, the resulting concentration 'C' of the mixture is given by

$$C = \frac{C_s Q_s + C_r Q_r}{Q_s + Q_r}$$

- When the dilution ratio is quite high, large quantities of DO are always available which will reduce the chances of putrefaction and pollutional effects.

Dispersion due to currents

- Self purification of stream largely depends upon currents which will readily disperse the wastewater in the stream, preventing locally high concentration of pollutants.
- High velocity improves re aeration which reduces the time of recovery, though length of stream affected by the wastewater is increased.

UNIT V

CHARACTERISTICS AND COMPOSITION OF INDUSTRIES

Sedimentation

- If the stream velocity is lesser than the scour velocity of particles, sedimentation will takes place, which will have two effects:
- The suspended solids, which contribute largely to oxygen demand will be removed by settling and hence water quality to downstream will be increased.
- Due to settled solids anaerobic decomposition may takes place.

Oxidation

- The organic matter, present in the wastewater is oxidised by aerobic bacteria utilising dissolved oxygen of the natural water.
- The process prevails till complete oxidation of organic matter takes place.
- The stream which is capable of absorbing more oxygen rapidly through re aeration etc. can purify heavily polluted water in a short time.

Reduction

- The reduction occurs in the streams due to hydrolysis of the organic matter biologically or chemically.
- Anaerobic bacteria will split the organic matter into liquids and gases, thus paving way for their ultimate stabilization by oxidation.

Temperature

- At low temperatures, the activities of bacteria is low and hence rate of decomposition will also be slow, though DO will be more because of increased solubility of oxygen in water.
- At higher temperatures, however, the self-purification takes lesser time, though the quantity of DO will be less.

Sun Light

- Sun light helps certain microorganisms to absorb carbon dioxide and give out oxygen, thus assisting in self purification.
- Sun light acts as a disinfectant and stimulates the growth of algae which produce oxygen during day light but utilise oxygen at night.
- Hence whenever there is algal growth, the water may be supersaturated with DO during day light hours, through anaerobic conditions exit in night.

Zones of pollution in streams

- Zone of degradation
- Zone of active decomposition
- Zone of recovery
- Zone of clear water

Zone of degradation

- This zone is situated just below the outfall sewer when discharging its contents into the stream.
- The DO is reduced to 40% of the saturation values.
- There is an increase in CO_2 content, and reaeration is much slower than deoxygenation.
- Though conditions are un favourable for aquatic life, fungi at higher points and bacteria at lower points breed small worms which work over and stabilise sewage sludge.
- The decomposition of solid matter takes place in this and anaerobic decomposition prevails.

Zone of active decomposition

- This zone is just after the degradation zone and is marked by heavy pollution.
- Water in this zone becomes grayish and darker than the previous zone.
- The DO concentration in this zone falls down to zero.
- Active anaerobic decomposition takes place with the evolution of methane, hydrogen sulphide, carbondioxide and nitrogen.
- Protozoa and fungi first disappear and then reappear, while algae will mostly be absent.
- Near the end of this zone, as the decomposition slakens, reaeration sets in and DO again rises to its original level of 40%.

Zone of recovery

- In this zone the process of recovery starts, from its degraded condition to its former condition.
- The stabilization of organic matter takes place in this zone.
- Due to this most of the stabilised organic matter settles as sludge, BOD falls and DO content rises above the 40% value.
- Mineralisation is active, with the resulting formation of products like nitrates, sulphates and carbonates.
- Near the end of this zone, microscopic auqatic life reappears, fungi decrease and algae reappears.

Zone of clear water

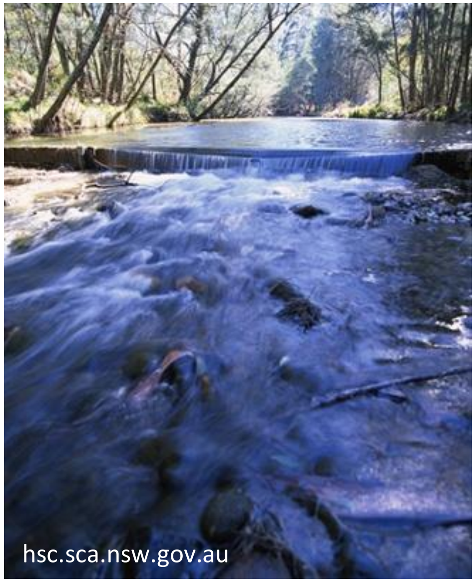
- In this zone the natural condition of stream is restored with the result that (i) water becomes clear and attractive in appearance. (ii) DO rises to the saturation level and is much higher than the BOD and (iii) Oxygen balance is attained.
- The recovery is said to be complete in this zone, though some pathogenic organisms present in this zone.

DISSOLVED OXYGEN IN STREAMS

How does DO typically enter water?

Aeration/turbulence

Photosynthesis



How is DO measured?

Gas permeable probe

Redox chemistry

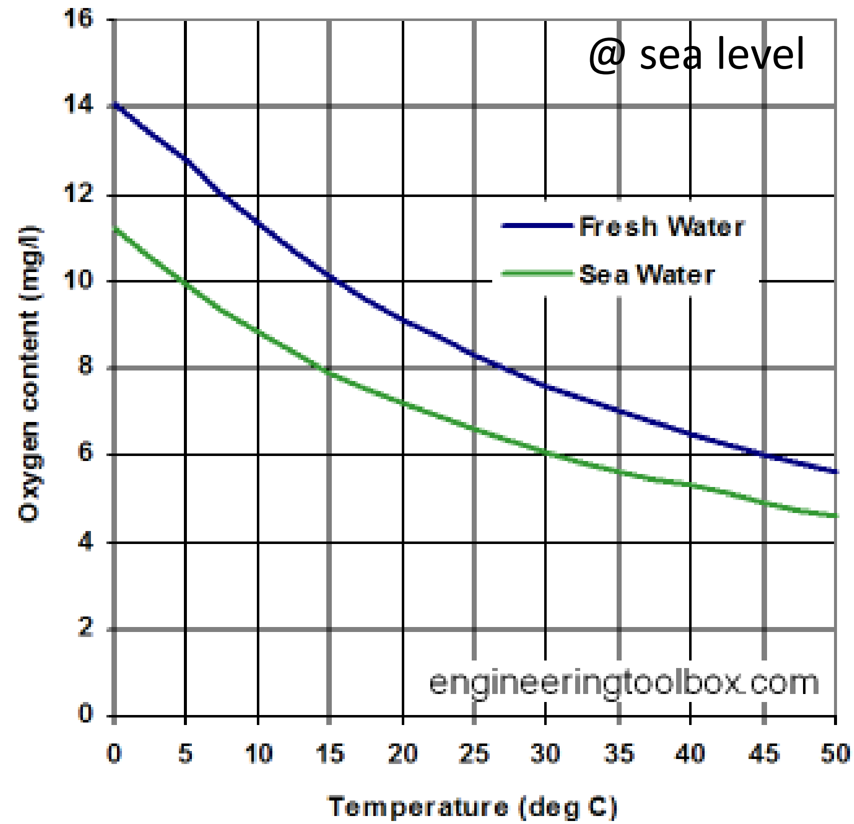
(Winkler Method)

DISSOLVED OXYGEN IN STREAMS

How is DO concentration expressed? mg/L or ppm

What affects oxygen solubility in water?
Temperature, Dissolved Solids (Salts), Altitude

What is the solubility of oxygen in water?
8 mg/L at 15°C in fresh water at sea level



Why is DO an important water characteristic?
Supports aerobic life
Prevents odors

DISSOLVED OXYGEN IN STREAMS

What DO levels do fish need to survive?

Warm water fish: > 5 mg/L
Cold water fish: > 6 mg/L

Typical U.S. Standard: 3 mg/L
(primary/secondary contact)

What happens when DO falls below these levels?

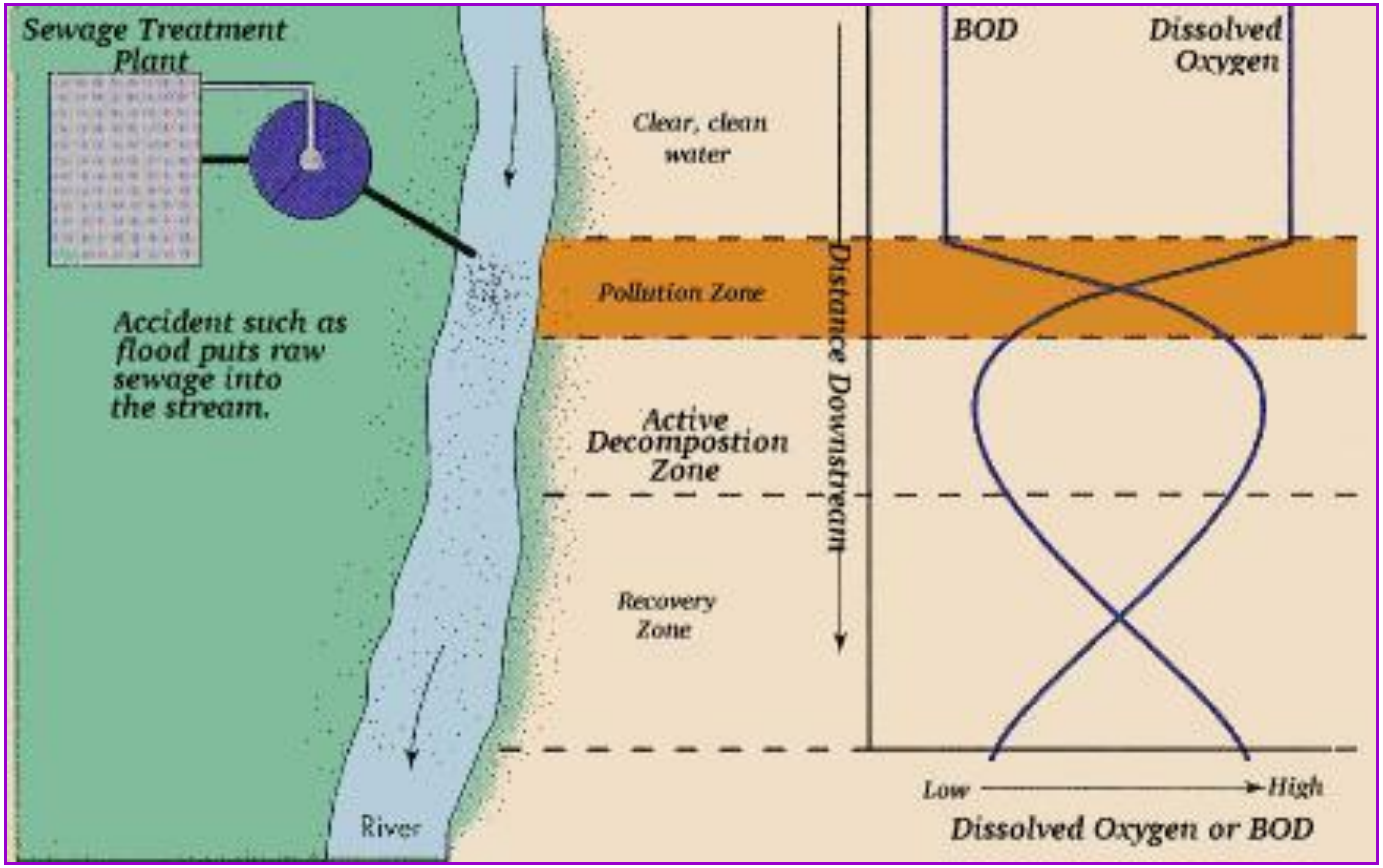
Stress on aquatic organisms
Fish kills (< 2 mg/L)
Anaerobic conditions
– odors, organic acids

Hypoxia in sea waters

Nitrate
Algae
Organic decay

Stratification due to:
- temperature
- density

DISSOLVED OXYGEN IN STREAMS



- Deoxygenation (k_d)
- Reaeration (k_r)

(k_r) α DO deficit (Δ)

(k_r) α DOs - DOx

WW organics + O_2 $\xrightarrow{\text{bacteria in stream}}$ CO_2 + H_2O + new bacteria + NO_3^- + SO_4^{2-} + PO_4^{3-}

(BOD)

C H N P S

DISSOLVED OXYGEN IN STREAMS

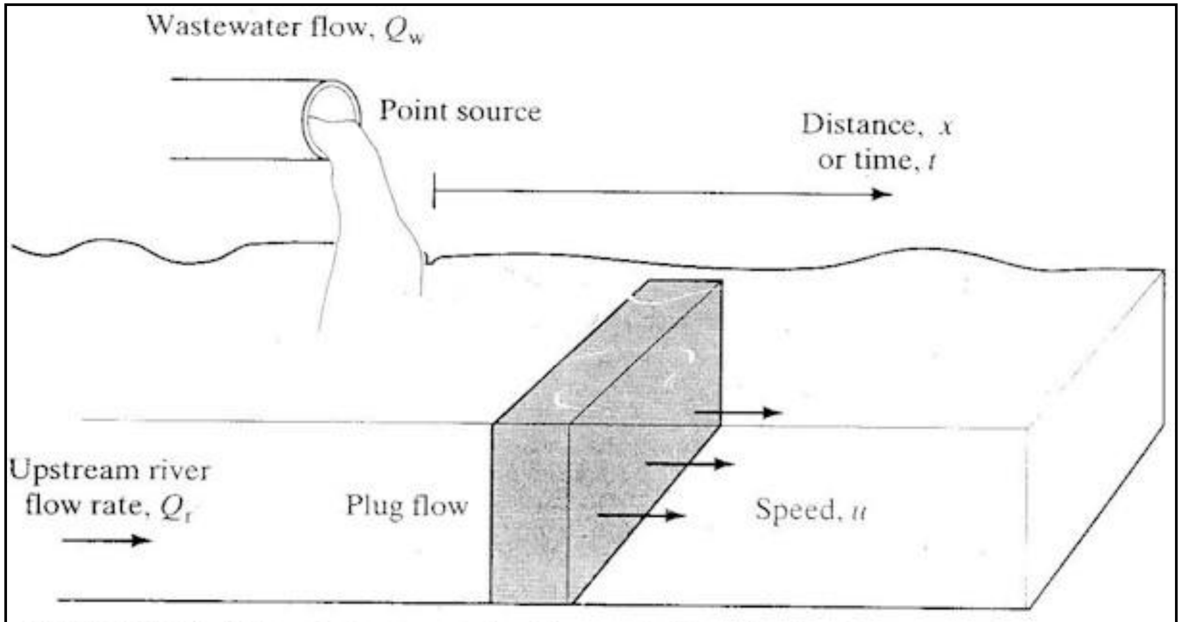


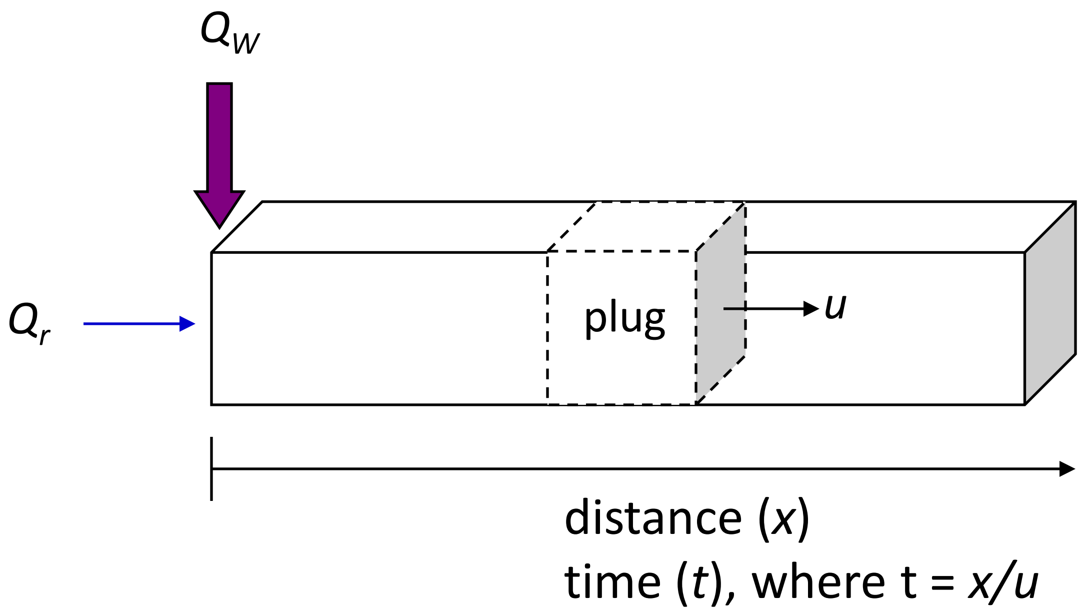
FIGURE 5.14 The point-source, plug flow model for dissolved-oxygen calculations.

Point-source plug-flow model

Assumptions:

1. Complete mixing within plug element
2. No mixing between adjacent plug elements

DISSOLVED OXYGEN IN STREAMS



BOD at x = 0:

$$BOD_0 = \frac{Q_w BOD_w + Q_s BOD_s}{Q_w + Q_s}$$

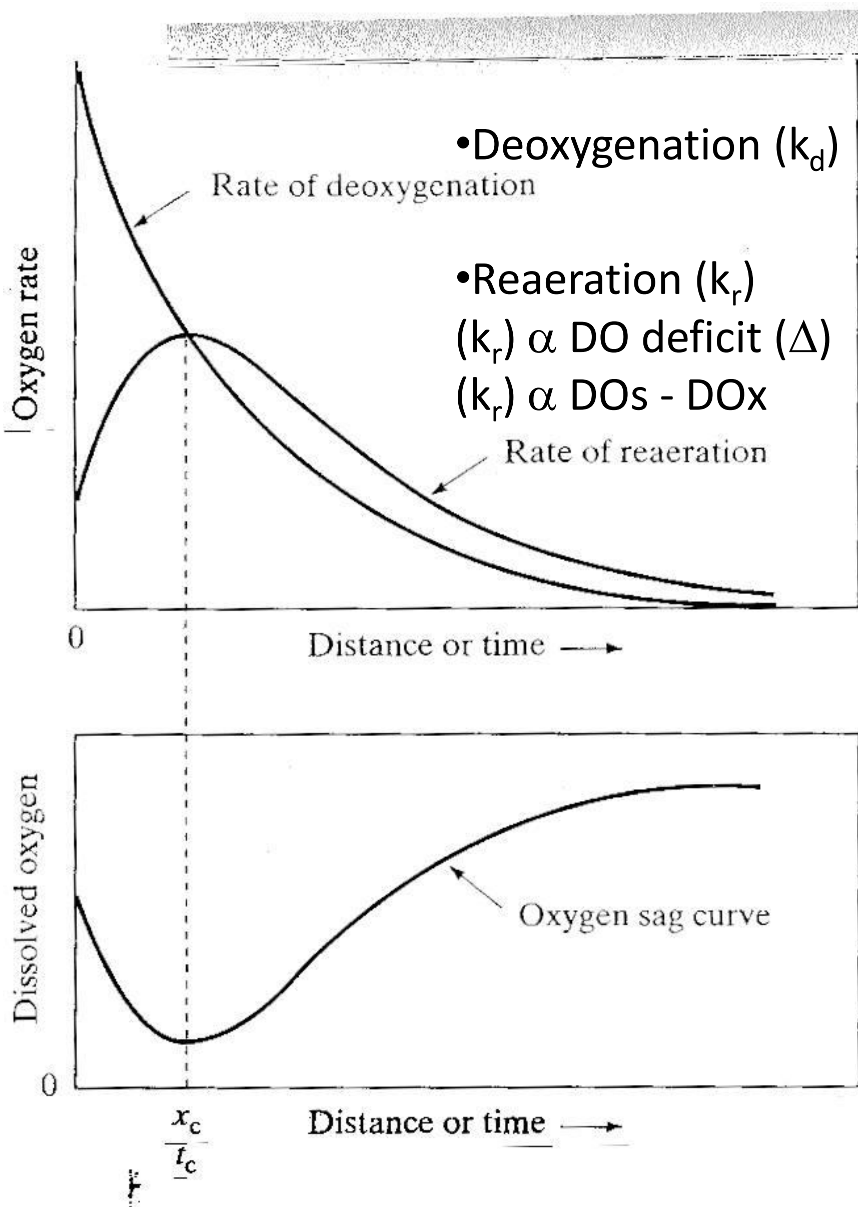
DO at x = 0:

$$DO_0 = \frac{Q_w DO_w + Q_r DO_r}{Q_w + Q_r}$$

If saturation value of DO for the river water is DO_s, the oxygen deficit at x = 0:

$$\Delta_0 = DO_s - DO_0$$

DISSOLVED OXYGEN IN STREAMS



- Deoxygenation (k_d)
- Reaeration (k_r)

(k_r) α DO deficit (Δ)

(k_r) α DOs - DOx

Critical Time

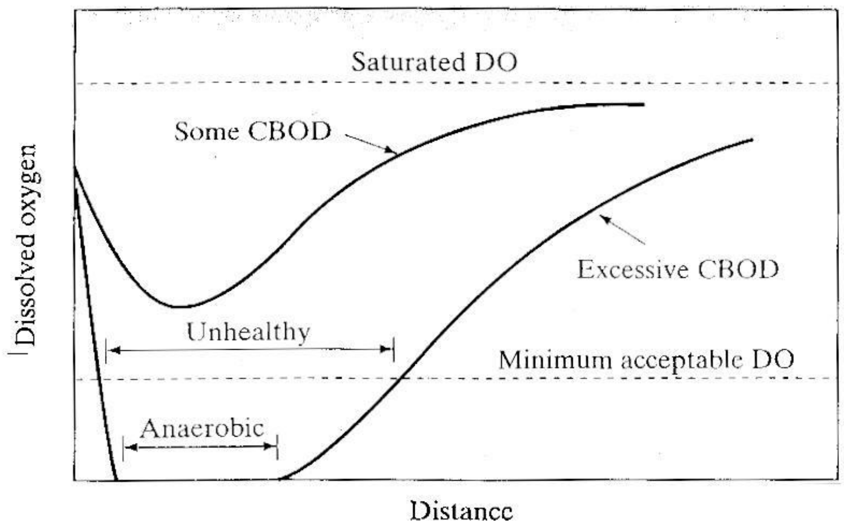
$$t_c = \frac{1}{k_r - k_d} \ln \left\{ \frac{k_r}{k_d} \left[1 - \frac{D_0 (k_r - k_d)}{k_d L_0} \right] \right\}$$

Maximum DO Deficit

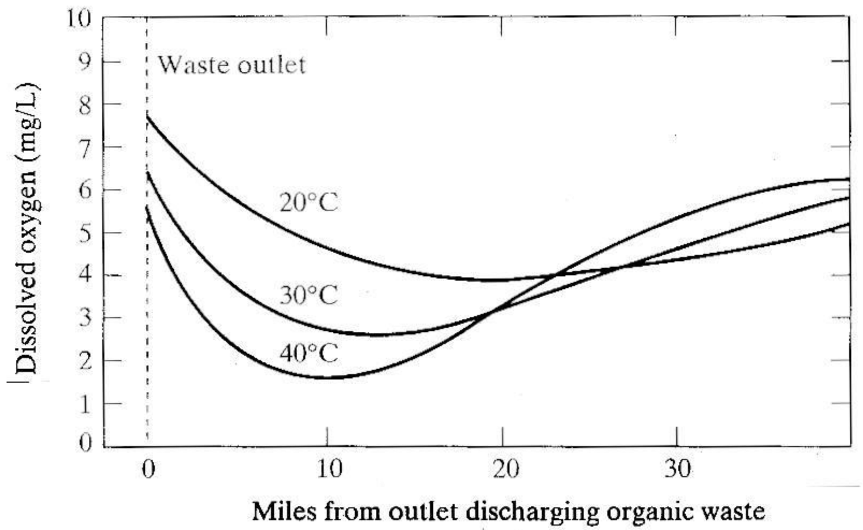
$$\Delta_{max} = \frac{k_d}{k_r} \left\{ BOD_0 e^{-k_d t_c} \right\}$$

FIGURE 5.16 While the rate of deoxygenation exceeds the rate of reaeration the DO in the river drops. At the critical point those rates are equal. Beyond the critical point, reaeration exceeds decomposition, the DO curve climbs toward saturation, and the river recovers.

DISSOLVED OXYGEN IN STREAMS



As a river gets more polluted, the oxygen sag curve drops below an acceptable level, and in me case anaerobic conditions can occur.



18. Changes in the oxygen sag curve as temperature increases. At higher temperatures the DO is lower.

Disposal of Wastewaters in Lake

- Water quality management is entirely different from that in rivers.
- River is a flowing water body while lake has stagnant waters, so in lakes only top surface would become saturated with DO, but the bottom layers would not have enough oxygen.
- Overturning of layers would not occur frequently, so that DO content would not be uniform through out the depth of lake.
- Overturning takes place only when there is change in the season due to which there will be temperature difference between water in different layers which cause change in the densities of different layers and overturning occurs.

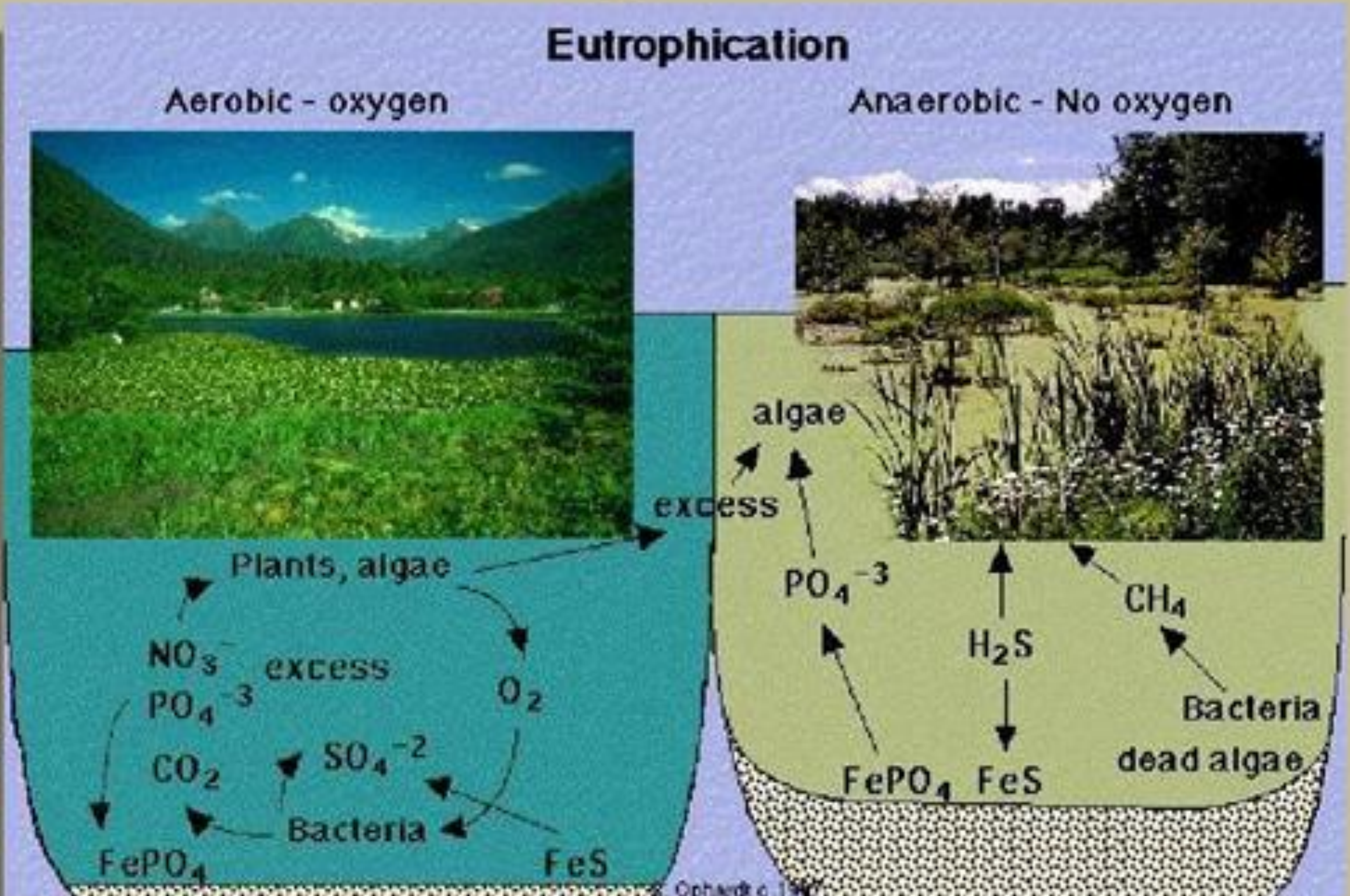
Lake Pollutants

- In Lake the phosphorous a nutrient largely contained in industrial domestic wastewater is seriously affecting the quality of lakes and hence it is considered as the prime lake pollutant.
- Oxygen demanding wastes may be the other important lake pollutant.
- The toxic chemicals from industrial wastewater can be present.

Eutrophication

- • Phosphorous acts as the nutrients for the algal growth.
- Increase in the phosphorous content would increase the algal growth.
- Excessive in the phosphorous content would increase the algal growth.
- Excessive algal growth (Algal Bloom) will create lot of the problems like taste, odour, problems in oxygen diffusion in lower layer.
- Ultimately the entire lake can get covered with algae and it may become useless for other organisms

Eutrophication



Disposal of Wastewater in Sea or Ocean

- The saturation concentration of dissolved oxygen in water decreases with increasing salt concentration.
- DO in sea water is approximately 80 % of that in water.
- In addition to this deficiency, the temperature of sea water is lower than the sewage temperature, whereas the specific gravity is higher.
- Due to this deficiency, the temperature, whereas the specific gravity is higher.
- Due to this reasons, when the sewage is discharged into the sea water, the lighter and warmer sewage will rise up to the surface, resulting in lighter and warmer sewage will rise up to the surface, resulting in spreading of the sewage at the top surface of sea in a thin film or 'sleek'

- Moreover seawater contains a large amount of dissolved matter which chemically reacts with the sewage solids, resulting in the precipitation of some of the sewage solids, giving a milky appearance to the sea water and resulting in formation of sludge banks and thin milky layer formed at the top of sea water produce offensive hydrogen sulphide gas by reacting with sulphate rich sea water.
- As such the capacity of seawater to absorb sewage solids is not as high as that of fresh water of a river.
- Also the DO content is less. However, since the sea contains large volume of water, most of these deficiencies can be overcome if the sewage is discharged deep into the sea, much away from the coast line, with extreme care.

Points be kept in mind while discharging sewage into the sea

- •The sewage should be discharged in deep sea water.
- • In order to mix sewage properly with the seawater, the sewage should be released at a minimum depth of 3 to 5 m below the water level and taking it sufficiently inside the shore, and thus preventing nuisance to baths and recreation centres on the shore.
- • To prevent the backing up and spreading of sewage on the sea shore, the sewage should be disposed of only during low tides, large sized tanks may, therefore be constructed to hold the sewage during high tides. Provision of a large sized sewer, grated with non return valve at the end, is also an alternative to hold the sewage during high tides.

- Before deciding the position of the outfall point, the sea current, wind directions, velocity, etc., should be properly studied. The sea currents, wind direction, velocity, etc.. should be properly studied. The point of disposal should be such that the sewage is taken away from the shore by the winds, and not brought back near the shore by the winds, and not brought back near the shore.
- The outfall sewer should be placed on a firm rocky foundation, and encased in thick stone masonry, so as to properly protect it from wave action, floating debris, etc..
- The discharge of Industrial waste waters into sea should however, be controlled in respect of the quality of the effluents, by adhering to the following Indian standards., prescribed by IS 1968-1976.

Disposal of Sewage on land

- In this method, the sewage effluent either treated or raw is disposed of by applying it on land.
- The most common forms of land application are irrigation (Sewage farming) and rapid infiltration.
- When raw or partly treated sewage is applied on the land, a part of it evaporates and remaining portion percolates in the soil.
- If proper voids are maintained in the soil , the organic sewage solids are oxidized by the bacteria present in the soil under aerobic condition.

- • However, if the soil is made of heavy, sticky, and fine grained materials, the void space will soon get clogged resulting in non aeration of these voids which would lead to anaerobic condition and subsequent evolution of foul gases.
- • Application of too strong or too hard of sewage will also result in the quick formation of anaerobic conditions. The loads of sewage can be reduced by dilution or pretreatment.

Disposal of Sewage on Land

Sewage Farming

- The sewage effluents can be used for irrigating farms exactly in the same manner as irrigation water is used for farming.
- Wastewater can be applied to land by the following three methods.
- Sprinkler method or spray irrigation
- Subsurface irrigation
- Surface irrigation
- (a) Basin Method
- (b) Flooding method
- (c) Furrow method

- Out of these spray irrigation is most commonly adopted in western countries, while surface irrigation is commonly adopted in India.
- For spray irrigation the sewage should be pretreated otherwise the spray nozzles can get clogged.
- In the subsurface irrigation method, wastewater is supplied directly to the root zone of plants through the system of underground pipes with open joints.
- The method is not suitable for untreated wastewater containing lot of suspended solids

- • In surface method wastewater is applied directly on the farm and depending upon the land preperation and method of application of wastewater there can be different method of surface irrigation.

Sewage Sickness

- • When the sewage is applied continuously on a piece of land, the soil pores or voids may get filled up and clogged with sewage matter retained in them.
- The time taken for such clogging will depend upon the type of the soil and the load present in sewage. But once these voids gets clogged, free circulation of air will be prevented an anaerobic conditions will develop within the pores.
- Decomposition of organic matter would take place under anaerobic conditions with evolution of foul gases like H_2S, CO_2 and methane.
- This phenomenon of soil getting clogged, is known as sewage sickness

Methods of Preventing Sewage Sickness

- • In Order to prevent the sewage sickness of a land, the following preventive measures may be adopted.• Primary Treatment of Sewage: The Sewage should be disposed of, only after primary treatment, such as screening, grit removal, and sedimentation. This will help in removing settleable solids and reducing the BOD load by 30 % or so, and soil pore will not get clogged frequently.
- • Choice of Land: The piece of land used for sewage disposal should normally be sandy or loamy. Clayey lands should be avoided.
- • Under drainage of Soil: The land, on which the sewage is being disposed of, can be drained, if a system of under- drains is laid below, to collect the effluent. This will also minimize the possibilities of sewage sickness

- • Giving rest to the land: The land being used for the disposal should be given rest, periodically by keeping some extra land as reserve and stand-by for diverting the sewage during the rest period, the land should be thoroughly ploughed, so that it gets broken up and aerated.
- • Rotation of Crops: Sewage Sickness can be reduced by planting crops in rotation instead of growing single type of a crop. This will help in utilizing the fertilizing elements of sewage and help in aeration of soil.
- • Applying Shallow depths: The sewage should not be filled over the area in large depths, but it should be applied in thin layers. Greater depth of sewage on a land does not allow the soil to receive the sewage satisfactorily and ultimately results in clogging.
- • A Sewage sick land can be improved and made useful by thoroughly polughing and breaking the soil, and exposing it to the atmosphere.

Comparison of Disposal Methods

- • For most of Indian towns and cities the land disposal is a better choice because of following reasons:
- • India is a tropical country temperature remains high in most part of the year. Due to hot climate, DO content of the river water reduces, while the fish and aquatic life requires higher DO for their survival, thus making the dilution method more difficult and prohibitive.
- • Most of the rivers have a very small amount of dry weather flow (in summer) so amount of dilution available would be less. Also in most of the cities these rivers are the only source of drinking water. So disposal by dilution method cannot be used, and if used, a very high degree of treatment is required which would increase the cost of disposal.

- • Except for a few major cities, the water supplies in India are very low, thus resulting in the production of highly concentrated sewage, which on travelling in hot climate, becomes stale and septic by the time it reaches the disposal point, thus prohibiting the use of dilution method for disposal.
- • There are only a few coastal towns in India, which have strong tidal currents moving in the forward directions, and the necessary depth of water at the point of disposal, thus prohibiting the disposal of sewage in the sea on large scale.

Thank you