



Wastewater Treatment: Physical and Chemical Process

BASIC CONCEPTS:

- ◆ In order to dispose off the waste water, it should meet some standards set by local authorities. With these standards wastewater should be treated. More than one treatment is needed to achieve the desired change in quality. Thus, it is a chain processes operating in sequence.



- ◆ In some cases treatment processes do not destroy the impurity but simply concentrate them in the form of sludge or effluent stream.
- ◆ Selection of proper method based on the characteristics of wastewater is the key to solving treatment problems.



Nature of Impurities

- ◆ Rainwater, surface water, groundwater, seawater can be considered as the different forms of some basic material, varying in form and amount of impurities. These impurities decide the level of treatment provide for its use and disposal.



- ◆ Municipal water has many types of impurities like floating and large suspended solids(paper, rags, plastics, grit), dissolved solids(organic and inorganic);Dissolved gases(hydrogen sulfide, methane etc.) and microorganisms(pathogen,bacteria and viruses)
- ◆ Wastewater on the other hand can have much higher levels of impurities as discussed because of the human organic waste added to water along with detergents, pesticides, and microorganism.
- ◆ But wastewater can be called as water of different form if the concentration of impurities is reduced, it can have applications similar to water.

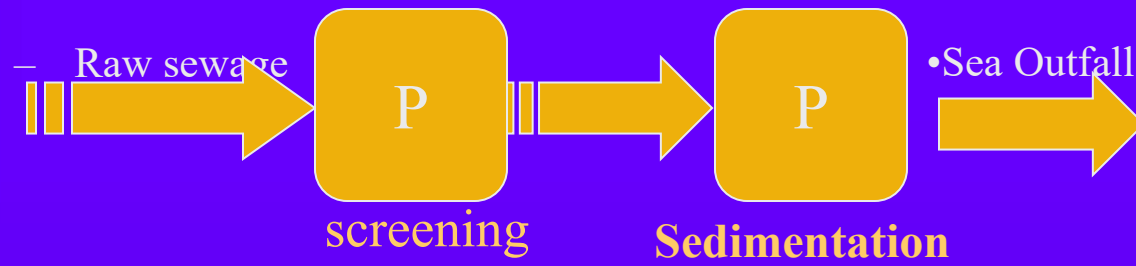


Different treatment processes

- ◆ Wastewater treatment is divided into three main processes.
- 1. Physical processes comprising screening or straining, sedimentation, flocculation and filtration.
- 2. Chemical treatment using adsorption, coagulation, ion exchange, precipitation.
- 3. Biological treatment processes with dispersed growth system(activated sludge, stabilization ponds); fixed film reactors(biological filters such as tricking filter)

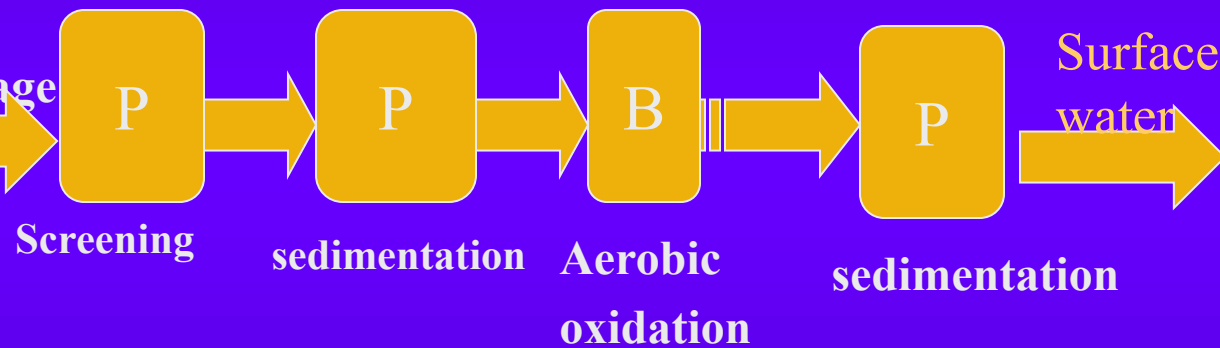


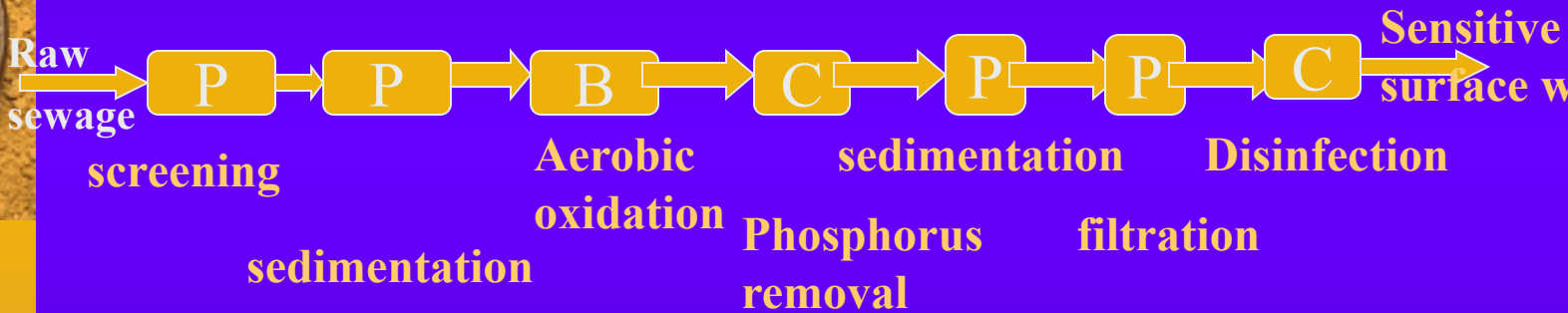
- ◆ Wastewater treatment processes normally uses physical processes initially and later chemical processes like precipitation. But if it not sufficiently treated by the two processes, the three can be used.





Raw sewage





Note: P-→ Physical Process
C-→ Chemical Process
B-→ Biological Process

Wastewater treatment
process chain



♦ Most of processes in wastewater treatment plant as it is most cost effective compared to batch process. However, batch process are preferred in some cases where the quantity of waste is small and the waste generation is not continuous.



Physical treatment processes

- ◆ The main aim of physical treatment process in a water treatment system is to protect the main treatment systems from possible damage or clogging. Various processes are used to remove large floating and suspended material.



Screening

- ◆ The first operation in the physical treatment process. Micro strainer with specially woven stainless steel meshes size between 20 to 40 micrometer are usually used in water treatment plants.
- ◆ The nature and quantity of screening collected depend upon the social, dietary, as well sewerage system of the city. It also depends on the screening bar spacing, which affect the loss of velocity head. This headloss indicates the performance of a screen. On an average its quantity ranges from .01 to .03 cu.m./1000 population per day.



- ◆ Screening is unpleasant in nature with a strong odor, particularly in high temperatures. Their density is usually 1800-1900 kg/cu.m. with a solid content of 15-30%
- ◆ Sample problem:
- ◆ A bar screen is installed in a wastewater treatment plant receiving a daily peak flow of crude sewage of 50,000 cu.m. Estimate headloss through the screen and also the gross area of the screen.



◆ Solution

- ◆ Maximum flow, $Q = 50,000 \text{ cu.m.} = .5788 \text{ cu.m/s}$
- ◆ Desired velocity through the screen, V , at ultimate flow = 0.8 m/s
- ◆ Net area of screen opening required, $A = .5788 / .8 = 0.72 \text{ m/s}$
- ◆ Since $Q = V/A$
- ◆ Using rectangular bars in the screen having 1 cm width, 1 m height and placed 5 cm clear spacing,
- ◆ Number of bars required = $.7235 * 100 / 5 = 14.46$
- ◆ Say 15 bars of 1 cm each
- ◆ Total area required for screen = $0.7235 + (15 * 10^{-2}) = 0.87 \text{ square meter}$



- ◆ Assuming that the inclination of the screen to the horizontal is at 60 degrees
- ◆ The gross area of screen would be
- ◆ $= 0.87 * (\text{square root of } 3/2) = 1 \text{ square meter}$
- ◆ Velocity through the clear screen, $v = 0.8 \text{ m/s}$
- ◆ Velocity above the screen , $u = 0.8 * 5/6 \text{ m/s} = 0.67 \text{ m/s}$
- ◆ Using the equation of continuity
- ◆ Headloss through the screen is usually given as
 - $= 0.0729 (v^2 - u^2)$
 - $= 0.0729 (0.8^2 - 0.67^2)$
 - $= 0.014 \text{ m}$



- ◆ If the screen openings are half plugged with screenings, leaves and debris, the velocity through the screen is doubled.

- $v = 0.8 * 2 \text{ m/s}$

- $= 1.6 \text{ m/s}$

$$\begin{aligned}\text{Maximum headloss} &= .0729 (1.6^2 - 0.67^2) \\ &= 0.15\text{m}\end{aligned}$$

At this maximum headloss the screen is to be cleaned.



Comminution and maceration

- ◆ **In situ maceration of floating and large suspended solids can be achieved by a comminutor or macerator in which the material is trapped between teeth mounted on a slotted rotating drum and a fixed comb.**



Grit removal

- ◆ In most sewerage plant, considerable amount of sand and grit are transported to the wastewater treatment plant. These materials arise from roads and other paved areas. These two should be removed earlier in order to prevent damage on the pumps and other mechanical equipments.



Sedimentation

- ◆ Is the separation of solids based on difference between densities of solids and wastewater due to gravity.
- ◆ Stoke's law
- ◆ $V_s = \frac{gd^2}{18V} (S_s - 1)$
- ◆ Where V_s = discrete particle terminal velocity; g is acceleration due to gravity; d = diameter of the particle ; V = kinematic viscosity of water
- ◆ S_s = specific gravity of the particle
- ◆ Practical consideration in settlement of the discrete suspension involves concept of ideal settling basin in which it is assumed that the following conditions exists.



- ◆ Quiescent settlement in the settling zone
- ◆ Uniform flow through the settling zone
- ◆ Uniform solids concentrations entering the settling zone.
- ◆ Solids entering the sludge zone are not resuspended.



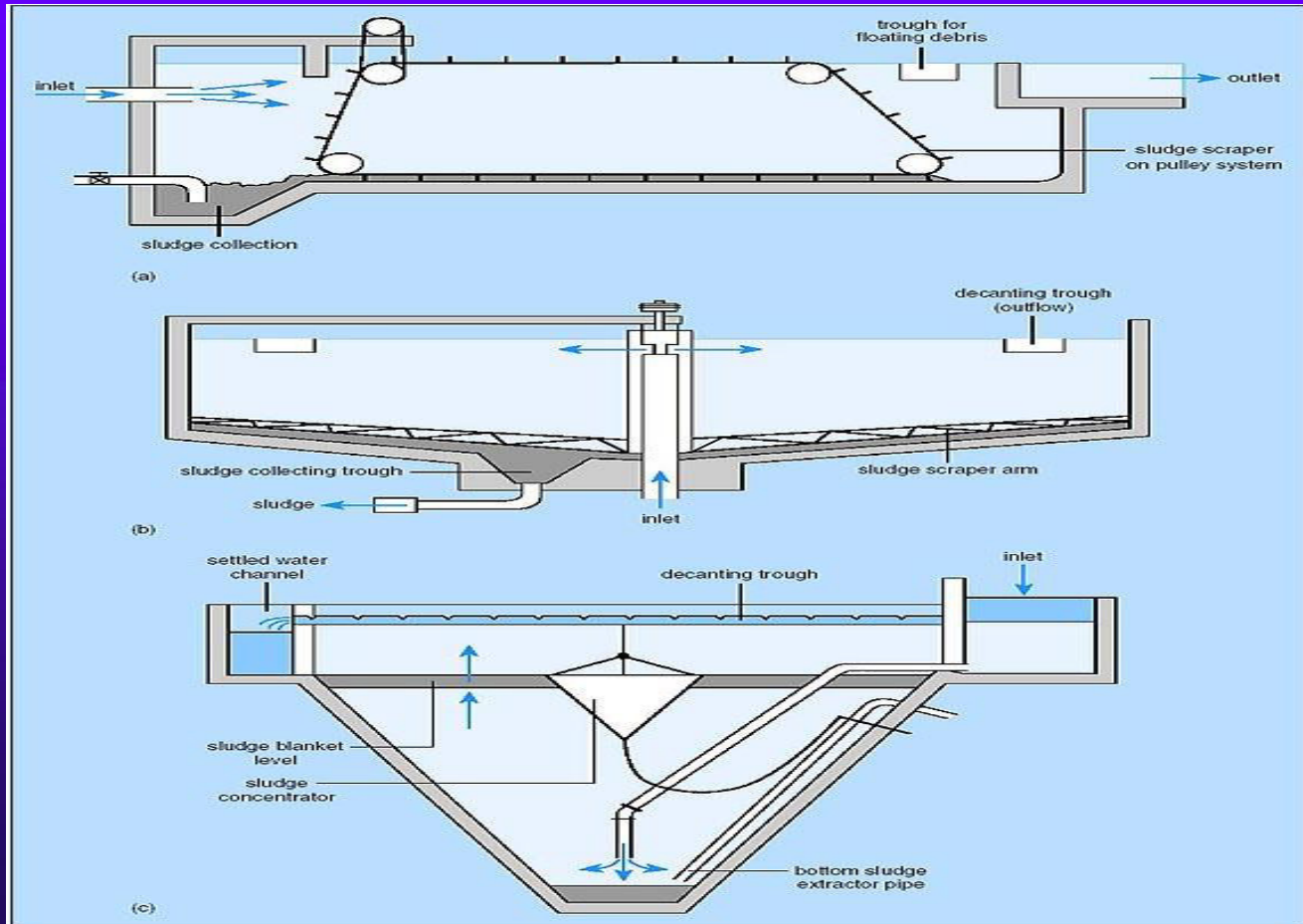
Horizontal and radial flow units	
Surface overflow rate	1- 1.5 m/h
Retention time	2 hr
Outlet weir loading	< 12.5 cu.m / mh
Width : length	
Rectangular units	1:4 to 1: 8
Vertical Flow units	
Surface overflow rate	1- 1.8 m/h
Retention time	2-3 hr
Outlet weir loading	< 12.5 cu.m /mh
Final settlement after biological treatment	
surface overflow rate	1.5 m/h
Retention time	2 hr
Outlet weir loading	< 10 cu.m / mh
Typical design criteria for sedimentation tanks.	



	Types of sedimentation tank	
parameter	Rectangular	circular
Max. length	90m	-
Max. width	30m	-
depth	2- 2.5	2- 3.5 m
Range of length/width ratio	1.5- 7.5	
Range of length/depth ratio	5 – 25	
Bottom slope	1%	7.5 – 10% (from periphery to center)
Max. diameter		30m
inlet	multiple pipes on the width side with baffle boards of depth 0.5 m and 0.8 m in front of the pipe inlets and surface for scum passover	central inlet pipe with concentric inlet baffle of diameter 15% of tank diameter and extending 1m below surface
Outlet	Overflow weir with V-notches to Provide uniform flow at low heads. Scum baffles provide ahead of weir for wastewater installations	peripheral weir provided with V- notch. Scum baffle extending 0.3 m below water surface provided ahead of effluent weir for wastewater installation
Peak velocity	Depends upon feed	
Scraper arms velocity	0.2 m.min	
	Design features of wastewater sedimentation tank	

Types of sedimentation tank

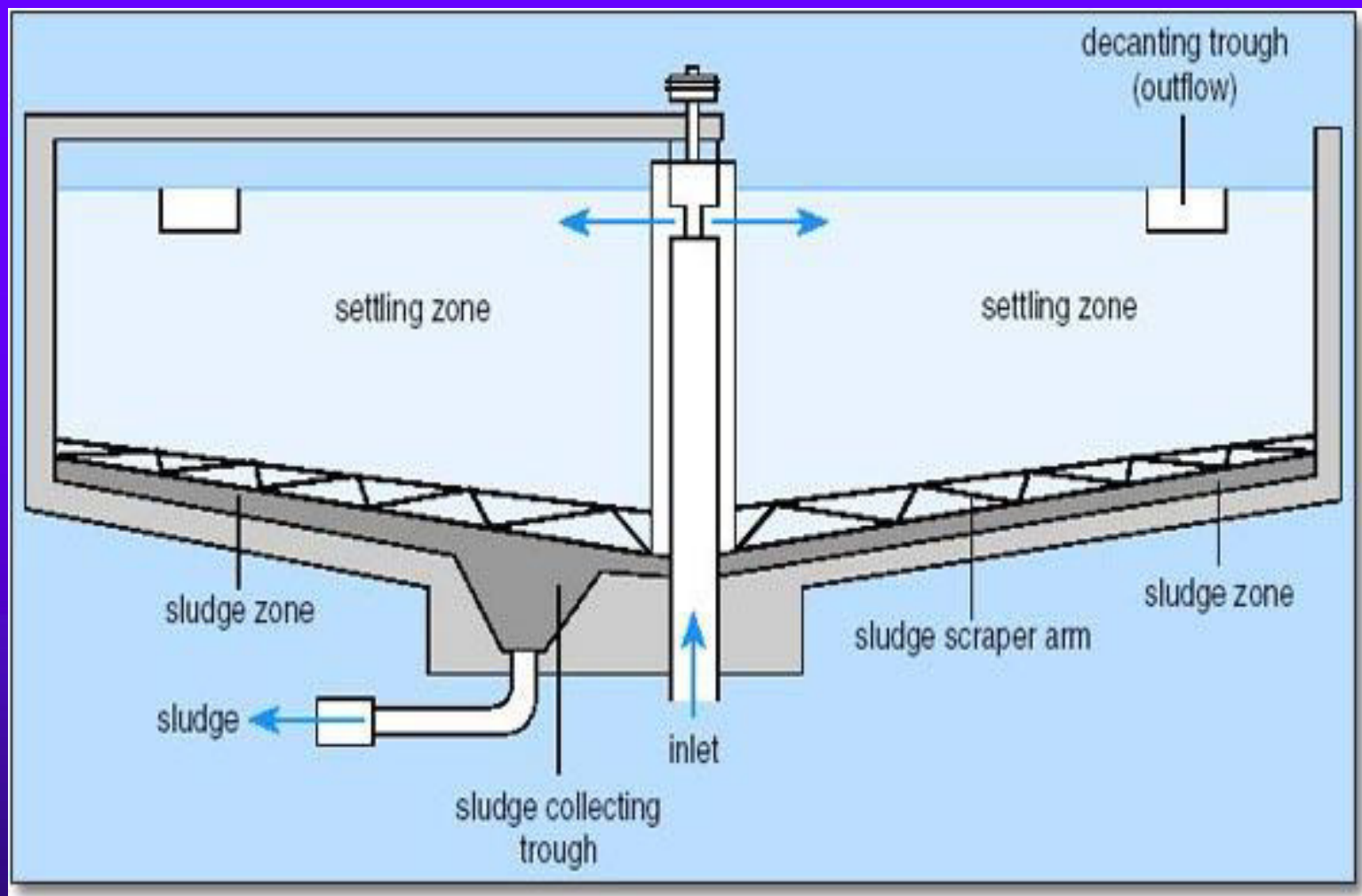
- ♦ Typical sedimentation tanks: (a) rectangular horizontal flow tank; (b) circular, radial-flow tank; (c) hopper-bottomed, upward flow tank





Important parts of a sedimentation tanks

- ◆ (a) Inlet zone – at the central well, which has a round baffle plate, the flow is established in a uniform radial direction so that short-circuiting does not take place.
- ◆ (b) Settling zone – where settling is assumed to occur as the water flows towards the outlet.
- ◆ (c) Outlet zone – in which the flow converges up and over the decanting weirs.
- ◆ (d) Sludge zone – where settled material collects and is pumped out.





Flocculation

- ◆ This process is used when the small suspended solids having low specific gravity and low settling velocity cannot be separated by sedimentation easily. In wastewater treatment, this usually occurs particularly with particles of less than 50 micrometer in size.



Advanced physical processes

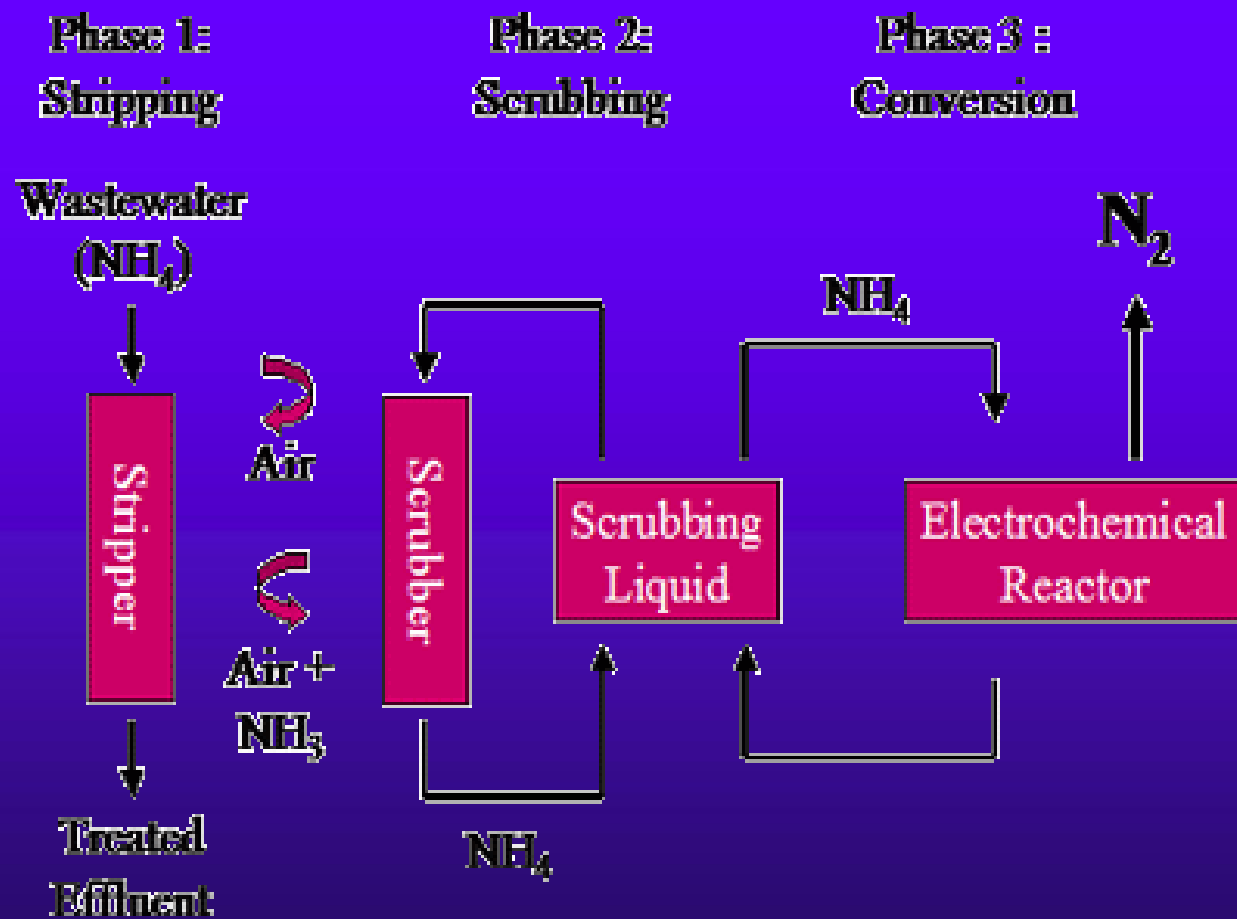
- ◆ These are used in order to get better treatment efficiency. Some of the better known operations used in advanced treatment are ammonia stripping, distillation, foam, fractionation, freezing.



Ammonia stripping

- ◆ Is also known as air stripping of ammonia. It is a modification of the aeration process used for the removal of gases dissolved in water.

Illustration of ammonia stripping





- ◆ In the first phase, sodium hydroxide (NaOH) is added to the wastewater stream just before being pumped into the stripping column. This raises the water pH to the point where ammonium ions (NH_4^+) are converted to ammonia gas. Ammonia removal is enhanced by pumping the wastewater stream into the top of the column which is packed with high surface area packing material. Air is pumped into the bottom of the column. The ammonia carried by the air stream is then transferred to liquid in the scrub column.
- ◆ At the core of AmmEL-HC is a patented electrochemical reactor that converts the ammonia dissolved in the scrubbing liquid to gaseous Nitrogen without producing nitrates or greenhouse gases. Chemically inert and occupying an 80 per cent proportion of our atmosphere, gaseous nitrogen is the ideal end product for safe dispersal into the environment.
- ◆ Testing of the AmmEL-HC system has demonstrated its capabilities. As shown below, a percentage removal ranging from 93% to 99% was achieved throughout the test.



- ◆ **Other advantages of AmmEL-HC include:**
- ◆ Improves performance of existing biological treatment plants by preventing ammonia toxicity in the activated sludge process
- ◆ Less expensive than conventional processes, including biological treatment
- ◆ Does not convert ammonia to nitrate and does not produce greenhouse gases
- ◆ Small footprint - can reduce overall cost of land for new biological treatment plants
- ◆ Can operate intermittently without start-up delays
- ◆ Fully automated - low maintenance
- ◆ Remotely monitored



distillation

- ♦ Is a unit operation in which the components of a liquid solution are separated vaporization and condensation.



Foam fractionation

- ◆ Is the separation of colloidal and suspended material by floatation and dissolved organic matter by adsorption.



freezing

Wastewater is sprayed into a chamber operating under a vacuum. A portion of wastewater gets evaporated and cooling effect produces contaminant free ice crystals in the remaining liquid.



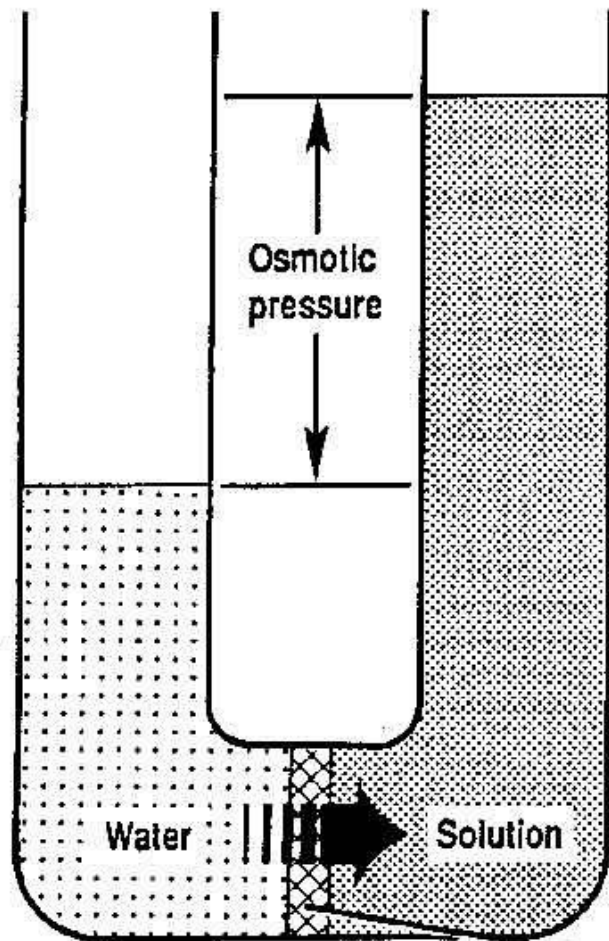
Gas phase separation

- ◆ Is a promising method for removal of ammonia as gas. This method is based on the development of selective permeable gas-phase membranes.

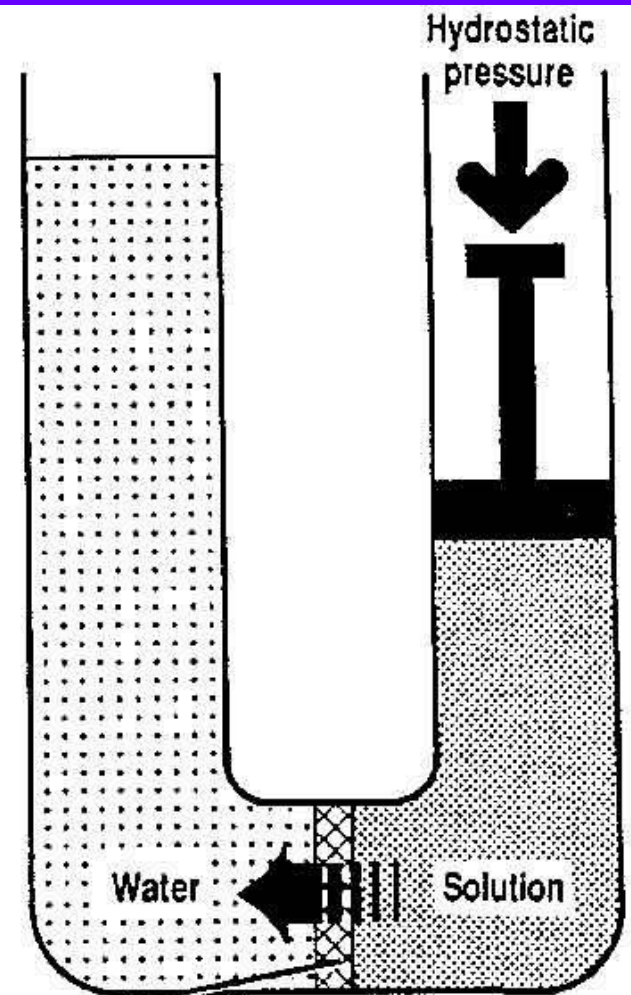


Reverse osmosis

- ◆ Is the process in which water is separated from dissolved salts in the solution by filtering through semi permeable membrane at a pressure than the osmotic pressure caused by the dissolved salts in wastewater.



OSMOSIS



REVERSE OSMOSIS

Semipermeable
membrane



Sorption

- ◆ Conventional alum treatment for removal of phosphate increases the concentration of sulphate ions in the solution. To avoid this, sorption is developed. Sorption is a process of removing various forms of phosphate without increasing the concentration of sulphates.



Chemical treatment processes

- ◆ Chemical precipitation- is the method of addition of chemicals to the wastewater, converting undesired soluble substances into an insoluble precipitate which can be removed easily and rapidly.



- ◆ The undesired constituents generally found in wastewater are:
- ◆ Suspended colloidal and supra colloidal solids and their associated organic matter. They should be removed in order to avoid damage to performance and reduction in efficiency.
- ◆ Phosphorus
- ◆ Toxic heavy metals and organics discharged from industrial plants and premises into the municipal wastewater treatment plant.



coagulation

- ◆ Is an important operation in removing colloidal solids. In wastewater treatment, chemical such as lime, ferric salts and commercial alum are used as coagulants. This process removes suspended solids (60-80%), BOD (50-70%) phosphorus (over 90%) and heavy metal (over 80%)
- ◆ Chemical clarification of wastewater can be combined with the activated carbon adsorption process to provide complete physical – chemical wastewater treatment. the use of chemical clarification has restricted application in developing countries because of its constant requirement of consumable chemical and consequent higher running costs.



- ◆ Jar Test – it is used to calculate the dosage of the coagulant.



Advanced chemical processes

- ◆ Ion exchange- although both natural and synthetic ion exchange resins are available, synthetic resins are used more widely because of their durability. Some natural zeolites (resins) are also used for the removal of ammonia from wastewater.

A vertical image on the left side of the slide shows a dark, rusted metal key with a circular head and a notched bit, resting on a coarse, light-brown granular surface.

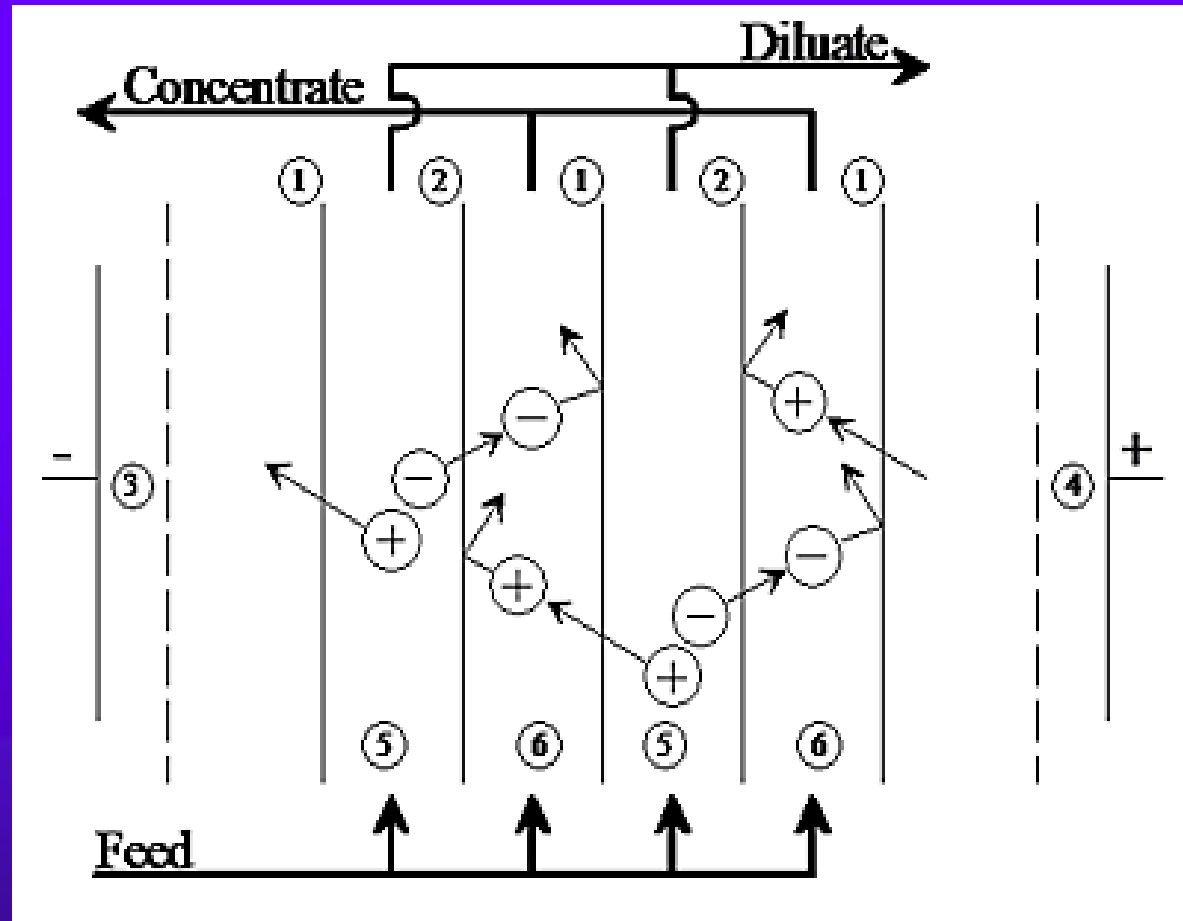
Electrochemical treatment

- ◆ Wastewater is mixed with seawater and is passed into a single cell containing carbon electrodes.



Electro dialysis

- ◆ Ionic components of a solutions are separated through the use of semi permeable ion-selective membranes. If the electrical potential is applied between the two electrodes, which in turn causes a migration of cations toward the negative electrode and migration of anions towards the positive electrode. Due to the alternate spacing of cation and anion permeable membranes, cells of concentrated and dilute salts are formed.



- ♦ . Principle of simple electrodialysis process. Diagram shows the membrane configuration with alternating cation-selective (1) and anion-selective (2) membranes between two electrodes ((3) and (4)), one at each end of the stack.



Oxidation and reduction

- ◆ **Oxidation** - Chemical oxidation is used to remove ammonia, to reduce the concentration of residual organics and to reduce bacterial and viral contents of wastewater. At present one of the few processes for the removal of ammoniacal nitrogen, found operationally dependable, is chlorination. Ammonia can be removed chemically by adding chlorine or hypochlorite to form monochloramine and dichloramine as intermediate products and nitrogen gas and hydrochloric acid as end products. Problems associated with this method is the presence of various organic and inorganic compounds that will exert chlorine demand. Chemical oxidation of organic material in wastewater.



Reduction

- ◆ Nitrates present in wastewater can be reduced electrolytically or by using strong reducing agents(e.g. ferrous oxide). The reaction must usually catalyzed while using reducing agents. The two step processes using different reducing agents and catalysts are limited by the availability of chemicals at low cost, and the fact that the treated effluent and waste sludge may contain toxic compounds derived from the chemicals used for catalyzing various reactions.



the end . . .