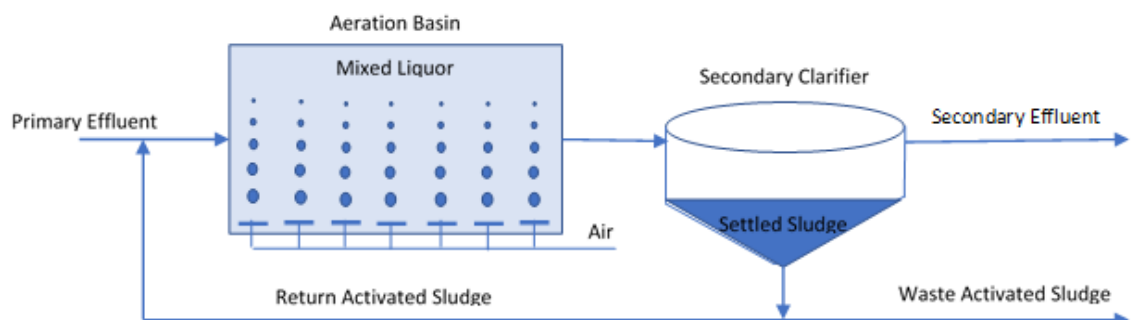


15. Activated Sludge

15.1 Process overview

Activated sludge is a secondary, biological treatment process used for the removal of suspended and dissolved organic matter from the primary treated wastewater.

- Utilizes an aeration basin/reactor and a secondary clarifier
- In the presence of oxygen, aerobic bacteria in the aeration basin consume the organic matter (BOD) in wastewater for their growth and reproduction, converting BOD into bacterial cell mass along with metabolic byproducts including carbon dioxide and water
- The aerobic bacteria is the predominant microbial life form in the aeration basin. Other higher microbial life forms — mainly protozoa, are present along with some metazoans.
- The microorganisms along with their metabolic byproducts and residual dead cell mass form a cluster called floc.
- The wastewater exiting the aeration basin enters a clarifier where the floc settles. The clear, treated secondary effluent flows out.
- A portion of the settled activated sludge floc, is returned from the clarifier to the front of the aeration basin to seed the activated sludge treatment of the incoming primary effluent. The recycled floc is called **Return Activated Sludge (RAS)**.
- The remaining settled floc from the clarifier is "wasted" —transferred for solids treatment (typically using digestion) prior to its ultimate disposal. The wasted floc is called **Waste Activated Sludge (WAS)**.
- The color of healthy activated sludge is tan to brown with an earthy/musty odor.



- For activated sludge treatment to be effective, it is critical to establish a healthy microbial population which **converts the BOD** into **easily separable biomass**.
- If the biomass does not settle well in the clarifier, it will be carried out in the treated secondary effluent producing a poor quality effluent with higher solids and organic content.

Mixed liquor:

- Mixed liquor is the mixture of raw and/or treated wastewater with the biomass.
- Mixed liquor sample is typically taken at the end of the aeration reactor.
- In the mixed liquor, the suspended solids comprised mostly of biomass with some undegraded and non-degradable material is called **Mixed liquor suspended solids (MLSS)**.
- The volatile fraction of the MLSS is termed **Mixed Liquor Volatile Solids (MLVSS)**.
- The MLVSS is the amount of biomass as a percentage of the MLSS. Generally, the MLVSS is 70 - 80%, implying that 70-80% of the MLSS is volatile (organic) solids.

15.2 Process parameters

15.2.1 Dissolved oxygen (DO)

Maintaining adequate **Dissolved oxygen (DO)** is key to the activated sludge process. DO is typically maintained between 0.5 to 3.0 mg/l in the aeration reactor.

15.2.2 pH

The microbiological population in the activated sludge is very sensitive to pH and needs to be maintained at neutral - 7 pH.

15.2.3 Temperature

Biological activity is temperature dependent. Microbial activity approximately doubles for every 10°C rise in temperature.

15.2.4 Oxygen uptake rate (OUR) and specific oxygen uptake rate (SOUR)

Oxygen Uptake Rate (OUR) involves measurement of the amount of oxygen used up by the microorganisms using a DO probe and is expressed in unit time of mg/L-hr (ppm O₂ consumed per hour). By knowing the OUR, we can establish the activity of the microorganisms in the aeration tank and know if they are consuming the oxygen provided for removing organic matter. **For conventional activated sludge process the typical OUR values range from 10 to 30 mg/L-hr**

Specific Oxygen Uptake Rate (SOUR) provides the OUR information based on the concentration of microorganisms present. SOUR is obtained by dividing OUR with MLVSS. The value is indicated and

measured in terms of unit of $\frac{\frac{mg}{l-hr} O_2}{\frac{mg}{l} MLVSS} * 1000 \frac{mg}{gm}$.

Optimal range of SOUR is usually between 8 to 20.

If a baseline OUR is established for a system - presence of toxic substances in that system can be identified by a drop in OUR. SOUR value above the optimal range indicates an increasing F:M - Higher BOD load with less than adequate microorganisms (represented by MLVSS) indicating a young sludge and the potential for straggler floc. A lower than optimal SOUR value indicates insufficient food to support the microorganisms indicating an older sludge and the potential for pin floc.

15.2.5 Food to Mass ratio (F:M)

In order to establish the amount of the MLSS to be maintained in the aeration tank, the parameter **Food to Mass Ratio (F:M)** is used. F:M is the ratio of the "food" – the mass of primary effluent BOD entering the aeration basin to the mass of the microorganisms in the aeration basin —MLVSS. Common ranges for F:M for a conventional activated sludge plant are from 0.15 to 0.5

15.2.6 Sludge age

- Sludge age is the average time (days) that a sludge particle (cell) spends in the system.

- Sludge age dictates the presence and predominance of the different types of organisms and is measured as Mean Cell Retention Time (MCRT) or Solids Retention Time (SRT).
- Sludge age is the average time that a sludge particle (cell) spends in the system
- Conventional AS process - MCRTs are in the range of 5 to 15 days
- The desired MCRT for a given plant must be found experimentally
- **F:M and MCRT are inversely related: that is a long MCRT means a low F:M and a short MCRT means a high F:M**
- Both, F:M and MCRT values vary from plant to plant and are established through a trial and error process.
- The MCRT is calculated as:

$$MCRT(days) = \frac{\text{Total MLSS lbs in the aeration system (aeration tank + clarifier)}}{\text{Total amount in lbs/day of suspended solids leaving the system (Effluent SS+WAS solids)}}$$

$$MCRT(days) = \frac{MLSS \text{ in aeration tank (lbs)} + MLSS \text{ in clarifier (lbs)}}{Effluent \text{ suspended solids (lbs/day)} + WAS \text{ SS (lbs/day)}}$$

15.2.7 Sludge settleability

- A settleability test is conducted on the mixed liquor from the aeration reactor to measure the compaction and settleability characteristics of the secondary solids.
- In the settleability test, a 1-liter mixed liquor sample is allowed to settle for 30-minutes in a graduated cylinder — settleometer.
- The **Sludge Volume Index (SVI)** of the sludge is calculated using results from the 30-minute settleability test and the MLSS value.
- SVI is expressed in ml/g and it is essentially the volume (ml) of 1 gram of the MLSS after 30 minutes of settling.
- $SVI (ml/g) = \frac{\text{Settled sludge volume in ml/l after 30 min}}{MLSS \text{ mg/l}} * 1000 \frac{mg}{g}$
- SVI provides a more accurate picture of the sludge settling characteristics than settleability or MLSS alone.
- 50 to 120 ml/g SVI value is considered optimal.
- Higher SVI values indicate sludge that is slow to settle and not compacting well.
- When SVI values are approaching 200 ml/g, activated sludge process is considered to be "bulking".
- Regular monitoring of SVI help identify changes occurring in the activated sludge process preventing settling problems before they occur.
- Like F:M and MCRT, the optimal SVI value for each plant varies and is also established by trial and error.

15.3 Microbiology

Bacteria are fundamental microorganisms in the stabilization of organic wastes and therefore of basic importance in the secondary wastewater treatment process.

Bacteria (singular, bacterium) are single celled organisms and represent the simplest forms of life. These organisms utilize soluble food and are capable of self-reproduction. Bacteria can be classified in many different ways.

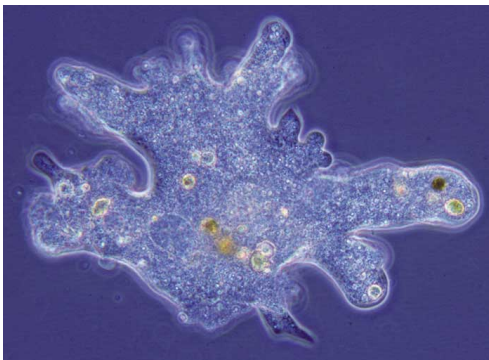
For wastewater bacteria are classified based on nutritive requirement, bacteria are classified as heterotrophic or autotrophic bacteria, although several species may function both.

1. **Heterotrophic bacteria** use carbon based organic compounds for both energy and food source. A term commonly used instead of heterotroph is "saprophyte" which refers to an organism that lives on dead or decaying organic matter. The heterotrophic bacteria are grouped into three classifications, depending upon their action toward free oxygen.
 - a. Aerobes : Require free dissolved oxygen to live and multiply.
 - b. Anaerobes : Oxidize organic matter in the complete absence of dissolved oxygen.
 - c. Facultative : Use free dissolved oxygen when available but can also respire and multiply in its absence, e.g. Escheichia coli.

2. **Autotrophic bacteria** use carbon dioxide as a carbon source and oxidize inorganic compounds for energy. Autotrophs of greatest significance in wastewater treatment are the nitrifying and sulfur bacteria.
 - a. Nitrifying bacteria : These bacteria are responsible for the oxidation of ammonia in wastewater to nitrates.
 - b. Sulfur bacteria : These bacteria are involved in the formation of sulfuric acid from the dissolved sulfides in the sewer conveyance systems.

The activated sludge is a complex ecosystem of aerobic microorganisms predominantly heterotrophic bacteria along with some autotrophic bacteria and other trophic organisms including protozoas, rotifers and nematodes which feed on the bacteria and particulate matter.

Protozoa are single-celled microscopic organisms, several hundred times larger than bacteria. It is the protozoa we observe under a microscope since bacteria are actually too small to see. There are four types of protozoa commonly found in activated sludge systems. They are identified by their method of movement within the wastewater environment. The four types are:



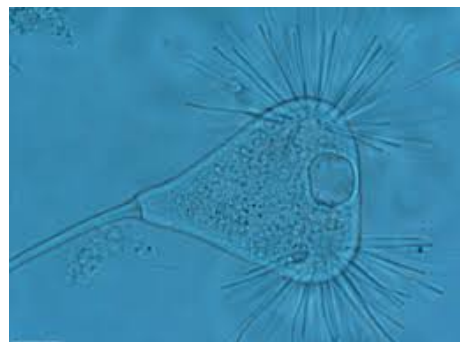
Amoeba



Stalked Ciliate

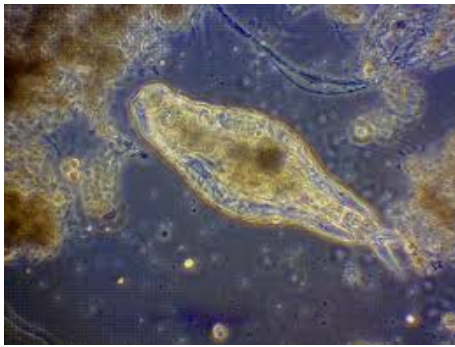


Flagellate



Suctorian

Other commonly found organisms included the multi-celled organisms - Metazoans such as Rotifers and Nematodes

**Rotifer****Nematode**

- The essence of the activated sludge system is to develop and maintain a diverse population of microorganisms (activated sludge) that treats wastewater and which can be managed.
- The activated sludge should be such that it **not only effectively remove the BOD**, but also **produces a floc that settles and compacts well** in the secondary clarifier thereby producing a secondary effluent with a low BOD content.
- The floc produced has a porous structure and is essentially an aggregate of bacteria and extracellular material including organic polymers - polysaccharides and other substances secreted by the microorganisms, and remnants of dead microorganisms.
- Typically, the trophic organisms such as the protozoas and rotifers which feed on the bacteria and other particulates are generally present on the outer surface of the flocs.
- A good quality activated sludge is brown in color with some froth and a slight musty odor.
- The settleability of the sludge is measured as SVI which is the volume of settled sludge in milliliters occupied by 1 gram of dry sludge solids after 30 minutes of settling in a 1,000 mL graduated cylinder or a settleometer.
- SVI of a good settling sludge is typically between 50 - 150 ml/g.
- MCRT is the key factor which establishes the organism mix in the activated sludge.
- As MCRT increases, the size and complexity of the organisms increases.
- The types of organisms predominating in the mixed liquor give an indication as to the age of the sludge.
 1. At low MCRT of about less than 4 days the simpler protozoas - amoebae and flagellates dominate.
 2. With an increase in MCRT more complex organisms such as the free swimming ciliates and stalked ciliates appear.
 3. At even higher MCRT, metazoans such as the rotifers and nematodes may be found

15.4 Activated sludge process control

- To ensure optimal treatment in the activated sludge process - maximum BOD removal with a well settling mixed liquor, controlling the inventory of solids (biomass) is a key process control parameter.
- New solids (biomass) are produced in the activated sludge reactors due to the consumption of the BOD by the microorganisms.
- The solids fraction of the mixed liquor which separate (settle) in the secondary clarifier are
 - Either returned to the influent end of the activated sludge reactor as Return Activated Sludge (RAS), or
 - removed from the system as Waste Activated Sludge (WAS).
- Thus, RAS and WAS pumping controls are used for maintaining the desired amount of solids in the system.

15.4.1 Controlling waste activated sludge (WAS) pumping rate

For process stability and control the wasting should be continuous and not intermittent and any increase or decrease in wasting should be made gradually, i.e., 20 - 25 percent per day. One of the following approaches is utilized to establish the WAS flow control

Constant Mean Cell Residence Time (MCRT)

Typical MCRT for conventional AS process ranges from 5 to 15 days and 20 to 30 days for extended aeration and for a given plant, the desired MCRT is established based upon operational experience. WAS flow control can be established to maintain the desired MCRT range for a given plant.

Constant food:mass (F/M)

This parameter is based upon the ratio of food (influent BOD) fed to the microorganisms each day to the mass of microorganisms held under aeration. WAS flow control can be used for controlling the mass of microorganisms in the system to maintain the desired F/M ratio.

Constant Mixed Liquor Suspended Solids (MLSS)

A MLSS concentration which provides the best effluent and highest removal efficiencies is selected and WAS flow control is established to maintain the desired MLSS concentration level. Wasting is increased when the MLSS concentration is higher and decreased or stopped when the MLSS concentration is lower than the desired level.

15.4.2 Controlling the return activated sludge (RAS) rate

RAS flow rate affects the concentration and the sludge age. Return Activated Sludge Control... To properly operate the activated sludge process, For conventional activated sludge operations, the RAS flow is generally about 30 to 100% of the incoming wastewater flow. Changes in the activated sludge quality will require different RAS flow rates due to settling characteristics of the sludge. The following approaches are used to control the RAS flow rate:

Constant RAS flow rate control - RAS pumping independent of influent flow

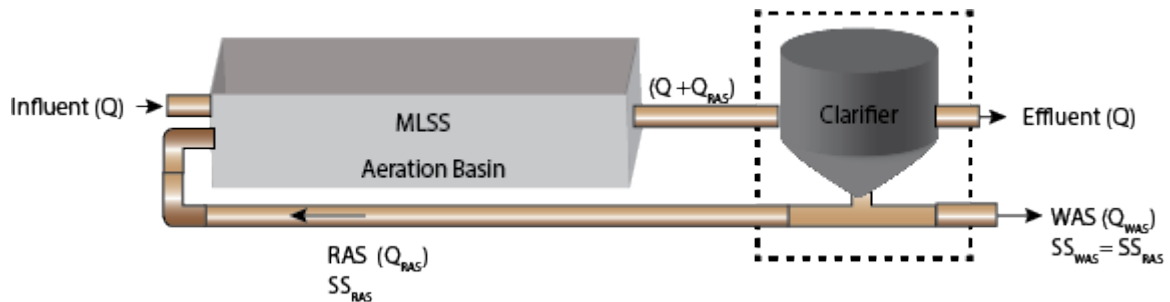
- Results in a continuously varying MLSS concentration that will be at a minimum during peak influent flows and a maximum during minimum influent flows. This occurs because the MLSS are flowing into the clarifier at a lower rate during peak flow when being removed at a constant rate. Similarly, at minimum influent flow rates, the MLSS are being returned to the aeration tank at a higher rate than are flowing into the clarifier
- Maximum solids loading on the clarifier occurs at the initial start of peak flow periods.
- The clarifier will have a constantly changing depth of sludge blanket as the MLSS moves from the aeration tank to the clarifier and vice versa.
- This RAS control option is especially advantageous for smaller plants as it entails little effort/minimal automation for RAS pumping control.
- A disadvantage of using the constant flow approach is that the F/M is constantly changing. The range of F/M fluctuation due to the effect of short term variation in the MLSS (because of hydraulic loading) is generally small enough so that no significant problems arise due to using this approach.

Constant percentage RAS flow rate control

- This approach requires a programmed method for maintaining a constant percentage of the aeration tank influent wastewater flow rate. The program may consist of an automatic flow measurement device, a programmed system, or frequent manual adjustments.
- The variations in the MLSS concentration due to the diurnal flow profile are reduced and the F/M varies less.
- The MLSS will remain in the clarifier for shorter time periods, which may reduce the possibility of denitrification in the clarifier.
- Clarifier is subjected to maximum solids loading when the clarifier contains the maximum amount of sludge. This may result in solids washout with the effluent.

Establishing RAS flow rate based on a solids balance approach

The following equation can be used for controlling RAS flow rate to maintain a target MLSS concentration given the influent flow and the RAS solids content.



Applying a mass balance approach to the secondary clarifier:

Mass of solids in = Mass of solids Out

$$(Q + Q_{RAS}) * MLSS = Q_{RAS} * SS_{RAS} + Q_{WAS} * SS_{RAS}$$

Notes:

- The solids leaving with the effluent - $Q * SS_{EFF}$ is negligible
- Also, $SS_{WAS} = SS_{RAS}$

Rearranging:

$$\Rightarrow Q_{RAS} = \left(\frac{Q * MLSS - Q_{WAS} * SS_{RAS}}{SS_{RAS} - MLSS} \right)$$

As $Q_{WAS} * SS_{RAS} \ll Q * MLSS$ and can be neglected

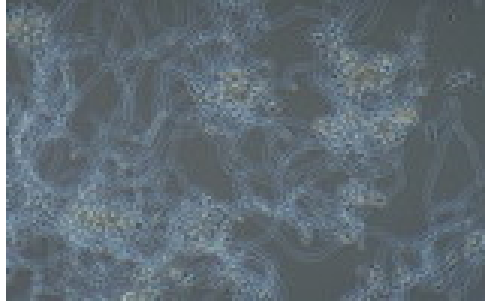
Rearranging:

$$Q_{RAS} = \left(\frac{Q * MLSS}{SS_{RAS} - MLSS} \right)$$

15.5 Process trouble shooting

The most common activated sludge quality issues include:

1. **Straggler floc:** This condition shows small, light, and fluffy floc particles with poor settling characteristics. It occurs due to young sludge or low MCRT/MLSS levels and may be related to an inadequate microorganism population or an excessive BOD load (high F:M) which causes a log growth situation. The cells become dispersed rather than flocculated, settleability is poor, and the effluent becomes turbid. In this condition oxygen is used up quickly due to the high metabolism rate, and sludge production is high. One tell-tale sign of this condition is the production of huge amounts of a billowing white foam.
2. **Pin floc (Dispersed Growth):** Here flocs - pin floc is seen in the effluent. These are larger dimension spherical particles. The sludge settles well in the settleability test but the supernatant is cloudy. This floc consist mostly of floc-forming bacteria without a filament backbone. This condition occurs at starvation condition when all of the influent BOD has been used up (low F:M) and the old sludge age organisms are now in endogenous respiration.
3. **Rising sludge:** Under this condition, sludge settles well, compacts on the bottom of the clarifier, then starts to rise in clumps and patches to the surface. Rising sludge is typically evidenced as brown in color. Rising sludge occurs due to either denitrification or sludge septicity due to an excessive detention time in the clarifier.
4. **Bulking and foaming:** Typical bacteria present in activated sludge include spherical, rod shaped and filamentous. The presence of filamentous bacteria in activated sludge provide the important structural element for the bacterial floc. Bulking is indicated by $SVI > 150$ ml/g. However, certain condition cause an excessive growth of filaments which interferes with the settling (bulking) and cause foaming during aeration. Identifying which filaments are dominating in the system through a microscopic evaluation will help the operator to understand the condition in the treatment system so that corrective changes can be made.



Filaments proliferation

- a. **Bulking:** Activated sludge bulking is marked by poor compaction – high SVI_{30} and poor solids-liquid separation evidenced by high effluent TSS. To resolve bulking issue, it is important to find its cause and take remedial actions. This is accomplished through a microscopic examination to identify the type of the filament to provide a clue on the cause. Short term remedy to bulking includes Chlorinating – 2-3 mg/l per 1000 lbs MLVSS or use of polymers.
- b. **Foaming:** Activated sludge foaming is caused mostly by two filaments: *Nocardia* spp. and *Microthrix parvicella* (there are other non-filament causes of foaming - including excessive presence of surfactants. Both of these filaments have three causes in combination: (1) high grease and oil; (2) longer sludge age; and (3) low oxygen conditions or septicity. Foaming if left uncontrolled could potentially pose a permit compliance issue if the foam spills into the effluent. Additionally, *Nocardia* from the secondary sludge could cause digester foaming.

Filament Type	Cause	Remedy
S.natans, Type 1701 and H.hydrossis	Low D.O. (For the applied organic loading)	Low aeration basin DO concentration for the applied F/M leads to filamentous bulking by several filaments. Typically a minimum DO of 2 mg/l is required for F:M upto 0.5. The condition may also be remedied by raising the MLSS concentration (decreasing the F/M)
M.parvicella, Nocardia species, Type 0041, Type 0675, Type 1851 and Type 0803	Low Organic Loading Rate (Low F:M)	Increase the F:M by reducing the MLSS concentration. When reduction in the MLSS concentration may not be feasible due to impact on nitrification, other suitable methods such as the use of a selector may be considered
Thiothrix I and II, Beggiatoa species, N. limicola II, Type 021N, Type 0092, Type 0914, Type 0581, Type 0961 and Type 0411	Septic Wastes / Sulfides (High organic acids)	Reduce septicity using pre-aeration and through use of chemicals which prevent septicity and reduce sulfides
Thiothrix I and II and Type 021N (N deficiency) N. limicola III (P deficiency)	Nutrient Deficiency (N and / or P) (Industrial Wastes Only)	
Nocardia species, M.parvicella and Type 1863	High Grease / Oil	
Fungi	Low pH (Below pH 6.0) / Oil	The aeration basin pH should be maintained in the range 6.5 to 8.5. Low pH, <6.5, may cause the growth of fungi and fungal bulking. The aeration basin pH can be adjusted using caustic, lime or magnesium hydroxide.

Table 15.1: Troubleshooting Activated sludge filaments

15.6 Process modifications

15.6.1 Conventional activated sludge process

Process description

The primary effluent (AS influent) - Q , along with the return activated sludge (RAS) - Q_{RAS} , are introduced at the head of the aeration tank. The oxygen demand is the highest at this point and decreases uniformly as the wastewater travels from one end of the tank to the other.

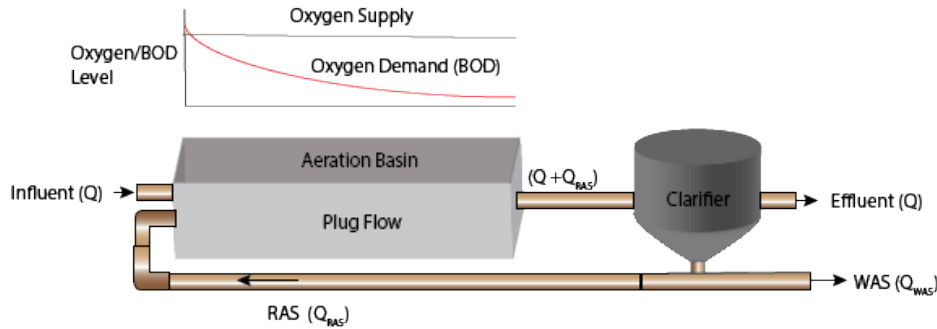


Figure 15.1: Conventional Activated Sludge Process

Process advantages and applications

The conventional activated sludge process is most suitable for low-strength, domestic wastes with minimal peak load considerations as this process is susceptible to failure from shock loads. Shock Load is elevated strength (higher BOD and contaminant levels) in wastewater for brief period of time.

Reasons for modifying the Conventional Activated Sludge Process

Several factors contribute to the need for modifying the Conventional Activated Sludge Process:

- Unique characteristics of the influent flow which may include - high BOD loads, potential toxic loads, storm flows, loads with high carbonaceous BOD but low nitrogen
- Space constraints
- Energy and labor (O&M) constraints
- Constraints requiring low solids production

15.6.2 Conventional step feed process

Process description

In this process modification, the primary effluent is fed to the aeration tank at several different locations within the tank. The distribution of the influent along the length of the aeration reactor allows for distribution of the load (BOD) over the aeration tank and reduce oxygen sags in the aeration tank. The return sludge is introduced separately from the primary effluent and in many cases is allowed a short re-aeration period before mixing with primary effluent.

Process advantages and applications

- Less aeration volume required to treat the same volume of wastewater compared to the conventional aeration.
- Better control in handling shock loads
- There is potential for:
 - lower applied solids to the secondary clarifier
 - lower oxygen requirement
- The step-feed process can be utilized on a variable basis using various modes (varying percent of the influent at the feed points) depending on the influent situation and the selection of the proper mode depends on the influent characteristics and the capabilities of the plant to handle the characteristics

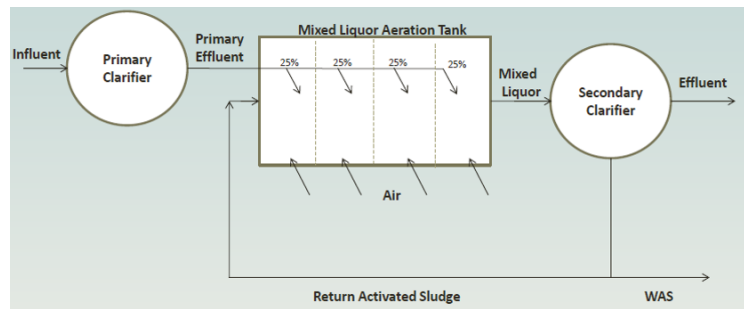


Figure 15.2: Conventional step feed

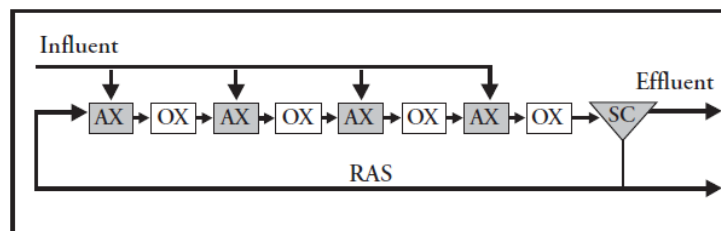


Figure 15.3: Step feed modification for Biological Nutrient Removal (BNR)

15.6.3 Contact stabilization

Process description

- This process modification requires two aeration tanks.
 1. Return Sludge Re-aeration tank:
 - This tank is for separate re-aeration of the return activated sludge before it is mixed with the incoming wastewater
 - The residence time in the stabilization tank is typically 4 to 6 hours
 2. Mixed Liquor Aeration tank (or Contact tank):
 - This tank is for mixing of the primary effluent with the re-aerated return activated sludge
 - Here, the organisms quickly take in and store large amounts of food from the primary effluent.
 - The residence time in this tank is approximately 30 to 90 minutes

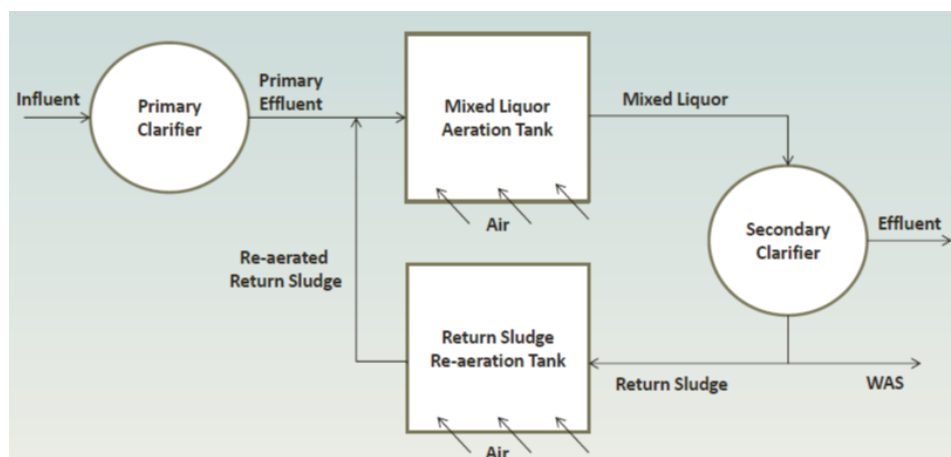


Figure 15.4: Contact Stabilization

Process advantages and applications

Because the contact stabilization system has a reservoir of microbes in the re-aeration tank, it is better able to withstand solids washouts that accompany major storms and avoid microbial kill-offs related to short-term toxic dumps

15.6.4 Pure oxygen system

Process description

Very similar to conventional activated sludge except that high purity oxygen is supplied to aeration tank (reactor) rather than air and this process treats more wastewater in a smaller space in a shorter period of time. The Aeration tanks (reactors) are enclosed and sealed to prevent the oxygen from escaping from the tanks. Pure oxygen from an oxygen generation system or is introduced in the headspace of the reactor. Mechanical surface aerators agitate the mixed liquor (essentially splash the liquid in the headspace) to dissolve the oxygen into the mixed liquor. High DO levels are maintained in the aeration tanks (4 mg/l to 15 mg/l). Roughly 90%-99% gaseous O_2 goes in and 45-70% gaseous O_2 is ventilated at the effluent end of the reactor.

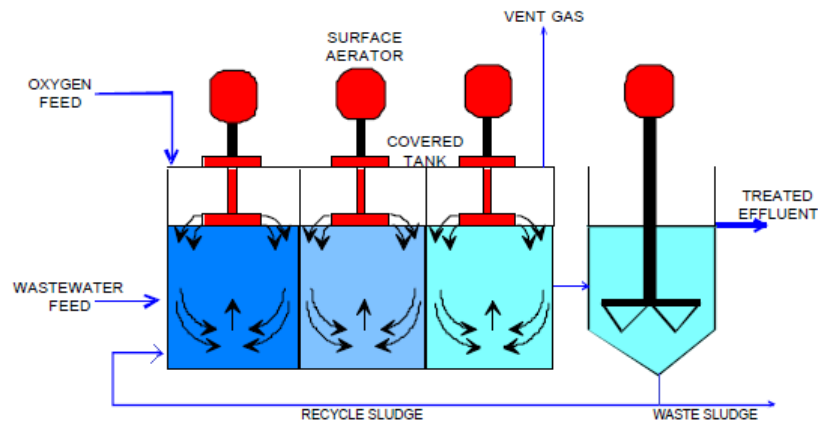


Figure 15.5: Pure Oxygen System

Process advantages and applications

- Pure oxygen systems are generally more stable and can treat large volumes of wastewater.
- It treats more wastewater in a smaller space in a shorter period of time

15.6.5 Sequencing batch reactors

Process description

Rather than treating a continuous flow through a number of tanks, Sequencing Batch Reactors (SBRs) treat flows in “batches” through a single tank - “reactor” through sequencing stages. It performs the same treatment steps as a conventional AS plant, but they do it in sequenced stages rather than in a continuous flow stream. Most commonly preliminary treated wastewater is directly fed to the SBR.

Typically SBR is operated in five stages:

1. Filling: Influent raw wastewater enters the reactor
2. Mixing & Aeration: This stage is where the BOD consumption and biomass production occurs. Mixing and aeration may be alternated to accomplish nitrification (during aeration) and denitrification (during mixing - without aeration - anoxic).
3. Settling - This is the clarification stage. - to allow for the activated sludge floc to settle.
4. Extraction - in this stage the supernatant treated wastewater is removed (for disposal) and part of the settled sludge is wasted.
5. Idle - This stage is essentially to prepare the reactor and the biomass to receive the raw wastewater - Filling stage. In this stage some aeration/mixing may be provided. The biomass in the reactor

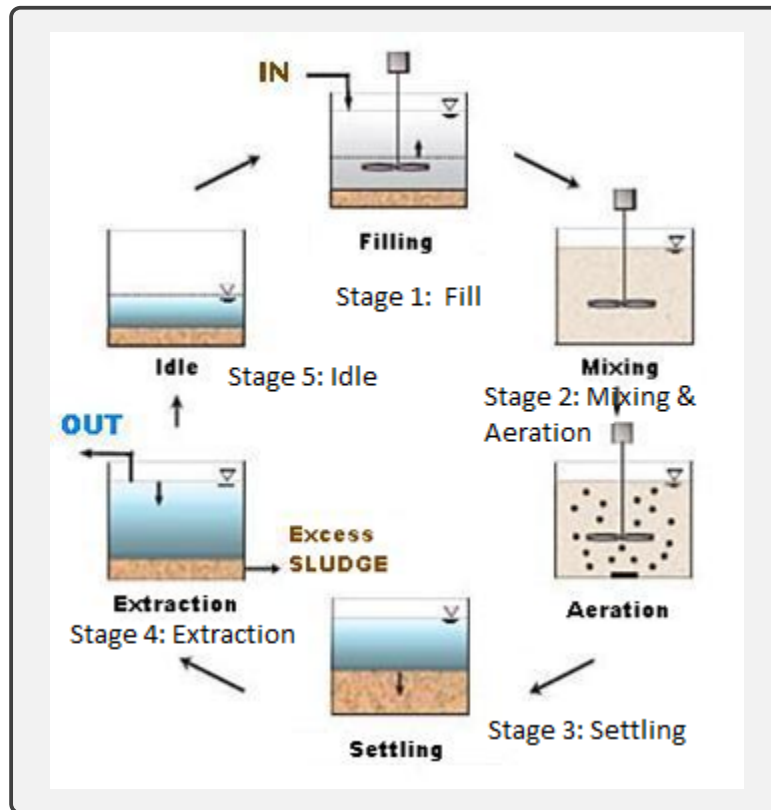


Figure 15.6: Sequencing Batch Reactor

enters the endogenous phase as the food is absent. The biomass metabolizes the stored food and the organisms feed on one another.

Process advantages and applications

- SBRs are ideal for small facilities as the process can be easily automated
- SBRs are very stable due to the high sludge ages maintained and the fact that all treatment takes place in a single tank
- SBR construction is less costly due to the elimination of secondary clarifiers and sometimes digestion facilities (fewer structures in general)

15.6.6 Extended aeration

Process description

This process typically directs raw sewage flow (without grit/screenings) into the aeration tank where it undergoes treatment for an extended period (usually 8 hours or more – 15 hours typical) followed by clarification. Mixed liquor concentrations are usually maintained at high concentrations. Typical F:M ratios are about 0.05 to 0.15 and MCRT of about 30 days.

Process advantages and applications

- This process modification is appropriate for small facilities that have light solids loadings – plants typically treating less than 1 MGD – as the aeration tank volume requirement is larger
- In addition to consuming all the incoming food, the microbes consume all food stored within cells - endogenous respiration, and other dead microbes in the system
- Extended aeration does not produce as much waste sludge as other process modifications
- The oxidation ditch is a variation of the extended aeration process. In the oxidation ditch, the aeration basin is ring or oval shaped. Aeration rotors or brushes cause the wastewater to flow around

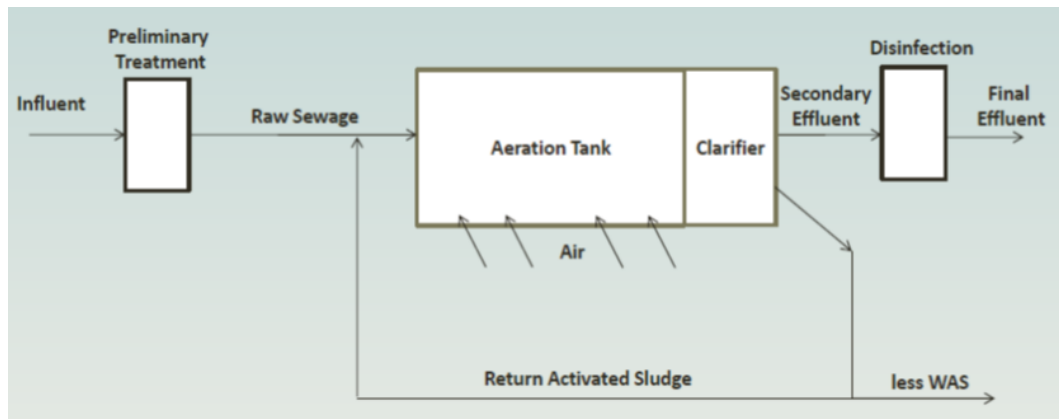


Figure 15.7: Extended Aeration

the ring and also aerate the wastewater.

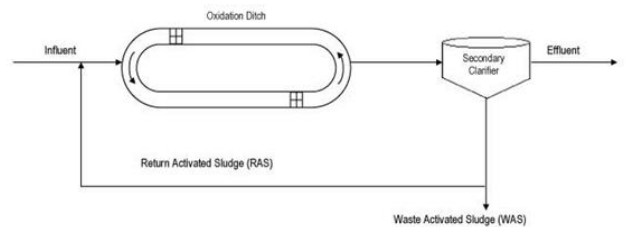


Figure 15.8: Extended Aeration - Oxidation Ditch

15.6.7 Krauss process

Process description

The process involves use of two aeration tanks. One aeration tank (Aeration Tank B in the graphic), is for blending return activated sludge (RAS) with anaerobic digester supernatant or sludge and aerating the solution. The other tank receives primary effluent (Aeration Tank A), return activated sludge, and the aerated mixture of return sludge and digester supernatant/sludge. Air (oxygen) is added to both aeration tanks.

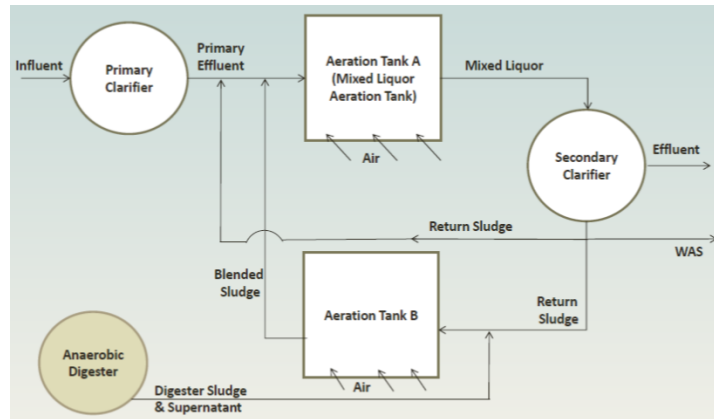


Figure 15.9: Krauss Process

Process advantages and applications

This process modification is widely used when wastewater contains a high ratio of carbonaceous to nitrogenous material in the wastewater (nitrogen deficient). This typically occurs when there is significant contribution of wastewater from canneries or dairies. When the little nitrogen present in the influent wastewater is consumed, further consumption of carbonaceous material ceases. The digester supernatant or sludge being typically rich in nitrogenous material provides the required nitrogen for the nitrogen deficient process stream.

15.7 Sample Math Problems

1. An activated sludge plant operates well at an F:M ratio of between 0.23 and 0.28. Calculate the minimum MLSS concentration, given the following:

Q = 0.4 MGD

Primary influent BOD = 250 mg/l

Primary effluent BOD = 128 mg/l

Aeration tank vol. = 350,000 gallons

Clarifier vol = 250,000 gallons

MLSS has 80% volatile solids

Solution:

$$F : M = \frac{(\text{lbs/day}) \text{ primary effluent BOD entering the aeration tank}}{(\text{lbs}) \text{ MLVSS in the aeration tank}}$$

$$\Rightarrow F : M \propto \frac{1}{\text{MLSS concentration}} \Rightarrow \text{F:M is inversely proportional to MLSS}$$

So to have minimum MLSS conc. F:M needs to be the maximum of the range provided

$$\text{If the MLSS concentration} = x: \Rightarrow F : M = 0.28 = \frac{0.4 * 128 * 8.34}{0.35 * x * 0.8} \Rightarrow x = \boxed{5,446 \text{ mg/l MLSS}}$$

2. Given that an activated sludge plant with an influent flow of 1.2 MGD is operated at an MCRT of 6 days and the parameters below, calculate the WAS flow rate (wasting rate) in gallon per day.

Solution:

Two aeration tanks – 0.5 MG each	Two final clarifiers – 0.25 MG each
Final effluent = $20 \frac{mg}{L}$	WAS – 7500 ppm
MLSS – $3600 \frac{mg}{L}$	MLSS volatile solids content = 80%

$$MCRT = \frac{lbs \text{ MLSS}(\text{system})}{\frac{lbs}{day} \text{ Effluent}_{SS} + \frac{lbs}{day} \text{ WAS}_{SS}}$$

Step 1: Calculate the lbs MLSS (system):

$$lbs \text{ MLSS (system)} = (2 * 0.5 + 2 * 0.25)MG * 3,600 \frac{mg}{L} * 8.34 = 45,036 \text{ lbs}$$

Step 2: Calculate the lbs/day Effluent_{SS}:

$$\frac{lbs}{day} \text{ Effluent}_{SS} = 1.2MG * 20 \frac{mg}{L} * 8.34 = 200.2lbs$$

Step 3: Plug in the values in the MCRT formula:

$$MCRT: 6 \text{ days} = \frac{45,036}{200.2 \frac{lbs}{day} + \frac{lbs}{day} \text{ WAS}_{SS}}$$

Step 4: Solving for WAS_{SS}:

$$\frac{lbs}{day} \text{ WAS}_{SS} = \frac{45,036}{6} - 200.2 = 7,306 \frac{lbs}{day}$$

Step 5: Solving for WAS flow using the lbs formula:

$$7,306 \frac{lbs}{day} = \text{WAS Flow (MGD)} * 7,500 * 8.34$$

$$\Rightarrow \text{WAS Flow (MGD)} = \frac{7,306}{7,500 * 8.34} = 0.116MGD = \boxed{116,000 \frac{gal}{day}}$$

