Suspended Growth Bio-Treatment : Activated Sludge Process for BOD Removal & Nitrification

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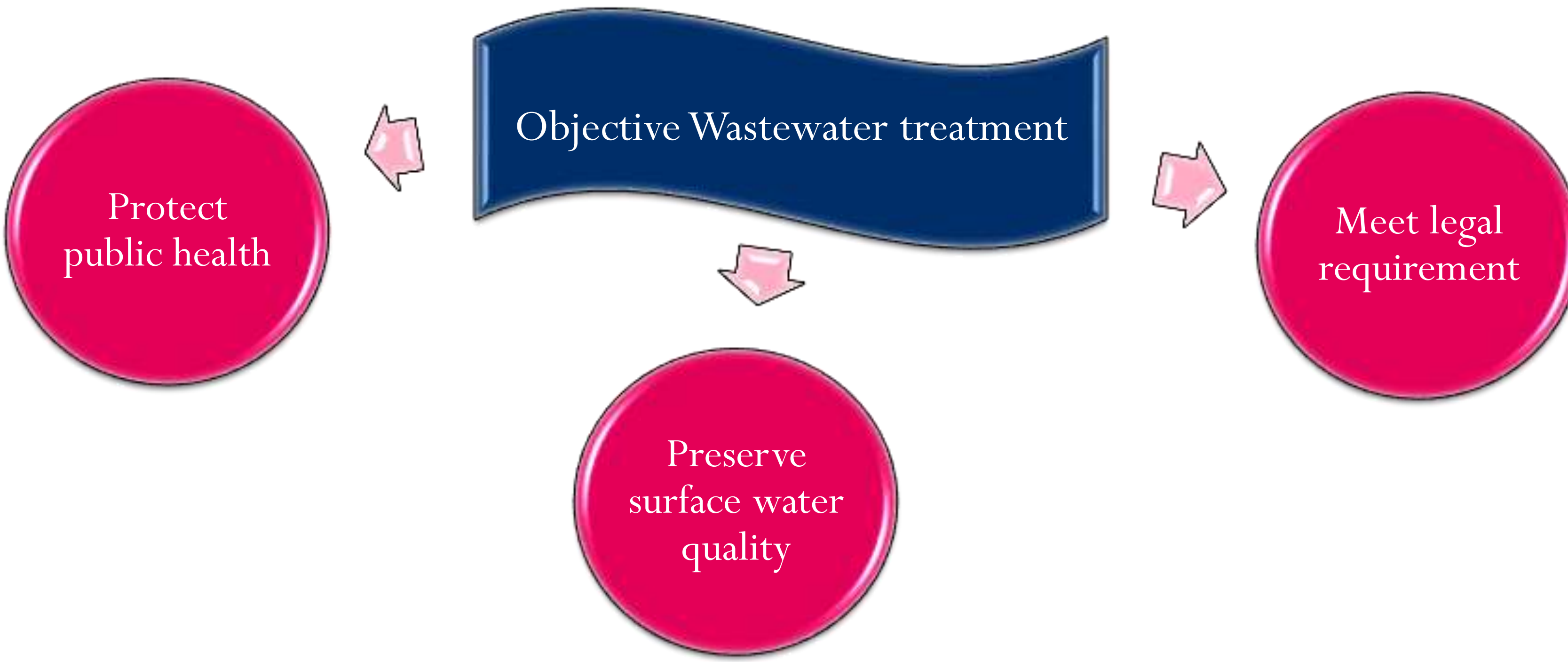
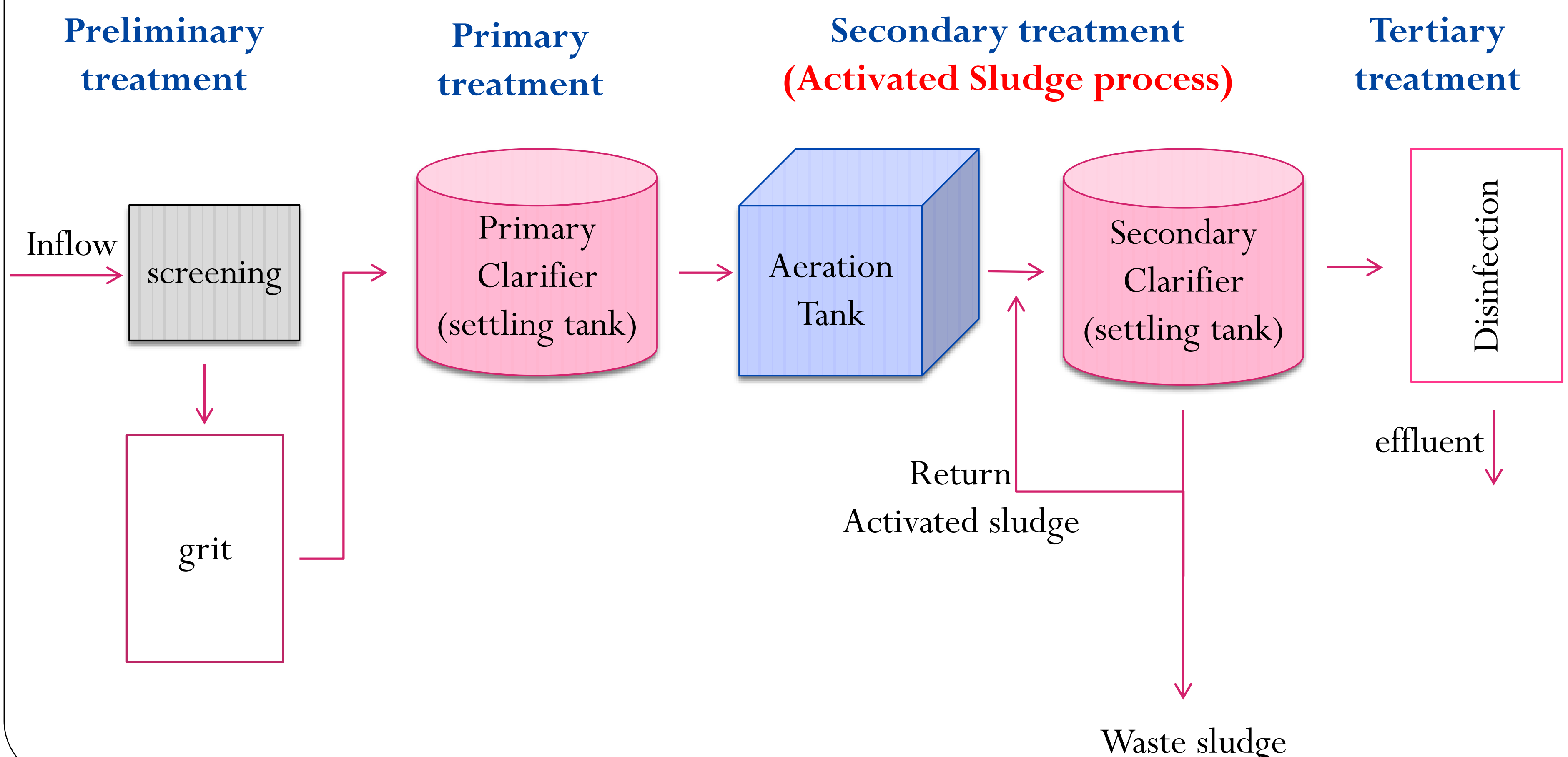
Wastewater

- Wastewater is sewage, storm water and water that has been used for various purpose around the community that has changes in nature and composition.



Wastewater Treatment Process



Activated Sludge Process

- Activated sludge is a sludge particles produced in WW by the growth of microorganism in aeration tank.

- Activated Sludge Process is a biological WW treatment process that uses microorganism to feed an organic contaminants in wastewater to produce high quality effluent for a reasonable operating and maintenance costs.

Activated Sludge Process

ADVANTAGES

Economical to produce high quality effluent

Low construction cost

Reasonable maintenance cost

Only require small land

Activated Sludge Process

Problem / Effect

Hydraulic overload

(High effluent TSS)

Poor primary clarification

(plugging, standing water, odors, reduced efficiency)

Nitrification

(High effluent TSS, High chlorine demand, Low pH)

Organic underload

(high energy use, nitrification)

Organic overload

(pass through of soluble BOD, odors, Low DO, poor effluent quality)

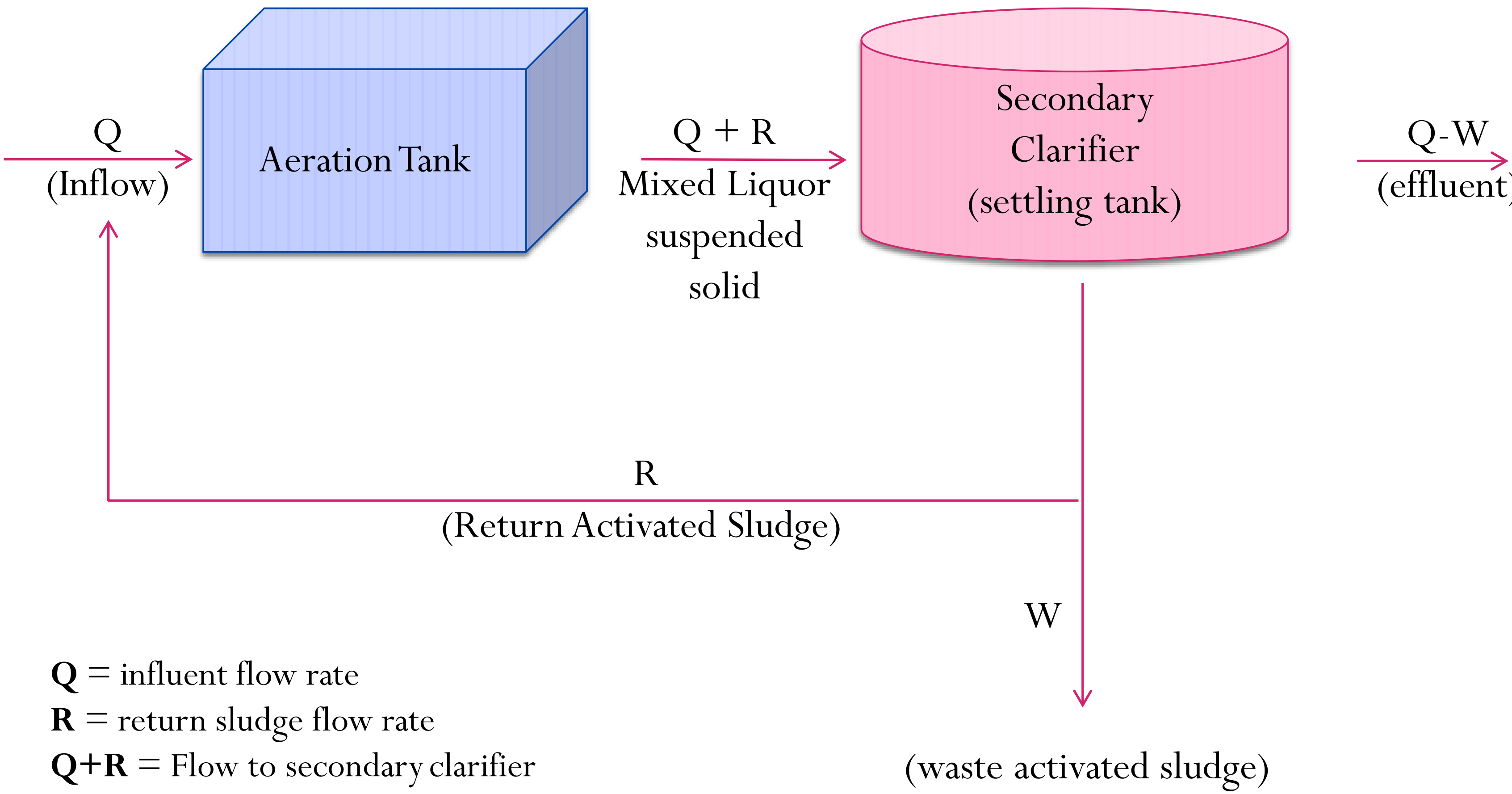
Nutrient shortage

(filamentous bacteria, rising sludge, pass through of soluble BOD)

Activated Sludge Process

Basic Activated Sludge Component	
Aeration tank	• Where the biological reactions occur
Aeration source	• Provides oxygen and mixing
Clarifier	• A tank when the solids settle and separated from treated wastewater
RAS (Return Activated Sludge)	• To return collecting solid to aeration tank
WAS (Waste Activated Sludge)	• To remove collecting solid from the process

Activated Sludge Process

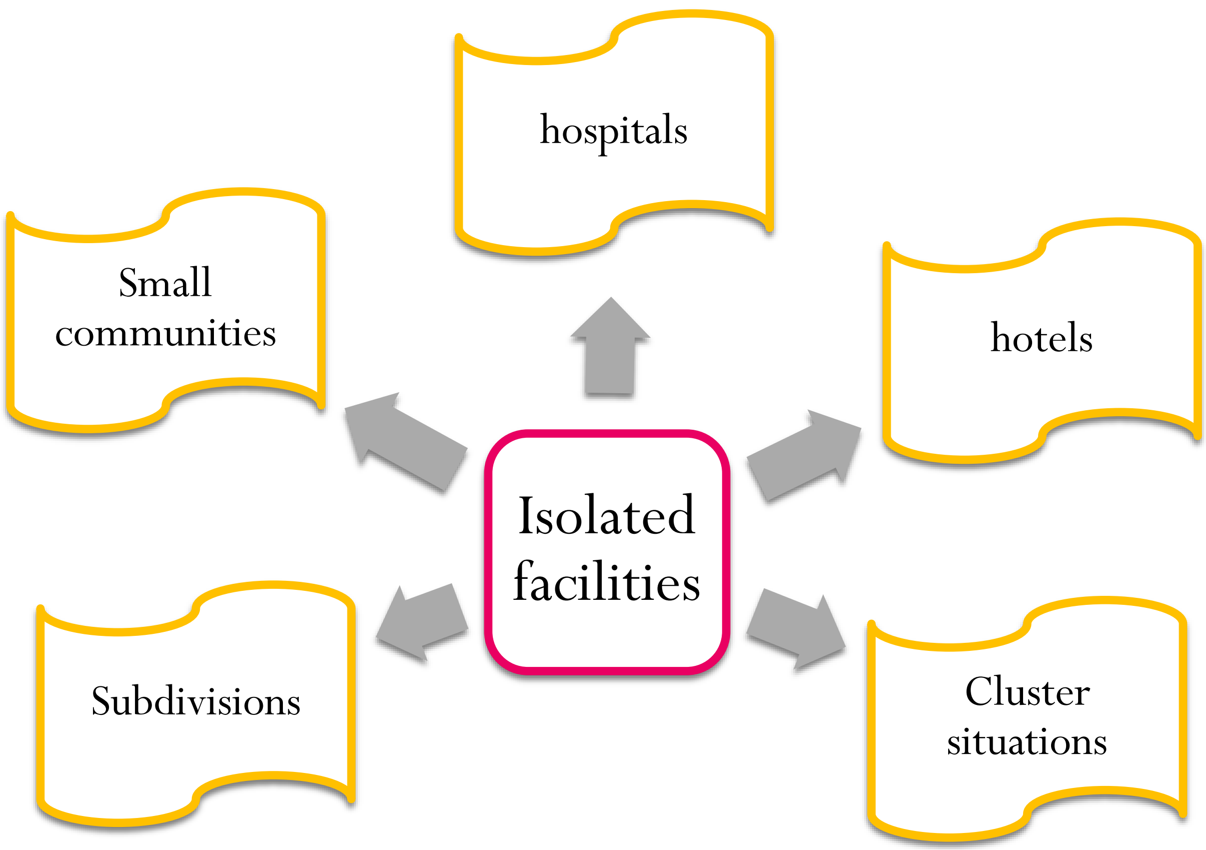


Q = influent flow rate
R = return sludge flow rate
Q+R = Flow to secondary clarifier
Q-W = effluent flow rate
W = waste sludge flow rate

Functions of Activated Sludge

- AS process is commonly used by large cities and communities due to economical reason where large volumes of WW need to be treated

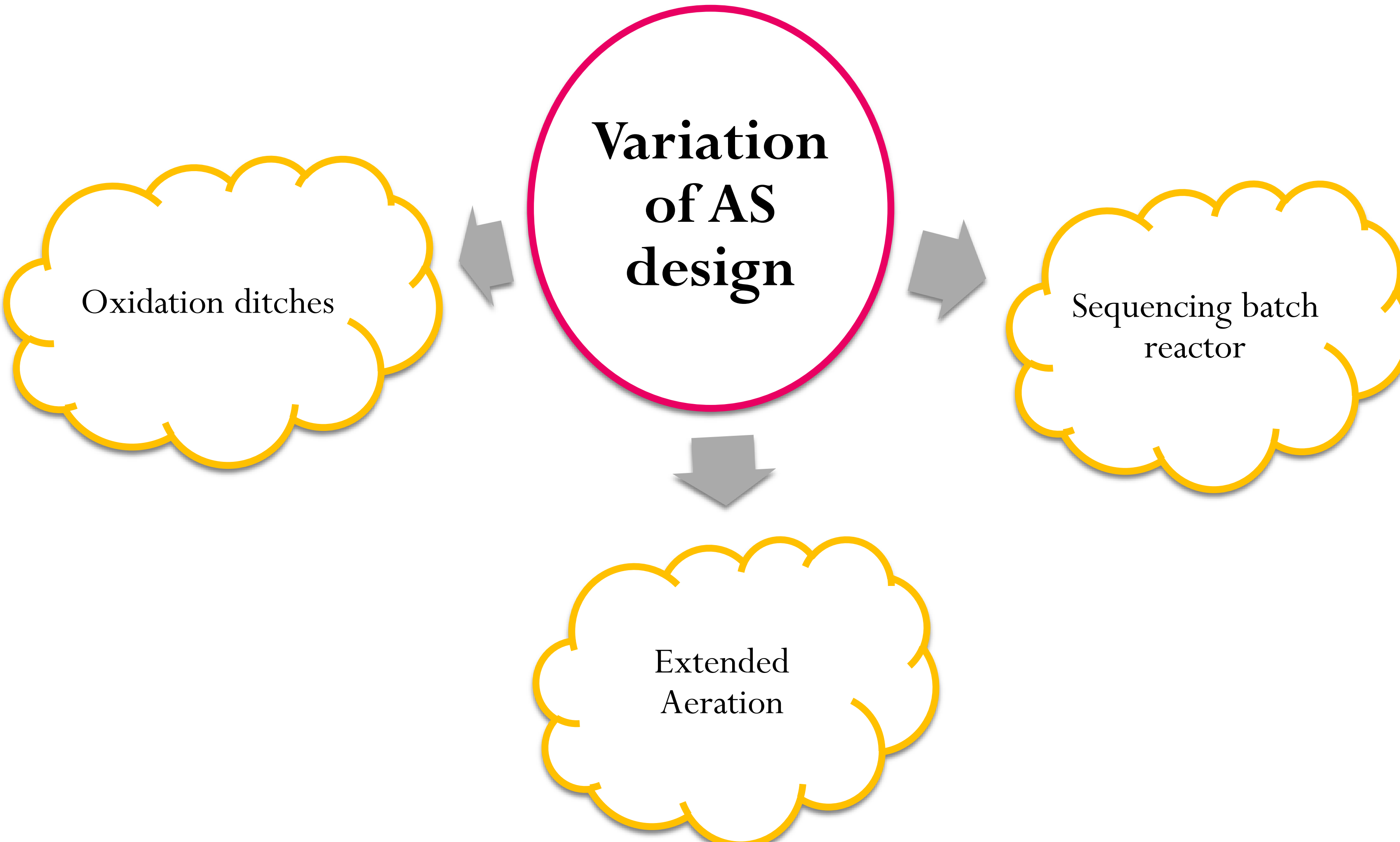
- AS process also been used in isolated facilities.



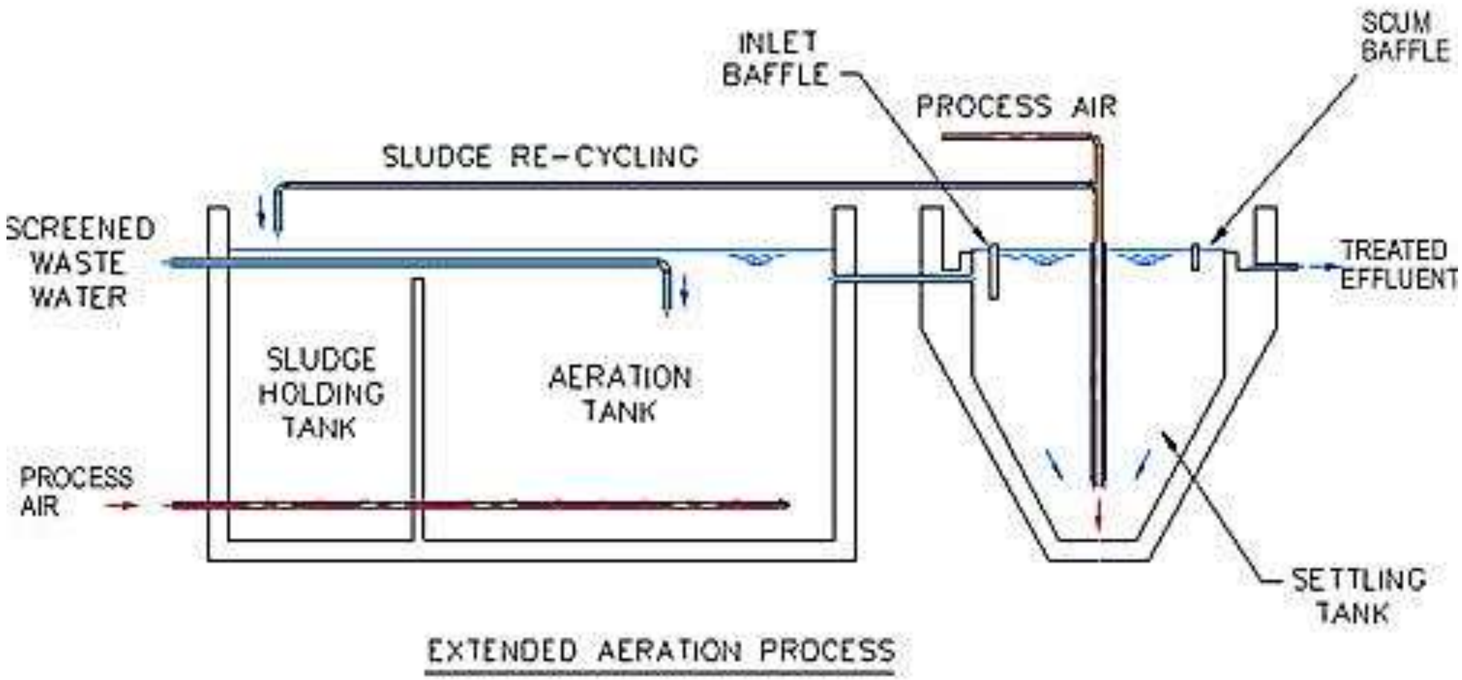
AS Design Considerations

- Internal factors
  - Reactors types
  - Process variations
  - Technology know-how
- External factors
  - Operation & maintenance costs and difficulties
  - Space limitations
  - Construction costs

Activated Sludge Technology



Extended Aeration Process

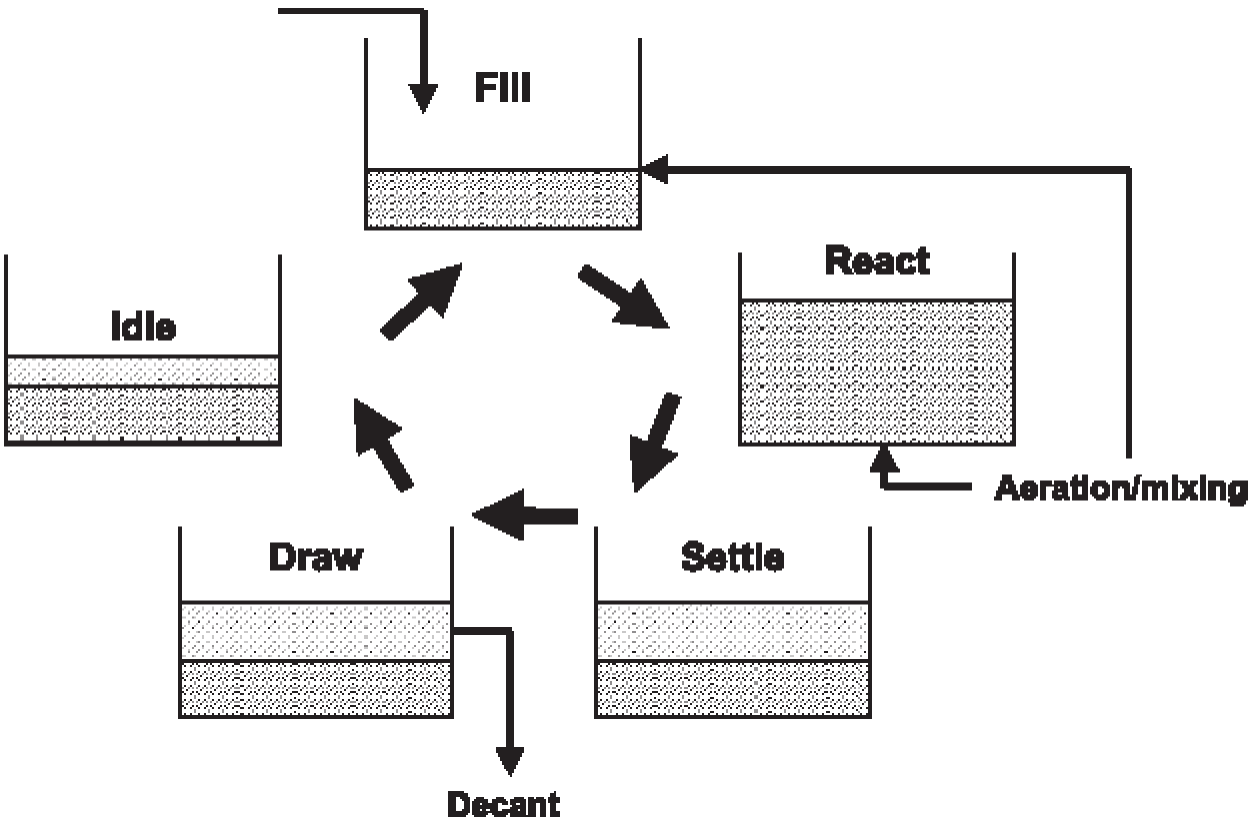


- http://water.me.vccs.edu/courses/ENV149/lesson17_print.htm

Extended Aeration Design

- Doesn’t use a primary clarifier.
- A longer detention time in the aeration tank.
- The aeration tank for an extended aeration process must be larger that conventional activated sludge process.
  - To give about 24 hours detention time (conventional AS process only 6 to 8 hours detention time)

Sequencing Batch Reactors (SBR) process



- http://web.deu.edu.tr/atiksu/ana07/epa02.html

Sequencing Batch Reactors (SBR) Design & Process

- SBRs is used to enhance removal of nitrogen, ammonia and phosphorus and also TSS and BOD.
- Equalization, aeration and clarification process are done in same tank.
- SBR consist of five common step carried out in sequence

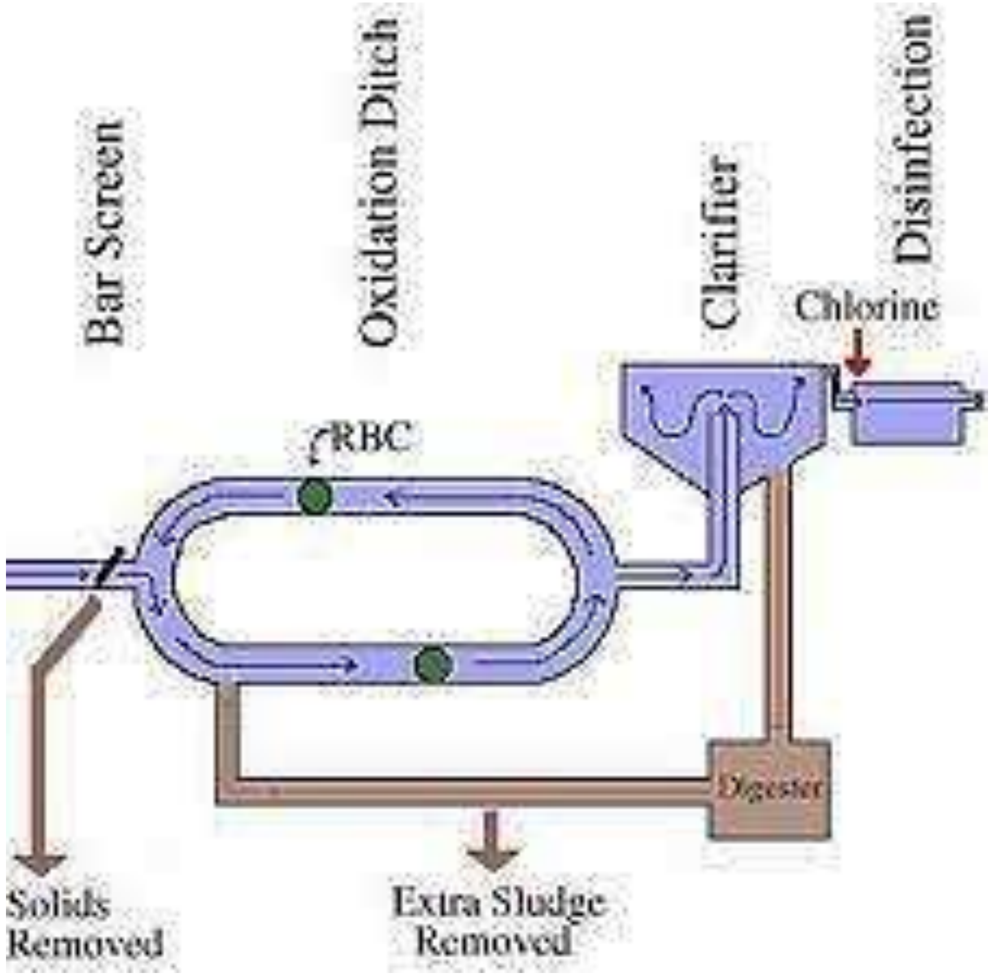
Fill → React (aeration) → Settle (sedimentation/ clarification) → Draw (the effluent is decanted) → Idle

Sequencing Batch Reactors (SBR)

System component	Suggested maintenance tasks
Reaction tank	Check for foaming and uneven air distribution; check for floating scum; check decanter operation and adjust cycle time sequences as required to achieved effluent target concentrations; check settled sludge volume and adjust waste pumping to maintain target MLVSS levels.
Aeration system diffused air	Check air filters, seals, oil level, and backpressure; perform manufacturer's required maintenance.
Aeration system mechanical	Check for vibrations and overheating; check oil level and seals; perform manufacture's required maintenance.
septic tank (primary clarifier)	Check for accumulated solids and order pumping if required.
Controls	Check functions of all controls and alarms; check electrical control box.
Sludge wasting	Pump waste solids as required to maintain target MLVSS range (typically 500 to 4 000 mg/L)
Analytical	Measure aeration tank grab sample for MLVSS, pH and setteability; collect final effluent decant composite sample and analyze for water quality parameters as required (BOD, TSS. pH, N, P)

Source: http://web.deu.edu.tr/atiksu/ana07/epa02.html

Oxidation Ditches process



Source : http://water.me.vccs.edu/concepts/oxidation.html

Oxidation Ditches Design & Process

- Oxidation ditch (OD) is a circular basin which the wastewater flows.
- OD consist of a ring or oval shape channel equipped with mechanical aeration devices (brush rotors or disk aerators)
- OD replaces the aeration basin and provides better sludge treatment.
- Bar screen is the only typical pretreatment used. Wastewater that passing through bar screen flows directly into OD.
- AS is added to OD (microorganisms will digest BOD in the water)
- Oxygen is added to mixed liquor by using rotating biological contactors (RBC's)
- After removing BOD from WW, the mixed liquor flows out from OD.
- Sludge is removed in clarifier.

Activated Sludge Design

Type	Advantages	Disadvantages
Extended aeration	▪ Easy to operate ▪ Easy to install ▪ Odor free ▪ Small footprint ▪ Low sludge yield	▪ Unable to achieve denitrification or phosphorus removal ▪ Limited flexibility in response to changing effluent requirements ▪ Large energy requirement
SBRs	▪ Able to achieve nitrification, denitrification, and phosphorous removal ▪ Large operation flexibility ▪ Minimal sludge bulking ▪ Few operation and maintenance problems ▪ Able to be operated remotely	▪ High energy consumption ▪ Difficult to adjust cycle times for small communities ▪ Frequent sludge disposal
Oxidation ditches	▪ Moderate energy requirements ▪ Unaffected by weather ▪ Provides high quality effluent in terms of TSS, BOD and ammonia ▪ Low sludge yields ▪ Capable of handling shock	▪ Noisy and odiferous if not operated correctly ▪ Unable to treat toxic waste streams ▪ Relatively large footprint

Sources : National Small Flows Clearinghouse. (2003). Explaining the Activated Sludge Process. *Spring*, Vol. 14. No.2. pg 6 (800) 624-8301. pg 6

BOD REMOVAL

Introduction of BOD

- Aerobic bacteria use organic matter in wastewater as ‘food’ in the presence of free oxygen.
- The ‘food’ available in wastewater is estimated by using BOD test.
- More dissolved oxygen (DO) is required if there is more ‘food’ present in waste.
- BOD test measures the strength of wastewater.

What is BOD??

- Amount of oxygen required by the micro-organisms to stabilize biodegradable organic matter under aerobic conditions.
- Quantity of dissolved oxygen in mg/L required by microorganisms for oxidation of carbonaceous biodegradable organic matter present in liquid.

BOD stages

- **First stage BOD**: measure of carbonaceous bio-degradable organic fraction and ultimate BOD.
- **Second stage BOD**: measure of oxygen consumption for nitrogenous portion of biodegradable organic matter.

Why we need to test BOD??

- To measure the extent to which a wastewater discharge will impact the dissolved oxygen concentration in a receiving stream.
- Measure oxygen consuming organic matter by measure the disappearance of oxygen from a bottle containing oxygen saturated water.
- To determine the oxygen requirements of wastewater.

Why we need to test BOD??

- Measurements of oxygen performed after 5 days of incubation to determine:
    1. The biochemical degradation of organic (carbonaceous demand)
    2. Oxygen used to oxidize inorganic materials (sulfides and ferrous iron)
    3. The reduced nitrogen
- To balance the influent wastewater BOD load and mass of micro-organisms, F/M ratio.
- The difference between initial and final dissolved oxygen (DO).

Determination of BOD

- Measure the initial DO concentration in diluted sample and final DO concentration after 5 days incubation at 20°C.
- The difference is assumed to be the DO consumed by microorganism in 5 days.
- Thus we can measure the BOD_5
- It also can be determined at any desired temperature and incubation period.
- However, BOD parameter does not provide information about amount of non biodegradable organic contents.

Food to microorganisms ratio (F/M)

- ✓ Sludge loading rate / organic loading rate.
- ✓ F is on BOD basis but often on COD basis.
- ✓ M fraction under aeration.
- ✓ F/M ratio is directly proportional to waste rate.
- ✓ A low ratio indicates the microbes are starving (mineralization).
- ✓ High sludge production resulted from high F/M ratio.

Measure Carbonaceous BOD

Microorganisms use carbon compound as food source, Carb. BOD

Carb. BOD is metabolized by micro- organisms lowering the Carb. BOD in effluent

Percent of Carb. BOD removal achieved by comparing influent and effluent Carb. BOD

Low Carb. BOD in effluent must be maintained

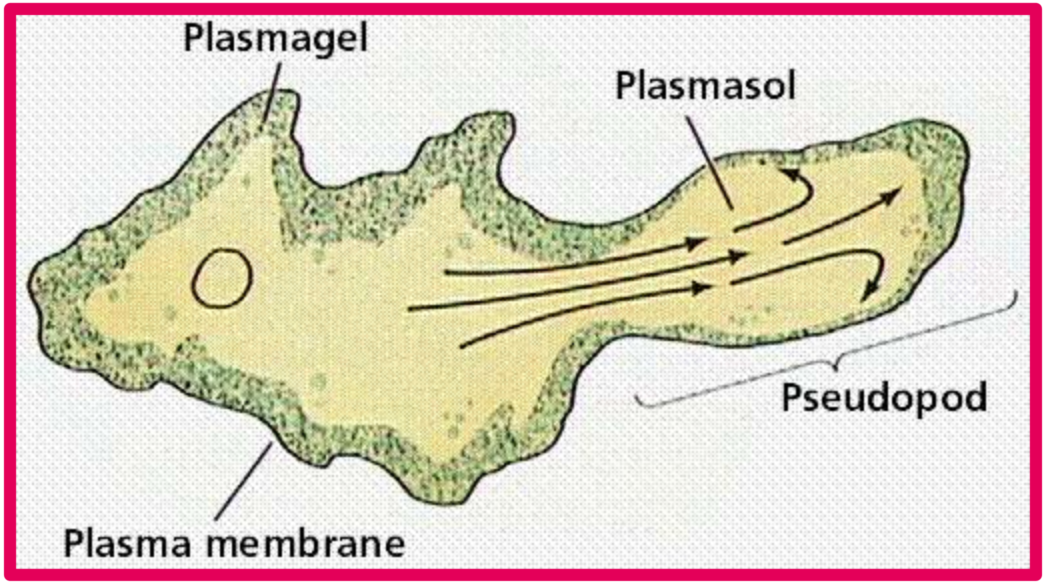
Divides the influent BOD by the mass of microorganisms, F/M ratio

Activated Sludge Microorganisms

- Most of BOD reduction is a result of activity of aerobic bacteria.
- 5 categories of microorganisms:
    a) Amoeboid
    b) Flagellates
    c) Free swimming ciliates
    d) Stalked ciliates
    e) Rotifers
- Predominance of one/more of these groups over the others give indication of the age and condition of sludge.

Amoeboid

- A single celled organism that is the first to develop in sludge
- Found in sludge regardless of sludge age
- If they are predominant the sludge is very young

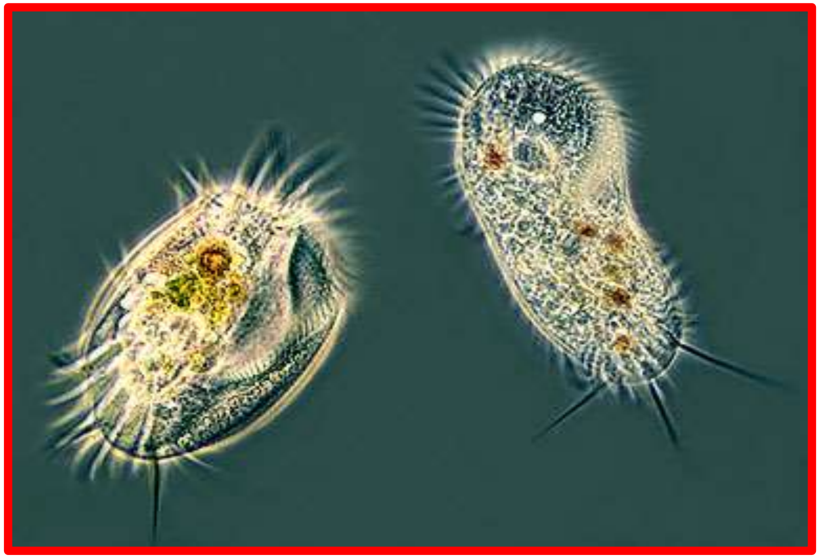


Flagellates

- A large single cell body with a whip like appendage called a flagellum.
- Are predominant with amoeboid when sludge is very young.
- Number of flagellates decreasing as the sludge age increased.

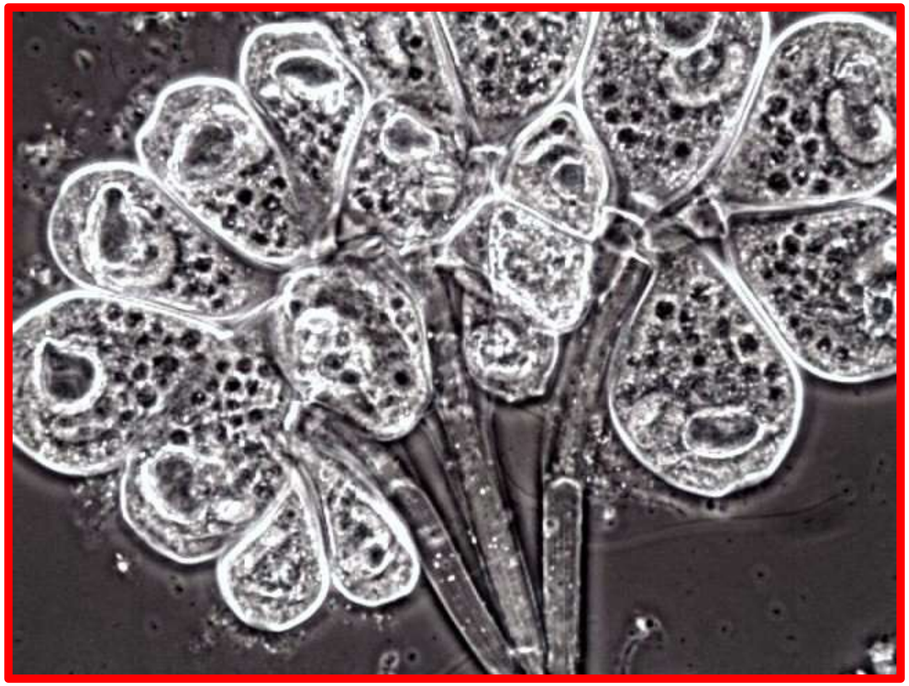
Free swimming ciliates

- Are small oval shaped with tiny hairs or also called as cilia.
- Cilia move in a wave-like motion to propel them in water and bring in food.
- Numbers increase as sludge reaches maturity and achieves its peak settle ability.
- But numbers drop off as the sludge age continues to increase.



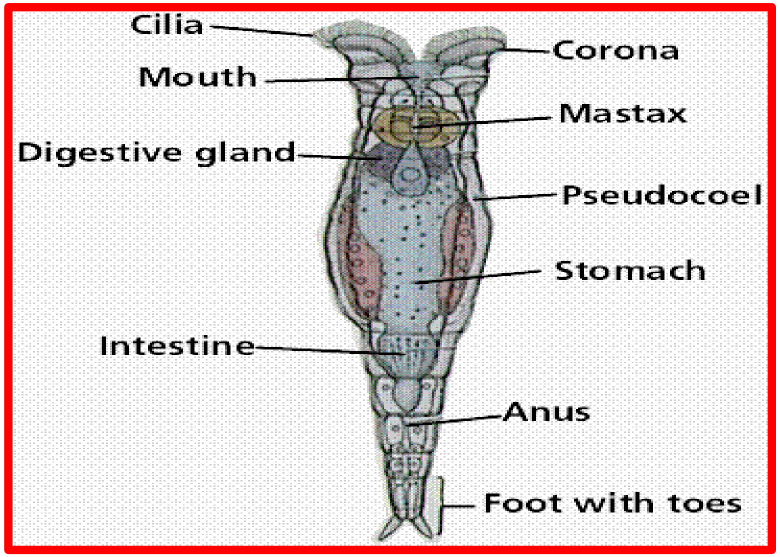
Stalked ciliates

- Look like a cluster of flowers attached to a sludge particle.
- Have cilia at ‘mouth’ to bring in the food.
- Predominant in good settling sludge and decline as sludge ages.



Rotifiers

- The most complex organisms of the group.
- Have 9 cells and are larger than other organisms.
- Have long telescoping body and move like a caterpillar; move by attaching to a particle and stretching out to another one.
- First seen is sludge as straggler floc disappears.
- Numbers continue to increase as the age of sludge increasing.
- Predominant in old sludge.



NITRIFICATION

WHAT IS NITRIFICATION?

- A biological process which nitrifying bacteria convert nitrogen in the form of ammonia (NH_3) into nitrite (NO_2^-) and nitrate ($N0_3^-$) in aerobic conditions.

- A biological oxidation between ammonia to nitrate which nitrite act as intermediate.

- Naturally occurs in lakes, rivers and stream.

- The process occurs when microorganisms combined with bio-degradable organic matter, dissolved oxygen (DO) which conversion between ammonia-nitrogen, nitrite-nitrogen and nitrate-nitrogen.

- The bacteria involved known as ‘nitrifiers’ or ‘aerobes’.

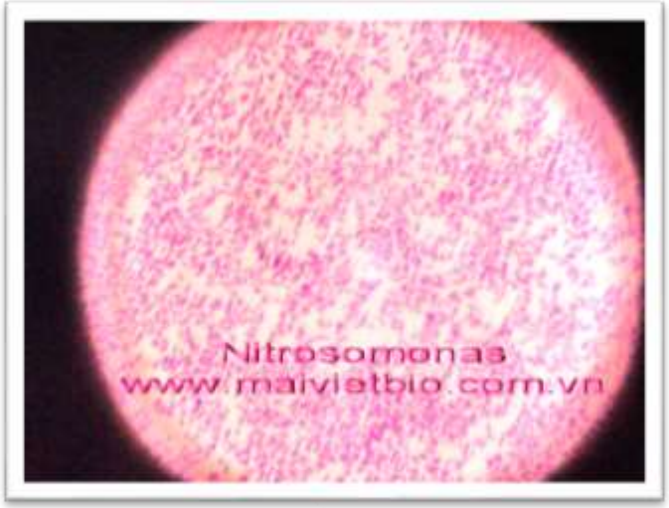
Microorganisms Involved in Nitrification

Nirosomonas

- $NH_4^+ \longrightarrow NO_2^-$

Nitrobacter

- $NO_2^- \longrightarrow NO_3^-$



Scientific name: Nitrosomonas
Rank: Genus

Source: http://www.maivietbio.com.vn/upload/453610202Nitrosomonas.jpg

Scientific name: Nitrobacter
Rank: Genus

Source: http://www.squidoo.com/nitrobacter

Process Involved in Nitrification

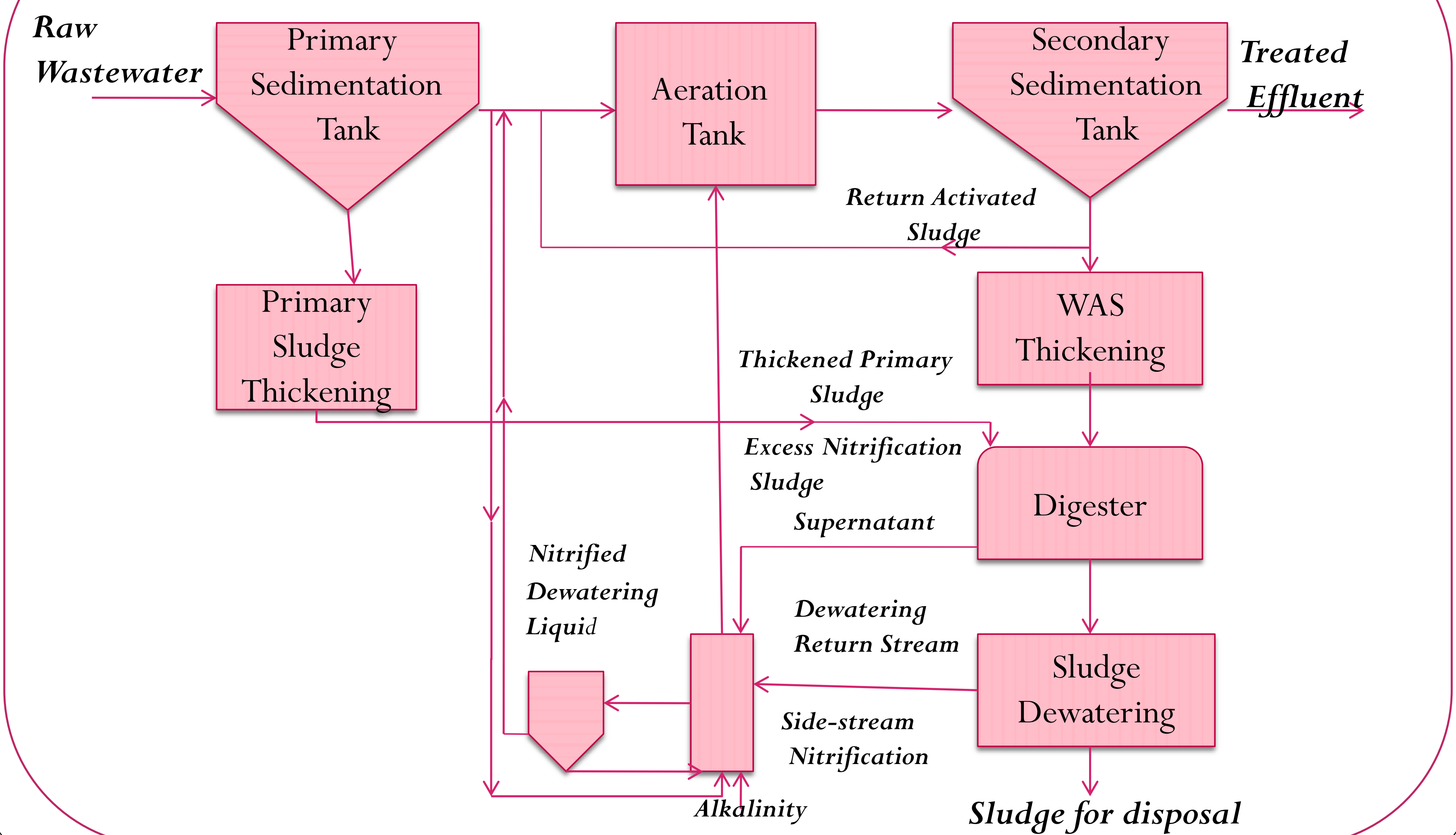
Energy

- $NH_4^+ + 1.5O_2 \rightarrow NO_2^- + H_20 + 2H^+$ (240-350 kJ)
- $NO_2^- + 0.5O_2 \rightarrow NO_3^- +$ (65-90kJ)

Assimilation

- $15CO_2 + 13NH_4^+ \longrightarrow 10NO_2^- + 3C_5H_7NO_2 + 23H^+ 4H_20$
- $5CO_2 + NH_4^+ 10NO_2^- + 2H_2O \longrightarrow 10NO_3^- + C_5H_7NO_2 + H^+$

With Plant Sludge Treatment



Aeration tank: Nitrification

↓

Mixed Liquour Suspended Solids (MLSS) transferred to the tanks; allowed to settle by gravity leaving a clear liquid (secondary effluent)

↓

Return MLSS from secondary clarifier tanks to the front of the aeration tanks (Return Activated Sludge or RAS)

↓

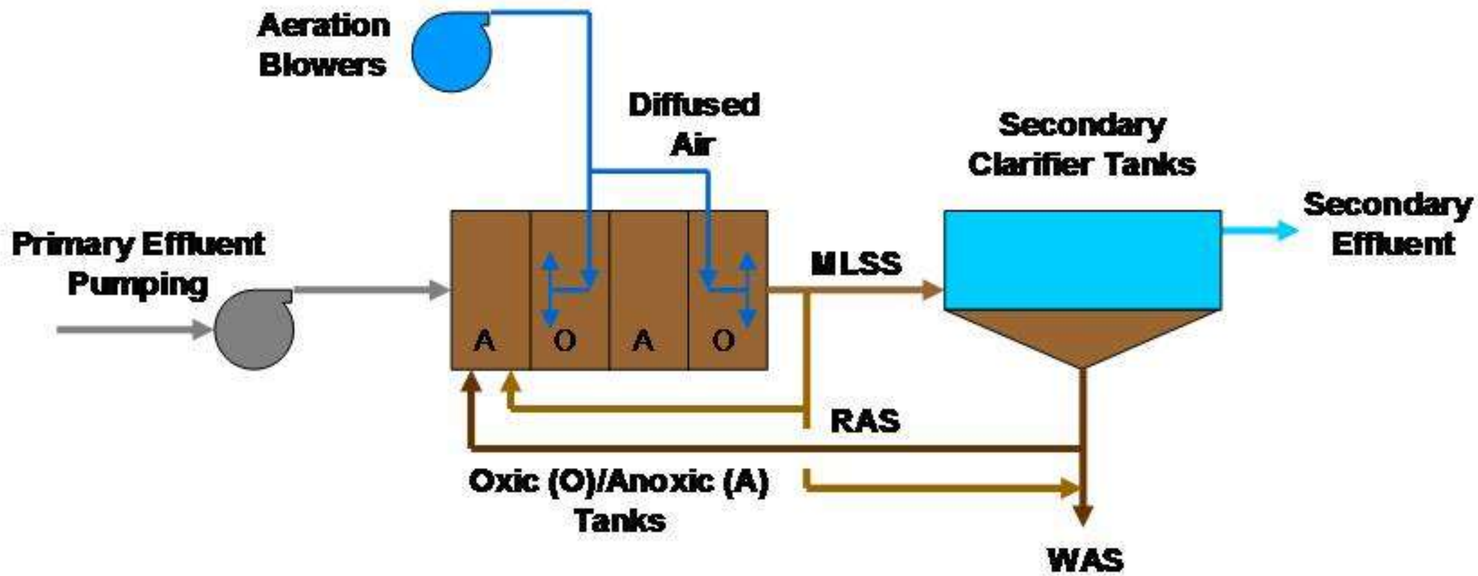
WAS (Waste Activated Sludge): MLSS or RAS is wasted from the activated sludge process.

↓

The supplemental nitrifiers are grown in separate small side stream aeration tank using: ammonia (digested sludge dewatering liquid & in the digester tank or commercial ammonia)

↓

The resulting biological sludge is continuosly and periodically discharged into the main aeration tank; provide the main activated sludge process with suplemental nirifiers.



BNR Secondary Treatment – Activated Sludge Process
With Nitrification (O) & De-nitrification (A)

Source: http://www.ieua.org./facilities/img/cc-bnr%20process.jpg

** Occurs in specific zones: Oxic (free DO) and Anoxic (devoid of free DO)*

Factor Affecting Nitrification

- Temperature
- Substrate concentration
- Dissolved oxygen (DO)
- pH
- Toxic & inhibitory substance

- Optimum pH for microorganisms: 7.5 (Nitrosomonas) & 8.5 (Nitrobacter)

- Temperature: between 30°C and 35°C (86°F and 95°F)

- Toxic compounds to nitrifiers: cyanide, thiourea, phenol and heavy metal.

  so; nitrous acid and free ammonia can inhibit nitrifying bacteria.

- Occurs only at DO level of 1.0 mg/L or more.

- Alkalinity required not less than 50-100 mg/L.

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