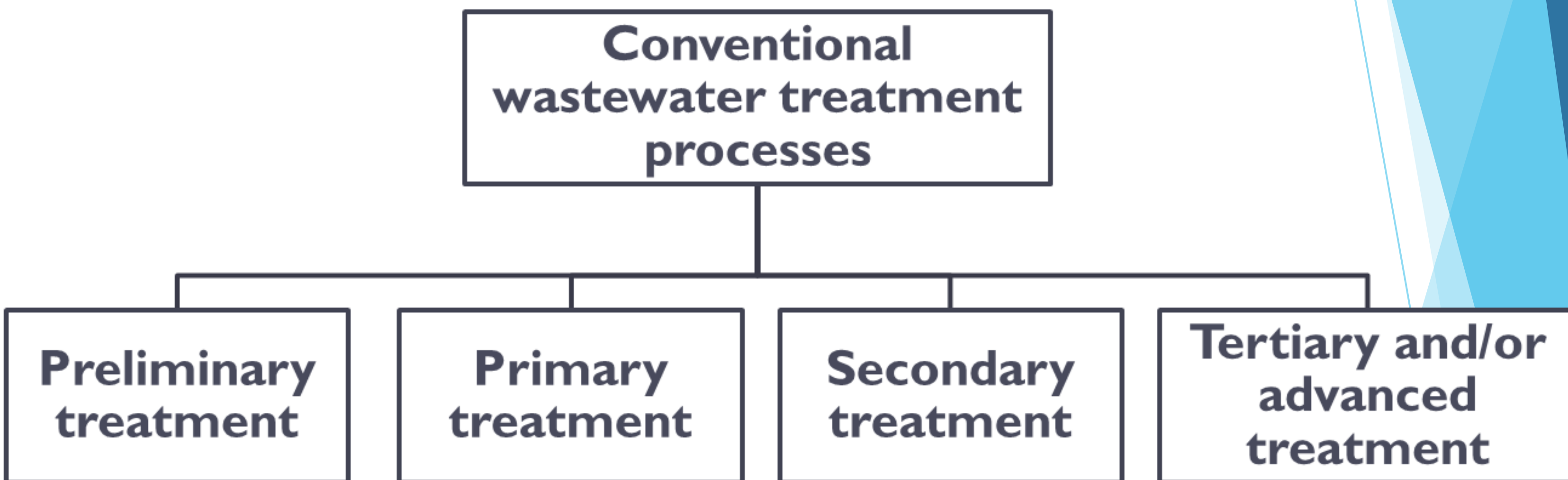
Waste water treatment

Introduction

- Wastewater treatment consists of applying known technology to improve or upgrade the quality of a wastewater
- Wastewater treatment involves collecting the wastewater in a central, segregated location (the Wastewater Treatment Plant) and subjecting the wastewater to various treatment processes
- The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed off without danger to human health or unacceptable damage to the natural environment
- With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose of these wastewaters safely and beneficially

Conventional wastewater treatment processes



- Conventional wastewater treatment consists of a combination of physical, chemical and biological processes and operations to remove solids, organic matter and sometimes, nutrients from waste water.
- General terms used to describe different degrees of treatment, in order of increasing treatment level, are preliminary, primary, secondary, and tertiary and/or advanced wastewater treatment.
- In some countries, disinfection to remove pathogens sometimes follows the last treatment step

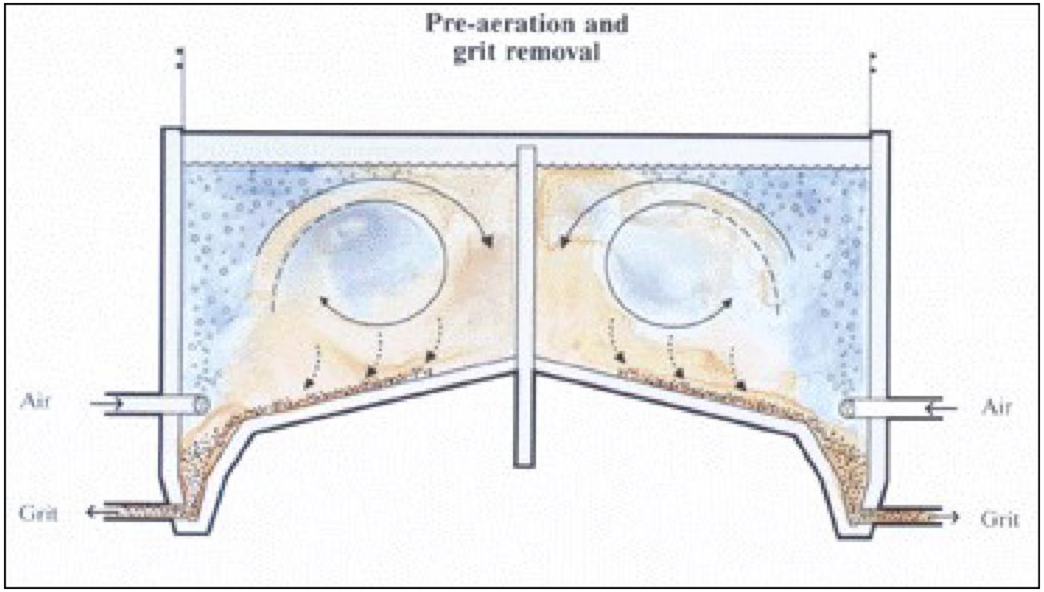
Preliminary treatment

- The objective of preliminary treatment is the removal of coarse solids and other large materials often found in raw wastewater
- Preliminary treatment operations typically include coarse screening, grit removal and, in some cases, comminution of large objects
- In grit chambers, the velocity of the water through the chamber is maintained sufficiently high, or air is used, so as to prevent the settling of most organic solids
- Comminutors are sometimes adopted to supplement coarse screening and serve to reduce the size of large particles so that they will be removed in the form of a sludge in subsequent treatment processes

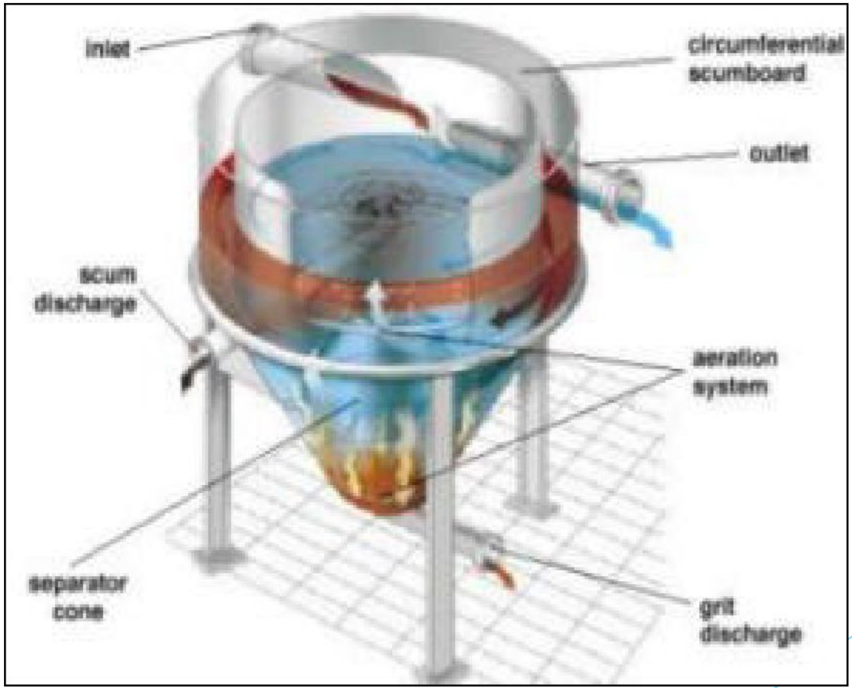
Grit removal

- **Grit** is the term used for small, but dense material such as sand, dirt, or broken glass. If not removed separately grit can cause wear and damage to mechanical devices in a treatment plant. There are several methods to remove grit, though the most common is to send it through a channel where the speed of the water is such that the grit settles and can be removed, while the the rest of the water can flow on to further treatment. Like the bar screen channels, there are always two of these channels, allowing for one to be cleaned or repaired while the other remains in use.

Grit chamber

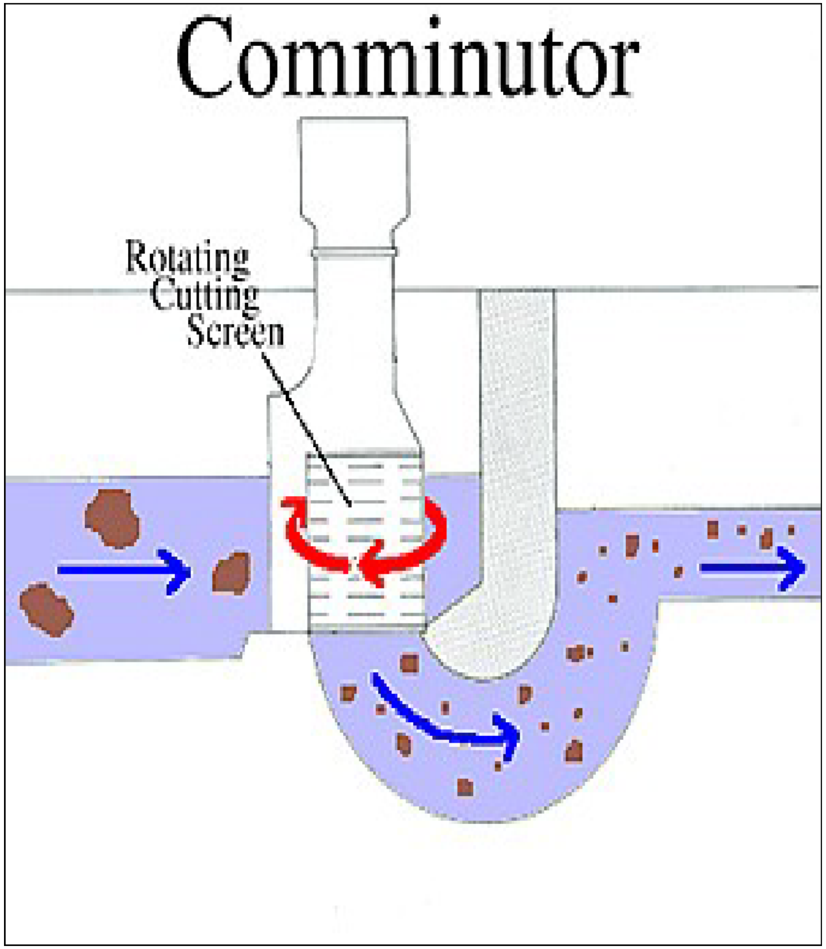


Aerated grit chamber :
diffused air keeps organic solids in suspension as grit settles



Vortex - Type Grit Chambers
Vortex is created
-Grit move to the outside of the unit and gets collected

Comminutor



- In this device all of the water flow passes through the grinder assembly.
- The grinder consists of a screen or slotted basket, a rotating or oscillating cutter and a stationary cutter
- Solids pass through the screen and are chopped or shredded between the two cutters

Primary treatment

- The objective of primary treatment is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming
- Approximately 25 to 50% of the incoming biochemical oxygen demand (BOD_5), 50 to 70% of the total suspended solids (SS), and 65% of the oil and grease are removed during primary treatment
- Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed during primary sedimentation
- In many industrialized countries, primary treatment is the minimum level of pre-application treatment required for wastewater irrigation
- It may be considered sufficient treatment if the wastewater is used to irrigate crops that are not consumed by humans or to irrigate orchards, vineyards, and some processed food crops

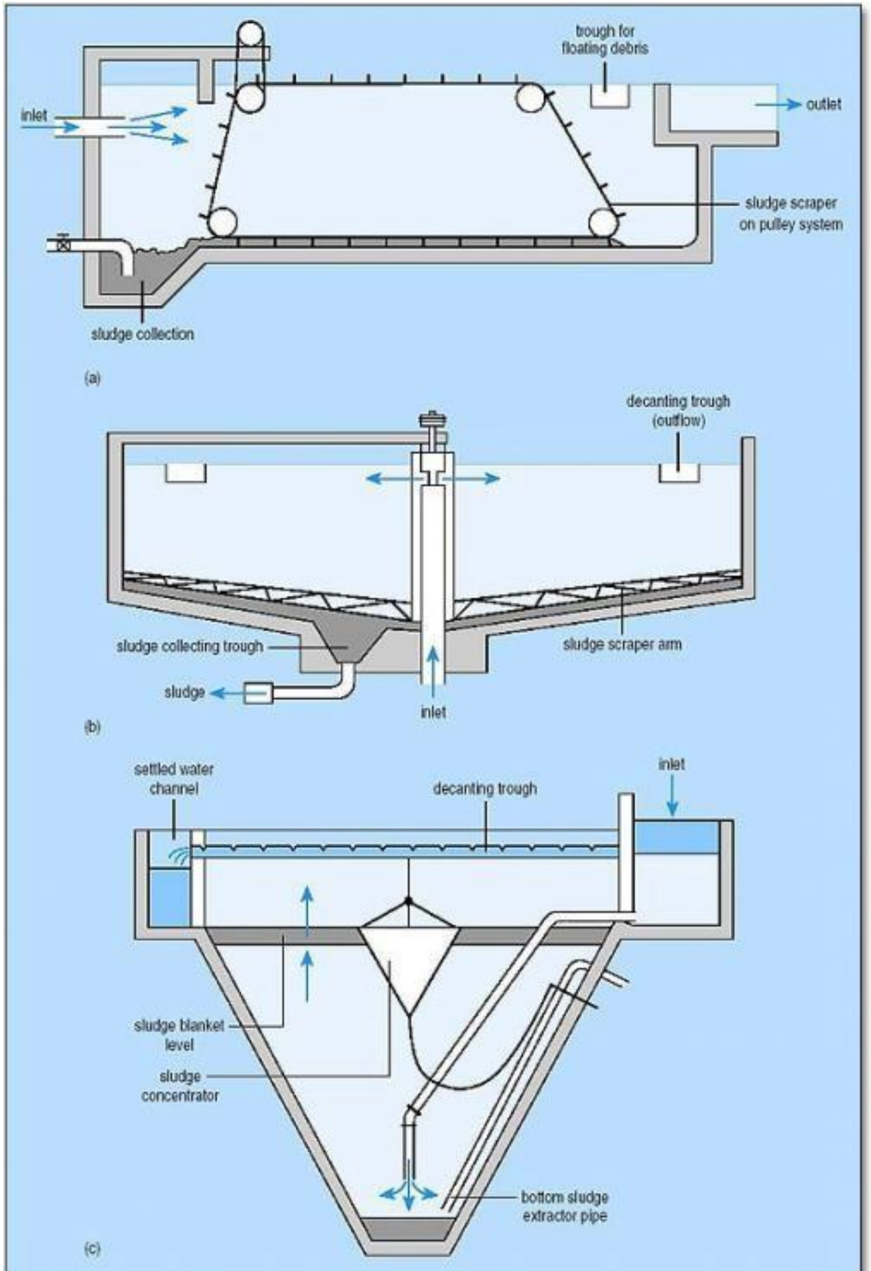
Contd…

- Primary sedimentation tanks or clarifiers may be round or rectangular basins, typically 3 to 5 m deep, with hydraulic retention time between 2 and 3 hours
- Settled solids (primary sludge) are normally removed from the bottom of tanks by sludge rakes that scrape the sludge to a central well from which it is pumped to sludge processing units
- Scum is swept across the tank surface by water jets or mechanical means from which it is also pumped to sludge processing units

Sedimentation

- Once the larger and smaller objects and grit have been removed the rest of the suspended materials are removed using gravity in large sedimentation tanks. These tanks can be either circular or square, depending on what matters more to those designing them. Circular tanks can have diameters anywhere from 3 to 90 meters across, and simpler to design and are more energy efficient. Square tanks size varies from 15 to 100 meters in length and 3 to 24 meters in width, and are favored by those with space constraints.

Sedimentation tank and clarifiers



<u>Typical sedimentation tanks:</u>

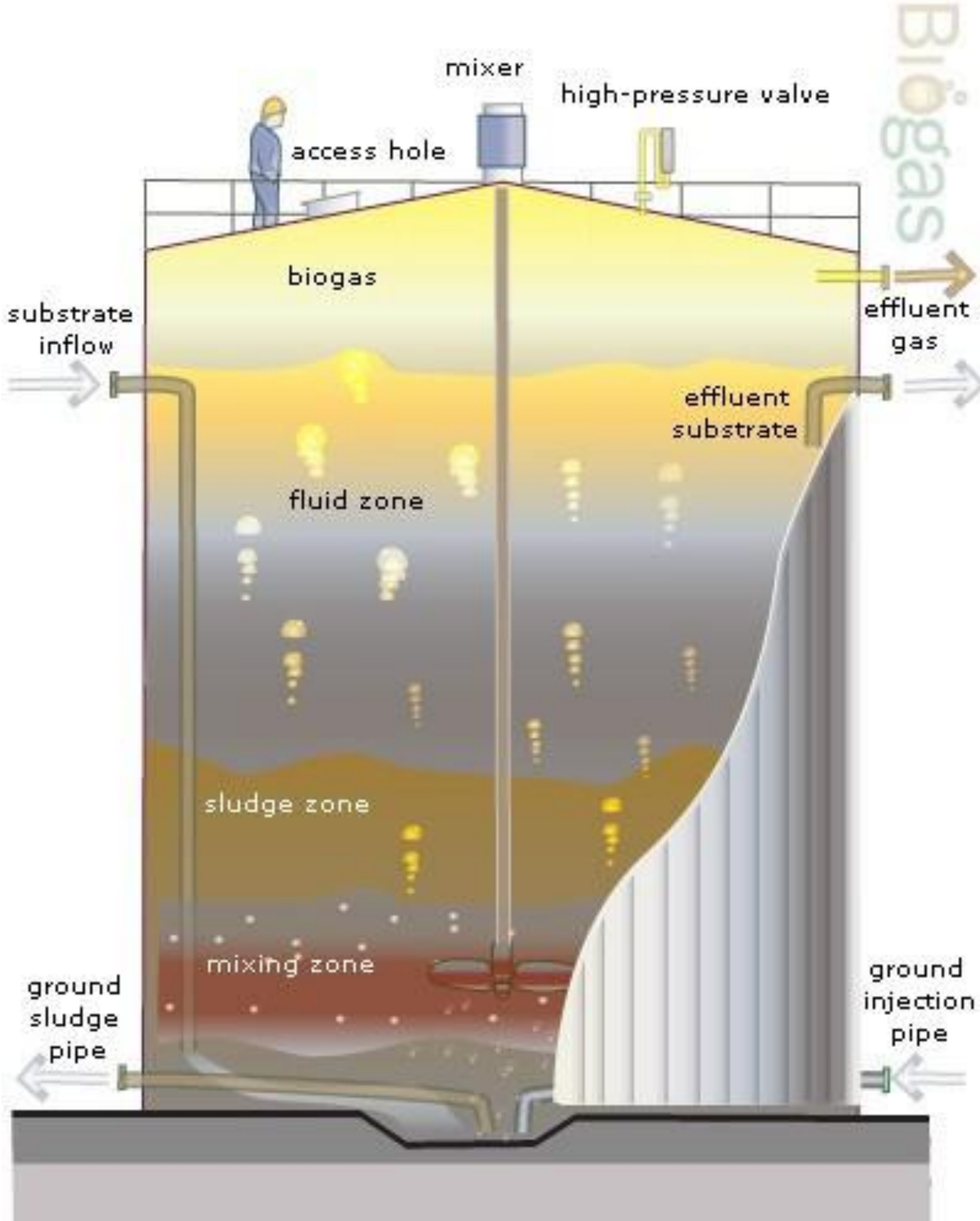
(a)rectangular horizontal flow tank;

(b)circular, radial-flow tank;

(c) hopper-bottomed, upward flow tank

- In large sewage treatment plants (> 7600 m^3/d), primary sludge is most commonly processed biologically by anaerobic digestion
- In the digestion process, anaerobic and facultative bacteria metabolize the organic material in sludge, thereby reducing the volume requiring ultimate disposal, making the sludge stable (nonputrescible) and improving its dewatering characteristics
- Digestion is carried out in covered tanks (anaerobic digesters), typically 7 to 14 m deep
- The residence time in a digester may vary from a minimum of about 10 days for high-rate digesters (well-mixed and heated) to 60 days or more in standard-rate digesters
- Gas containing about 60 to 65% methane is produced during digestion and can be recovered as an energy source
- In small sewage treatment plants, sludge is processed in a variety of ways including: aerobic digestion, storage in sludge lagoons, direct application to sludge drying beds, in-process storage (as in stabilization ponds), and land application.

Anaerobic Digester



SECONDARY WASTE WATER TREATMENT

SECONDARY TREATMENT

- The primary effluent is passed into large aeration tanks where it is constantly agitated which allows vigorous growth of useful aerobic microbes into flocs.
- Flocs are the masses of bacteria associated with fungal filaments to form mesh like structures.
- While growing, the microbes significantly reduces the **BOD (biochemical oxygen demand)** which is the amount of oxygen required to oxidize total organic matter in the effluent.
- The BOD test measures the rate of uptake of oxygen by micro-organisms, the greater the BOD of waste water, more is its polluting potential.

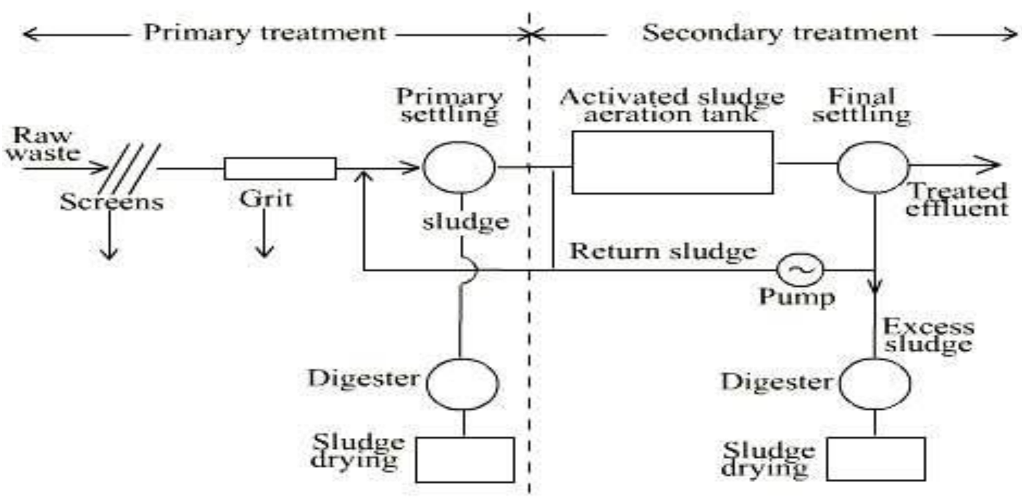
SECONDARY TREATMENT.....

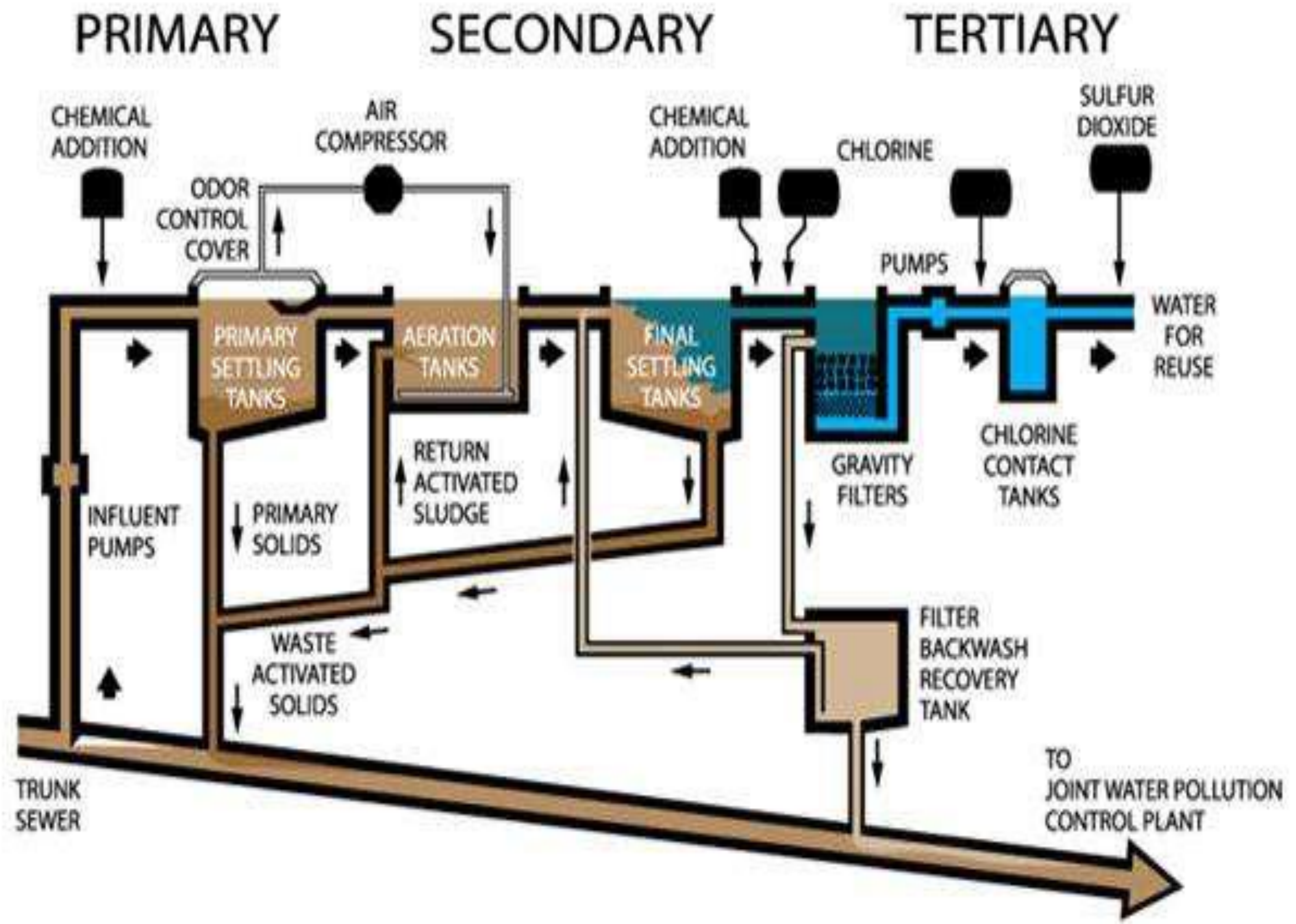
- Secondary treatment involves biological treatment called the activated sludge process.
- Waste water mixed with bacteria laden sludge and oxygen which allow the bacteria to break down organic matter.
- The water is passed into a sedimentation tank where the activated sludge is collected and removed.

ACTIVATED SLUDGE

Activated sludge is a process for treating sewage and industrial wastewaters using air and a biological floc composed of bacteria and protozoa.

Flow sheet of an activated sludge system





PRIMARY
SECONDARY
TERTIARY
CHEMICAL ADDITION
AIR COMPRESSOR
ODOR CONTROL COVER
CHEMICAL ADDITION
CHLORINE
SULFUR DIOXIDE
PUMPS
PRIMARY SETTLING TANKS
AERATION TANKS
FINAL SETTLING TANKS
WATER FOR REUSE
GRAVITY FILTERS
CHLORINE CONTACT TANKS
RETURN ACTIVATED SLUDGE
INFLUENT PUMPS
PRIMARY SOLIDS
WASTE ACTIVATED SOLIDS
FILTER BACKWASH RECOVERY TANK
TRUNK SEWER
TO JOINT WATER POLLUTION CONTROL PLANT

Why Tertiary Treatment?

To remove:

1. Totally suspended solids and organic matter
2. Specific Organic and inorganic constituents from industrial effluent
3. Pathogens from secondary treated effluents
4. To make water suitable for land applications
5. To reduce Totally dissolved Solids (TDS) from secondary treated effluent.

To further improve the effluent quality before it is discharged to the receiving environment

Methods used in TertiaryTreatment

- The final stage of the treatment involves:
- 1. Biological Process
-     1.1 Nitrogen Reduction
-     1.2 Phosphorus Reduction
- 2. Physio-Chemical Process
-     2.1 Sand filters
-     2.2 Chemical Addition

- 3. Disinfection (Removal of pathogens)
-     3.1 Chlorination
-     3.2 Ultra violet radiation
-     3.3 Ozone treatment

TO Remove:

- **Ammonia**

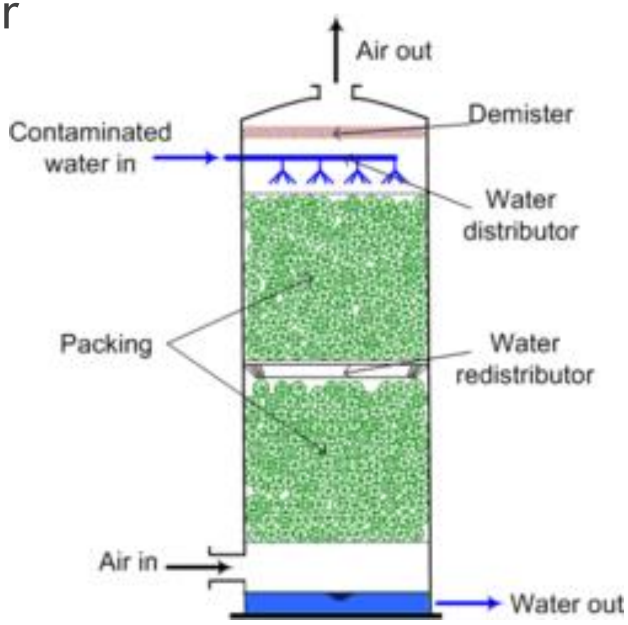
1) Air Stripping
2) Biological Nitrification and Denitrification

Air Stripping

To remove: Volatile compounds

- **Air stripping** is the transferring of volatile components of a liquid into an air stream.

1. Ammonia → Vapour Phase
2. Released into air



Note: Volatile compounds have relatively high vapor pressure and low aqueous solubility

1) Nitrification

Conversion to Nitrate

Biological Nitrification

Conversion of Ammonia to Nitrite *(Nitrosomonas)*

$NH_4^+ + 2\ O_2 \rightarrow NO_2^- + 2\ H^+ + H_2O$

Conversion of Nitrite to Nitrate *(Nitrobacter)*

$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$

2) Denitrification

Conversion to N_2 gas

Biological Denitrification

- Denitrifying bacteria obtain energy from the conversion of NO_3^- to N_2 *gas*, but <u>require a carbon source</u>

$$NO_3^- + CH_3OH + H_2CO_3 \rightarrow C_5H_7O_2N + N_2 + H_2O + HCO_3^-$$

Organic matter *Cell mass*

Precipitation

To remove: Heavy metals

- The precipitates are to be removed from the treated water by settling and or filtration.

1. Precipitated as Hydroxides ($CaO/Ca(OH)_2$
2. Sulphide Precipitates (H_2S or Na_2S) : Barium may be removed as $BaSO_4$

Removal of Calcium: $Ca^{2+} + Na_2CO_3 \longrightarrow CaCO_3 + Na^{2+}$

Note: Can't remove light metals like Sodium and Potassium

Ion Exchange

To remove: Soluble compounds

- Nitrates(NO_3^-) are highly soluble in water – cannot be removed by precipitation
- Ion exchange is used to remove nitrates from waste water

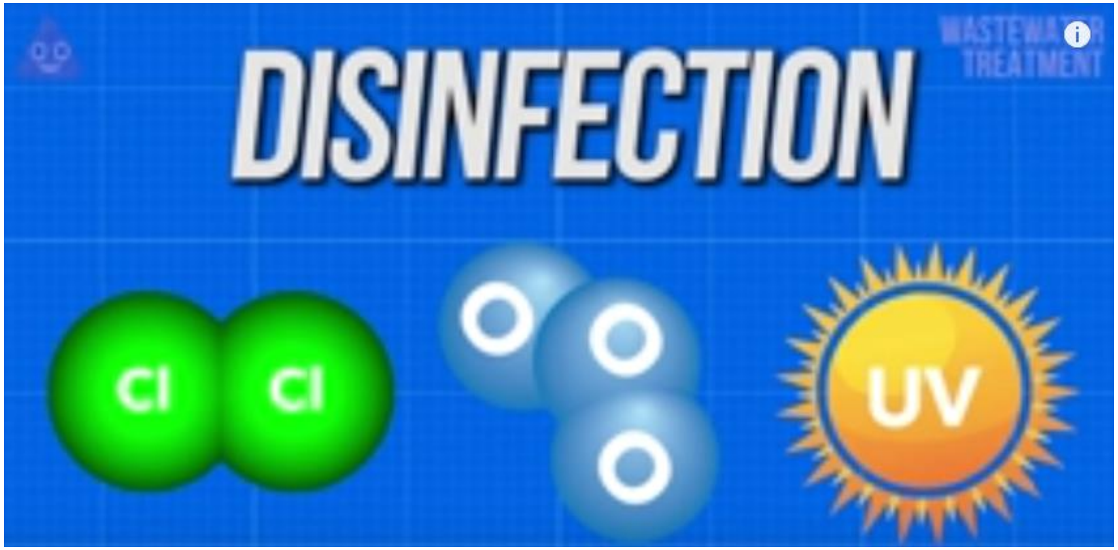
$$X\text{-}OH^- + NO_3 \longrightarrow X\text{-} NO_3^- + OH^-$$

- The ion exchangers may be natural or synthetic zeolite(aluminosilicate)
- Eg: **Anion Exhangers:** $CaCl_2$, $MgCl_2$, $FeCl_2$

  Cation Exhangers: Na^+

TO Remove:

Pathogens Such as Viruses and Bacteria

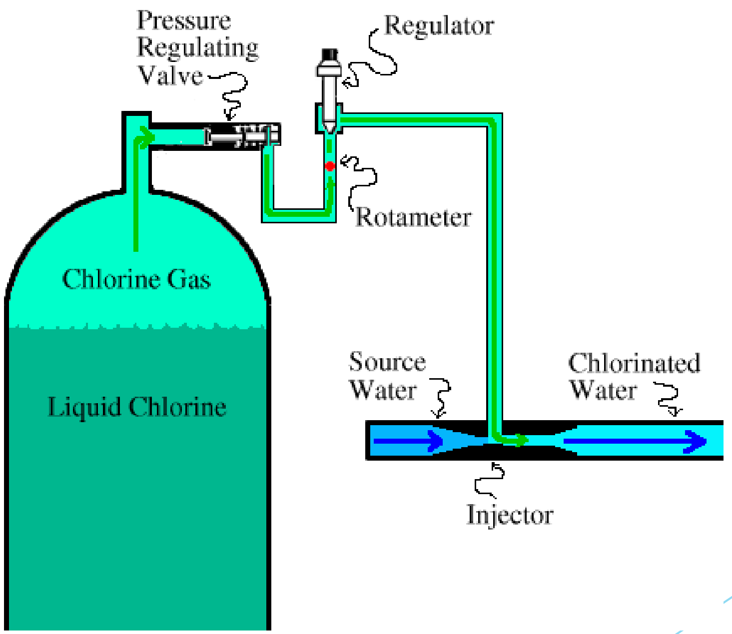


Chlorination

To remove: Airborne pathogens

When dissolved in water, chlorine converts to an equilibrium mixture of chlorine, **hypochlorous acid** (HOCl), and **hydrochloric acid** (HCl):

$Cl_2 + H_2O \rightleftharpoons HOCl + HCl$



Note: Water is acidified

Ozone treatment

To remove: Pathogens

- The precipitates are to be removed from the treated water by settling and or filtration.

Ozone treatment

To remove: Pathogens

- **The advantages of using ozone as a disinfectant are:**
- (i) Its high germicidal ability,
- (ii) Its ability to oxidize most odorous and colouring substances, and
- (iii) It leaves behind only dissolved oxygen after treatment.

- **Its major disadvantages are:**
- (i) It has to be produced at the site:
- (ii) It cannot be stored and transported;
- (iii) Its relatively higher cost (compared to chlorine), and
- (iv) Its inability to maintain germicidal action beyond the treatment unit.

UV Radiation

To sterilize: Bacteria

Ultraviolet water purification is the most effective method for disinfecting bacteria from the **water**.

- **Ultraviolet Purification Advantages**
- 1. Chemical Free: UV purification does not use any chemicals like chlorine or leave any harmful by products.
- 2. Taste & Odor Free: UV does not add any chemical taste or odor to the water.
- 3. Extremely Effective: kill disease-causing microbes by destroying 99.99%.
- 4. Requires very little energy: Uses about the same energy as it would to run a 60 watt light bulb.
- 5. Low Maintenance: Set and forget type of system, just change UV bulb annually.

Note: Bacteria is sterilized and not killed

- .

Table 9.13 : Tertiary Treatment Methods and their Effectiveness

Treatment Methods	Capable of Removal
Filtration Air/Steam Stripping	Suspended solid particles Dissolved ammonia, volatile organic compounds (VOCs)
Adsorption	Dissolved organics including VOCs, colouring and odoriferous compounds.
Biological Processes	Nitrogenous and Phosphorous compounds.
Membrane separation process, such as, Micro filtration, Ultra filtration, Nanofiltration, Reverse Osmosis (RO).	Dissolved organics and inorganics.
Ion–exchange processes	Dissolved anions and cations.
Precipitation	Heavy metal ions and some other ionic substances.
Oxidation-Reduction	Organics and some inorganics.
Disinfection	Micro-organisms including virus.

TO refer:

- **How Do Wastewater Treatment Plants Work?** https://www.youtube.com/watch?v=FvPakzqM3h8