ENVE 302

Environmental Engineering Unit Processes

CHAPTER: 8

Activated Sludge Configurations

for BOD removal and Nitrification

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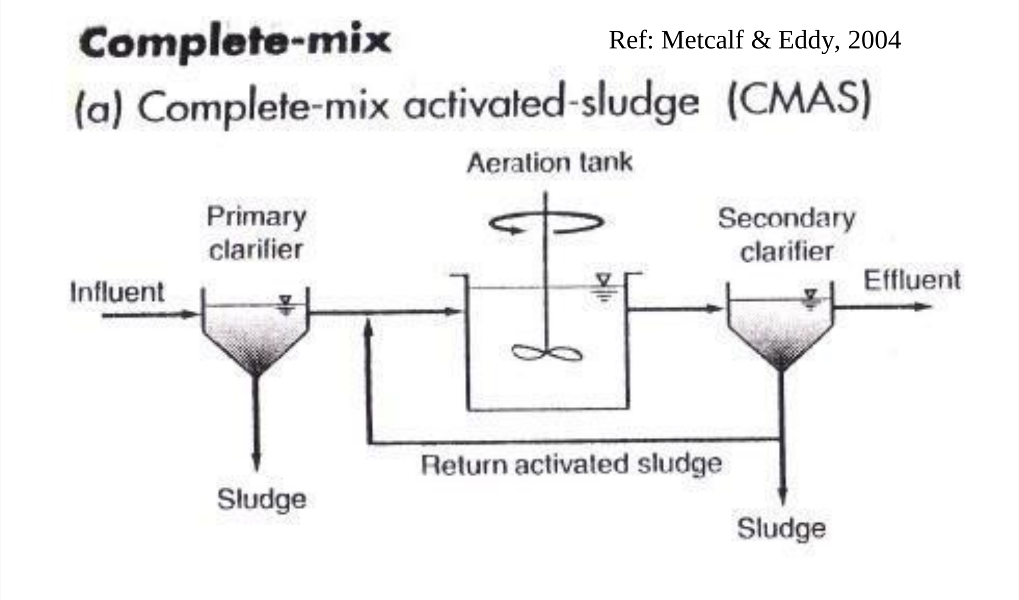


- organic load
- MLSS conc.
- oxygen demand

} UNIFORM throughout the tank

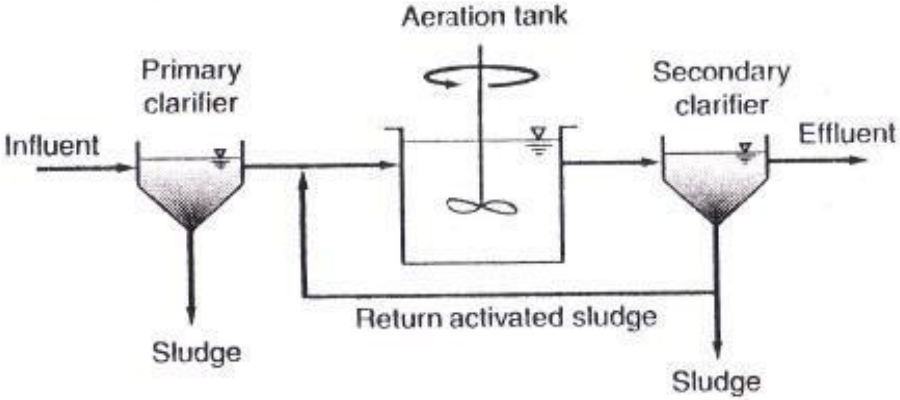
- dilution of shock loads

- tends to have low F/M ⟶ filamentous growth ⟶ sludge bulking

Ref: Metcalf & Eddy, 2004

Complete-mix

(a) Complete-mix activated-sludge (CMAS)



The CMAS process is an application of the flow regime of a continuous-flow stirred-tank reactor. Settled wastewater and recycled activated sludge are introduced typically at several points in the aeration tank. The organic load on the aeration tank, MLSS concentration, and oxygen demand are uniform throughout the tank. An advantage of the CMAS process is the dilution of shock loads that occur in the treatment of industrial wastewaters. The CMAS process is relatively simple to operate but tends to have low organic substrate concentrations (i.e., low F/M ratios) that encourage the growth of filamentous bacteria, causing sludge bulking problems

Plug Flow

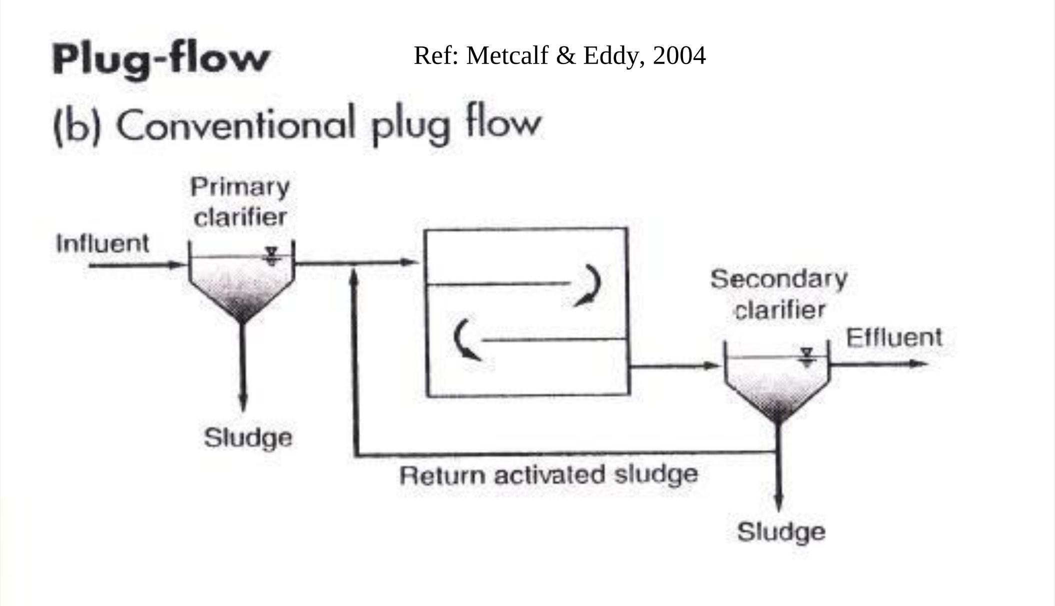
- The true plug flow recycle system is theorotically more efficient in the stabilization of most soluble wastes then in the continous–flow-stirred-tank recycle system.

- In actual practice;

  a true plug flow regime is essentially impossible to obtain because of longtitudinal dispersion caused by aeration and mixing

- By dividing the aeration tank into a series of reactors the process approaches plug-flow kinetics with improved treatment efficiency compared to a complete mix process.

- Because of the greater dilution with the influent wastewater the complete mix system can handle shock loads better than staged reactors in series.



- 3-5 channels
- In early designs;

Uniform air application throughout the tank

low DO concentration in the initial passes of the tank

- Modern designs;

Tapered aeration

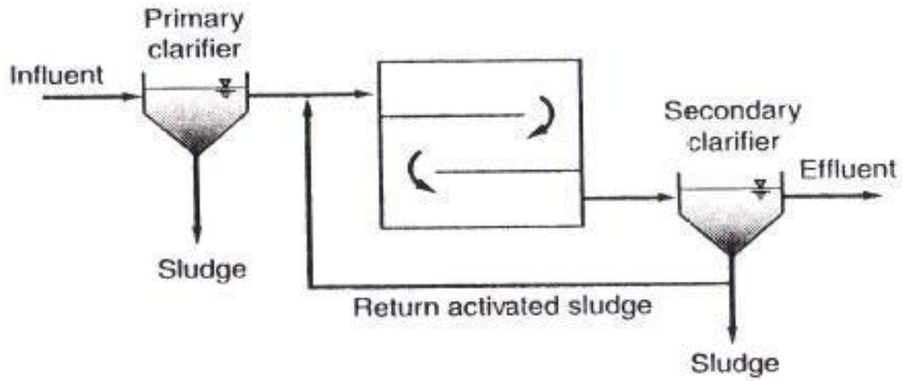
application of higher rates of DO in the begining of the tank

application of lower rates of DO near the end of the tank

Ref: Metcalf & Eddy, 2004

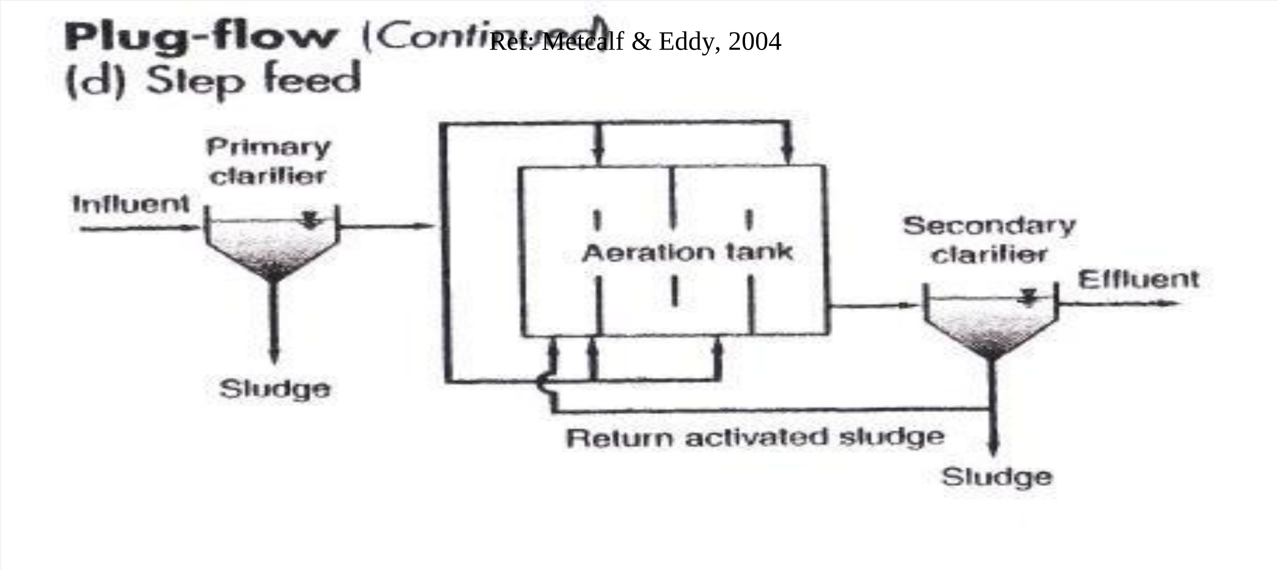
Plug-flow

(b) Conventional plug flow



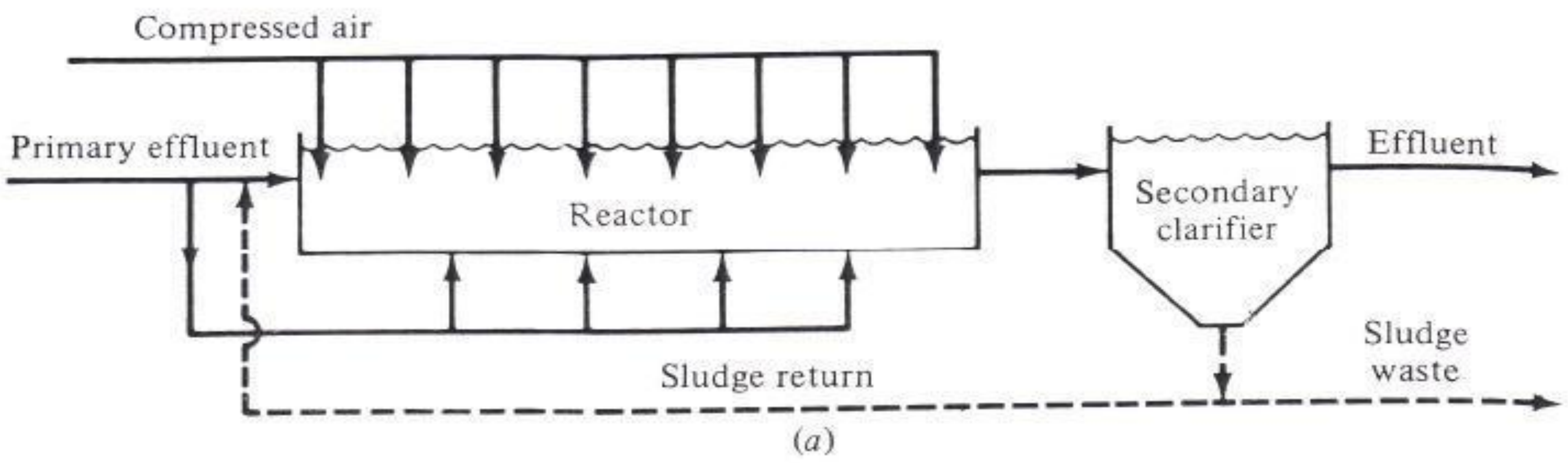
Settled wastewater and return activated sludge (RAS) enter the front end of the aeration tank and are mixed by diffused air or mechanical aeration. Typically, from 3 to 5 channels (passes) are used. In early designs, air application was generally uniform throughout the tank length; however, low DO concentrations usually occurred in the initial passes of the tank. In modern designs, the aeration system is designed to match the oxygen demand along the length of the tank by tapering the aeration rates, i.e., applying higher rates in the beginning and lower rates near the end of the tank. During the aeration period, adsorption, flocculation, and oxidation of organic matter occur. Activated-sludge solids are separated in a secondary settling tank

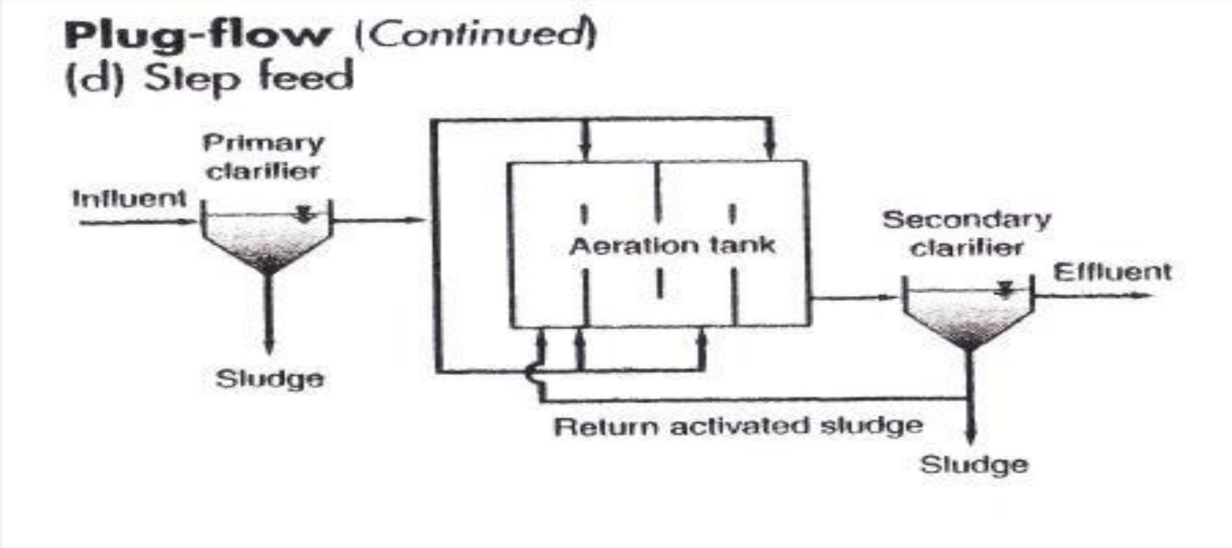
High-rate aeration is a process modification in which low MLSS concentrations are combined with high volumetric BOD loadings. The high-rate system is characterized by short τ, high sludge recycle ratio, high F/M loading, and relatively low MLSS concentration. High-rate systems produce a lesser effluent quality, in terms of BOD and TSS concentration, as compared to conventional plug-flow or complete-mix systems. Because of the high loading used, more care must be taken to keep a stable operation. Adequate mixing and aeration are very important



- Capable of carrying higher solids inventory
- Higher SRT for the same volume as a conventional plug-flow process
- Modification of conventional plug-flow.
- influent wastewater is introduced from 3-4 feed points to equalize F/M ratio thus lowering peak oxygen demand.
- Complicated design for process and aeration system

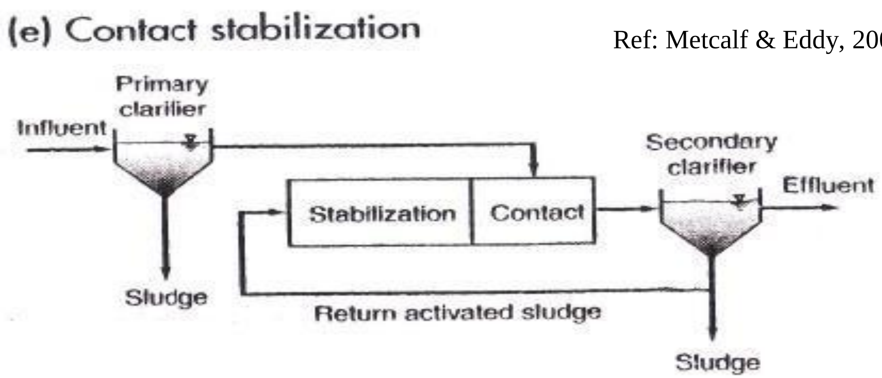
Plug-flow - Step-feed





Ref: Metcalf & Eddy, 2004

Step feed is a modification of the conventional plug-flow process in which the settled wastewater is introduced at 3 to 4 feed points in the aeration tank to equalize the F/M ratio, thus lowering peak oxygen demand. Generally, three or more parallel channels are used. Flexibility of operation is one of the important features of this process because the apportionment of the wastewater feed can be changed to suit operating conditions. The concentration of MLSS may be as high as 5000 to 9000 mg/L in the first pass, with lower concentrations in subsequent passes as more influent feed is added. The step-feed process has the capability of carrying a higher solids inventory, and thus a higher SRT for the same volume as a conventional plug-flow process. The step-feed process can also be operated in the contact-stabilization mode by feeding only the last pass, and high wet-weather flows can be bypassed to the last pass so that the solids load to the secondary clarifier can be minimized



Ref: Metcalf & Eddy, 2004

MLSS concentration in the contact zone < MLSS concentration in the stabilization zone

- Contact zone detention time: 30-60 min
- Stabilization zone detention time: 1-2 hr
- Requires much less aeration volume

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- Short contact time limits the amount of ;
  BOD degraded , NH_4 oxidized

In the contact zone:

- rapid removal of soluble BOD
- capturing of colloidal & particulate organics in the floc

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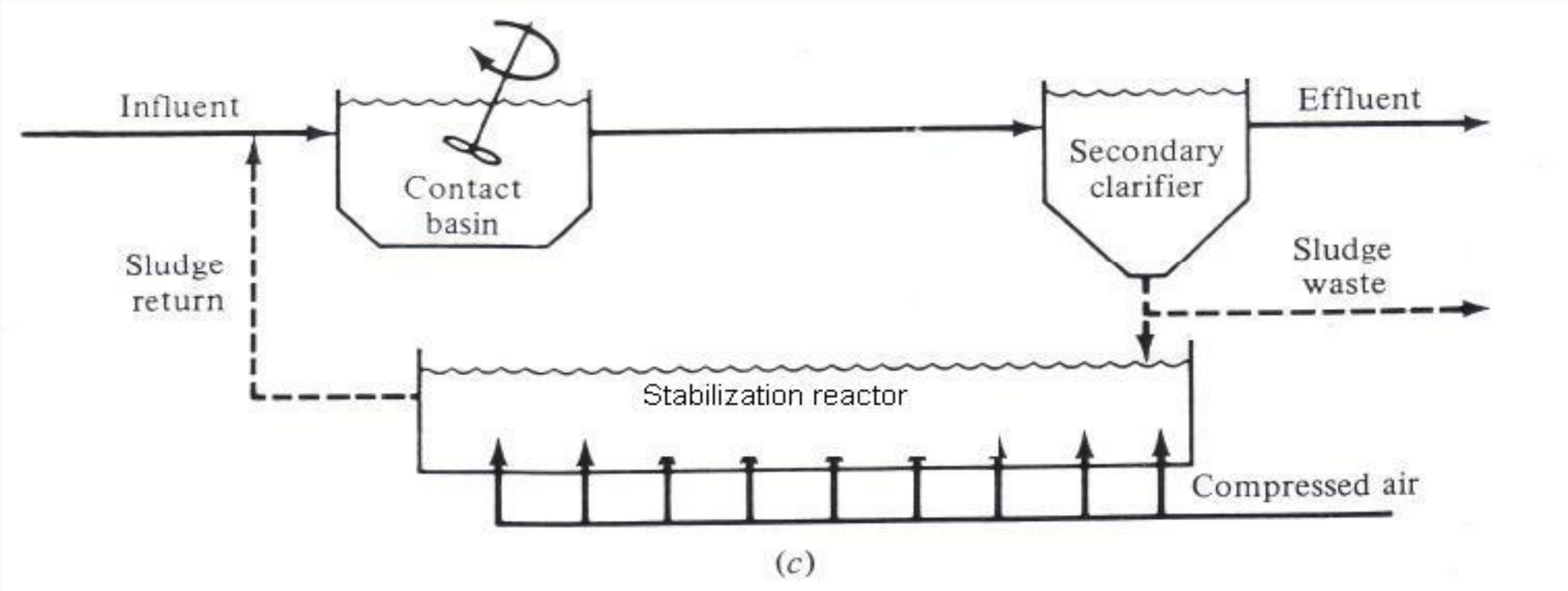
to be degraded later in the stabilization zone

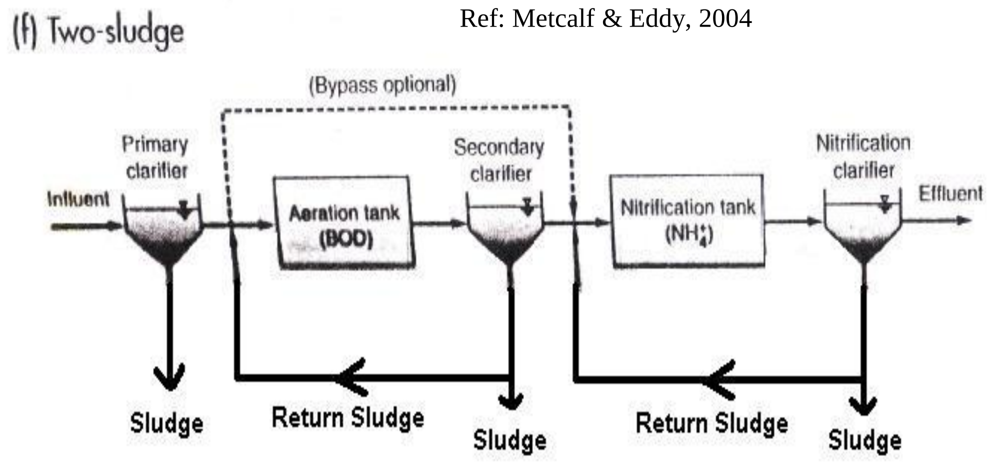


Stabilization → Degradation of activated sludge flocculation

Sludge is stabilized;

- To reduce pathogens
- To eliminate offensive odor
- To inhibit, to reduce or eliminate the potential for putrefication

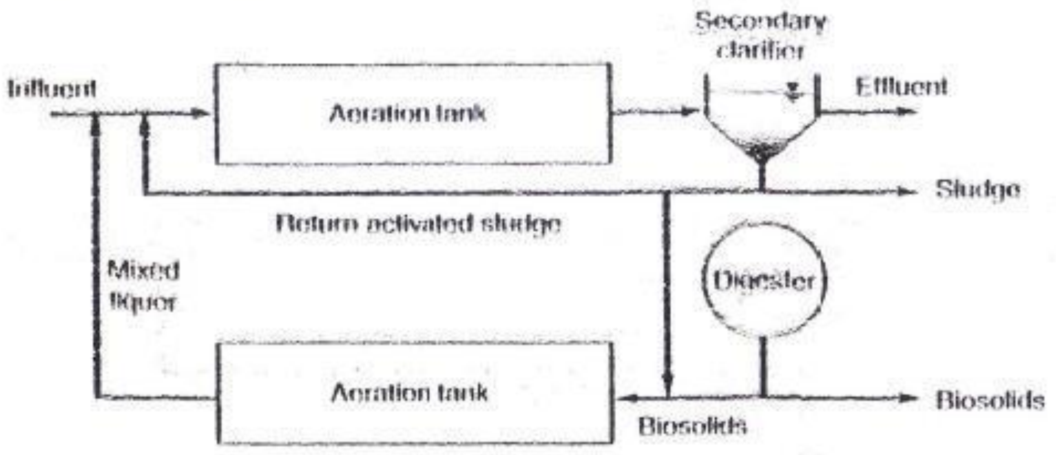
Ref: Metcalf & Eddy, 2004



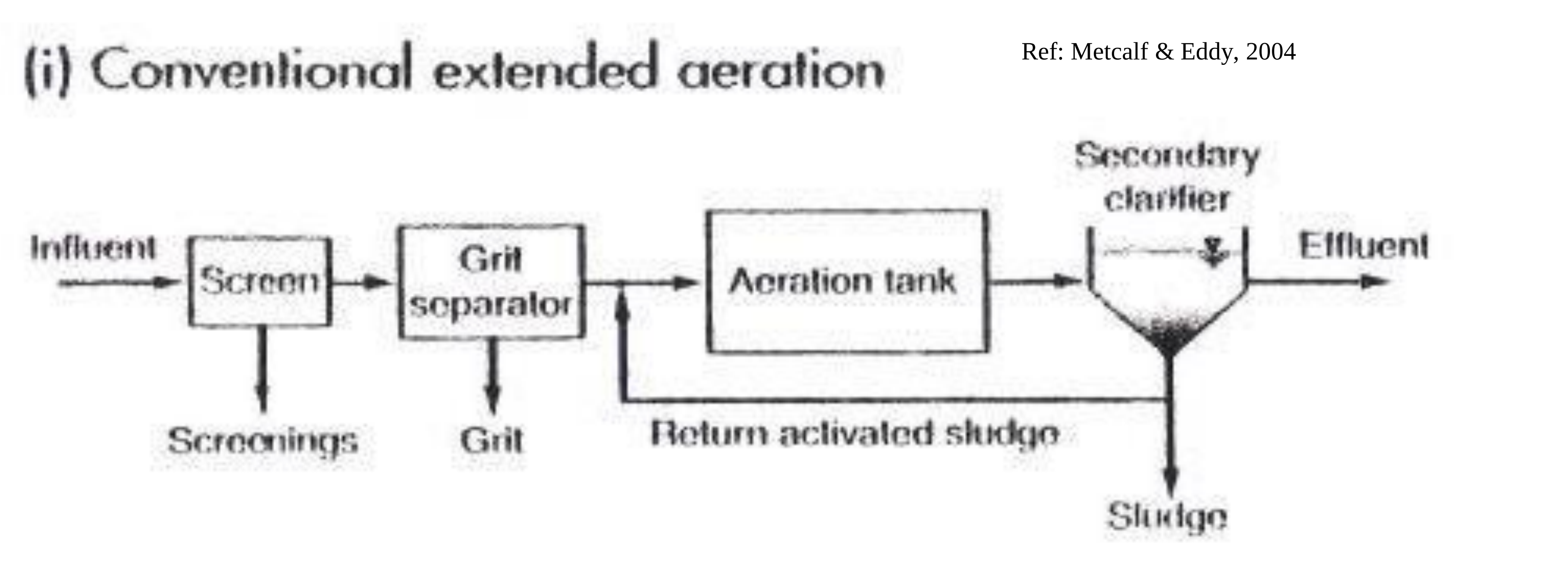
The two-sludge process is a two-stage system using high-rate activated sludge for BOD removal followed by a second stage for nitrification, which is operated at a longer SRT. A portion of the wastewater influent may be bypassed around the first stage to provide BOD and suspended solids for the nitrification process and promote flocculation and solids capture in secondary clarification. The main reason to separate the BOD removal stage from the nitrogen removal stage is to treat toxic substances in the first stage, and thus protect the more sensitive nitrifying bacteria. With better industrial treatment programs in place today, BOD removal and nitrification are done more commonly in a single-sludge process.

(h) Kraus process

Ref: Metcalf & Eddy, 2004



The Kraus process is a variation of the step aeration process used to treat nitrogen deficient industrial wastewater. Digester supernatant is added as a food source to a portion of the return sludge in a separate aeration tank designed to nitrify. The resulting mixed liquor is then added to the main plug-flow aeration system. Besides providing nitrogen, nitrate is available to serve as an electron acceptor in the event of oxygen limitations



- similar to conventional plug-flow process

- It operates in the endogenous respiration phase of the growth curve which requires a low organic loading and long aeration time (low F/M, high θc)

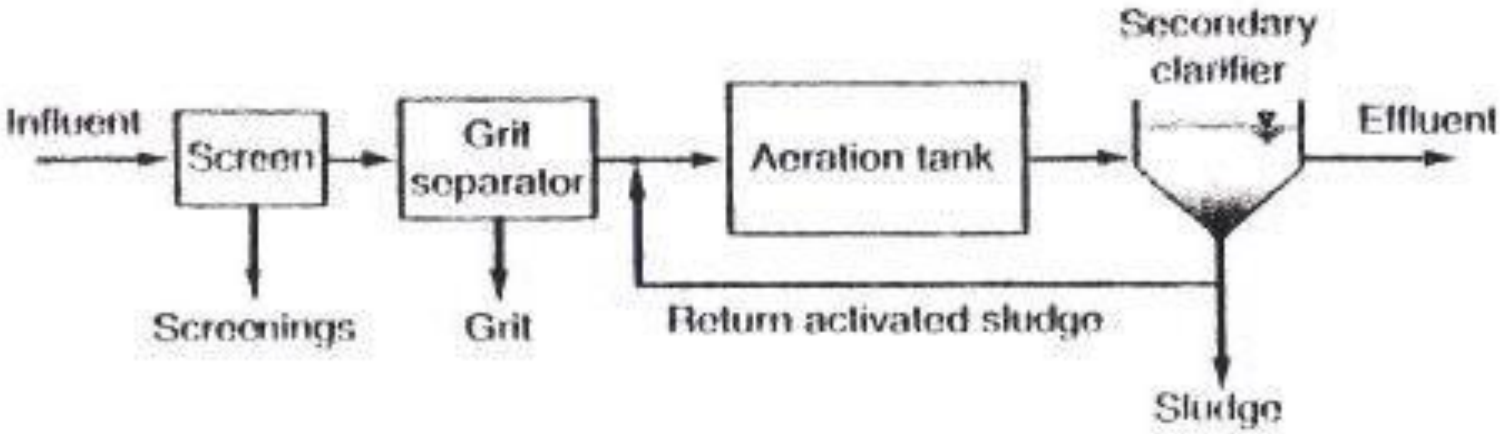
- Low F/M ratio
  θc = SRT =20-30days (well stabilization of biosolids)

- aeration energy use is high

- well stabilized sludge, low biosolids production → well stabilization biosolids

(i) Conventional extended aeration

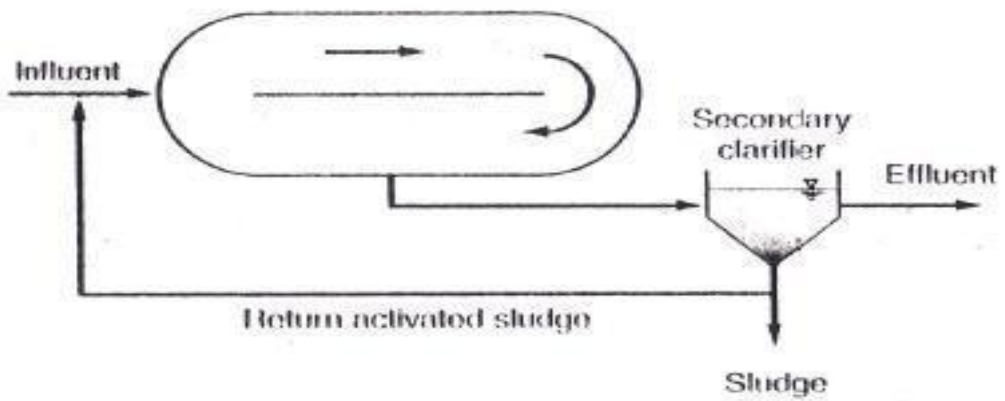
Ref: Metcalf & Eddy, 2004



The extended aeration process is similar to the conventional plug-flow process except that it operates in the endogenous respiration phase of the growth curve, which requires a low organic loading and long aeration time. Because of the long SRTs (20 to 30 d) and τ's on the order of 24 h, aeration equipment design is controlled by mixing needs and not oxygen demand. The process is used extensively for preengineered plants for small communities. Generally, primary clarification is not used. Secondary clarifiers are designed at lower hydraulic loading rates than conventional activated-sludge clarifiers to better handle large flowrate variations typical of small communities. Although the biosolids are well stabilized, additional biosolids stabilization is required to permit beneficial reuse

j) Oxidation ditch

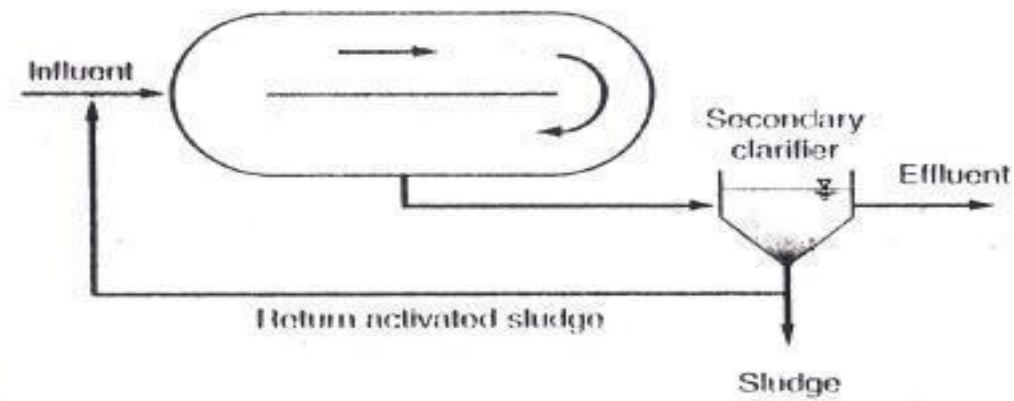
Ref: Metcalf & Eddy, 2004



The oxidation ditch consists of a ring- or oval-shaped channel equipped with mechanical aeration and mixing devices. Screened wastewater enters the channel and is combined with the return activated sludge. The tank configuration and aeration and mixing devices promote unidirectional channel flow, so that the energy used for aeration is sufficient to provide mixing in a system with a relatively long hydraulic retention time. The aeration/mixing method used creates a velocity from 0.25–0.30 m/s (0.8–1.0 ft/s) in the channel, which is sufficient to keep the activated sludge in suspension. At these channel velocities, the mixed liquor completes a tank circulation in 5–15 min, and the magnitude of the channel flow is such that it can dilute the influent wastewater flow by a factor of 20–30. As a result, the process kinetics approach that of a complete-mix reactor, but with plug flow along the channels. As the wastewater leaves the aeration zone, the DO concentration decreases and denitrification may occur. Brush-type or surface-type mechanical aerators are used for mixing and aeration (see Sec. 5–12 in Chap. 5). Secondary sedimentation tanks are used for most applications, and in some cases intrachannel clarifiers have been used

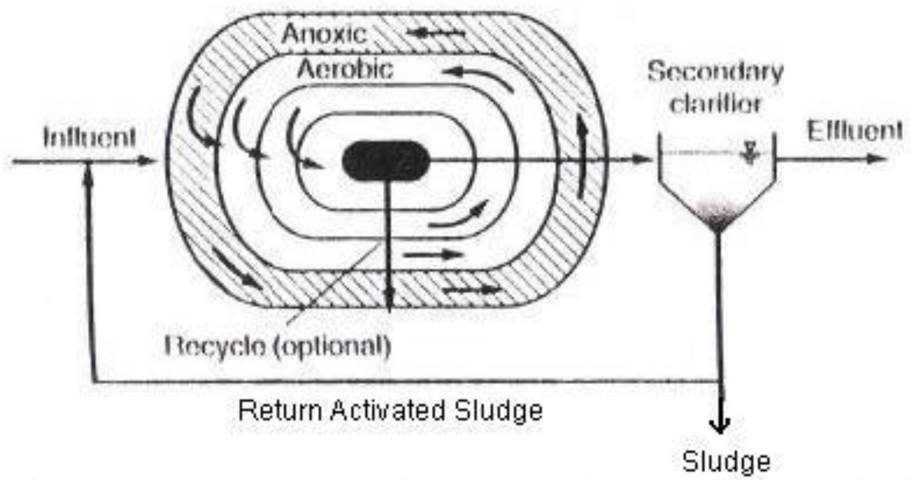
j) Oxidation ditch

Ref: Metcalf & Eddy, 2004



- Large structure, greater space requirement
- Requires more aeration energy than conventional CMAS and plug flow treatment
- Uses less energy than extended aeration well stabilized sludge, low bio-solids production

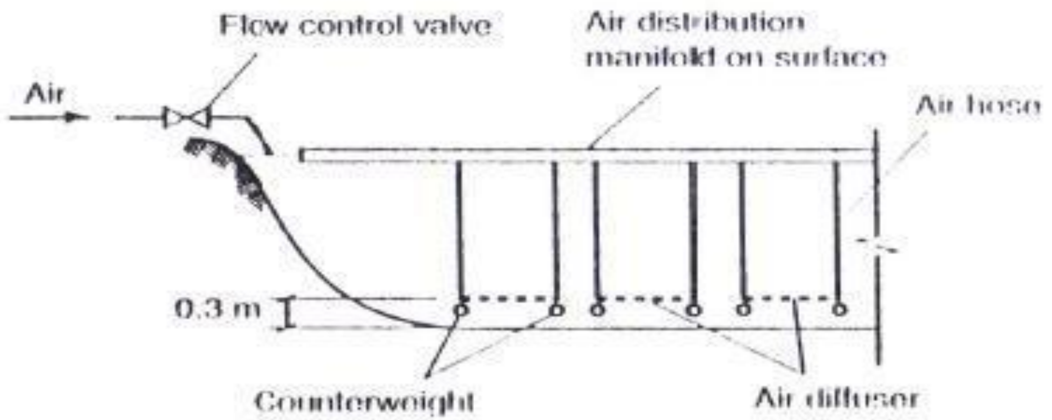
(k) Orbal™ Ref: Metcalf & Eddy, 2004



The Orbal™ process is a variation of the oxidation ditch and uses a series of concentric channels within the same structure. Wastewater enters the larger outer channel and mixed liquor flows typically toward the center of the structure through at least two more channels before entering an internal clarifier or a distribution box. Disk aerators mounted on a horizontal shaft provide aeration. Channel depths range up to 4.3 m (14 ft). One version of the Orbal design (Bionutre™) limits the aeration rate in the first channel so that both nitrification and denitrification (anoxic condition) occur

(m) Biolac™ process

Ref: Metcalf & Eddy, 2004

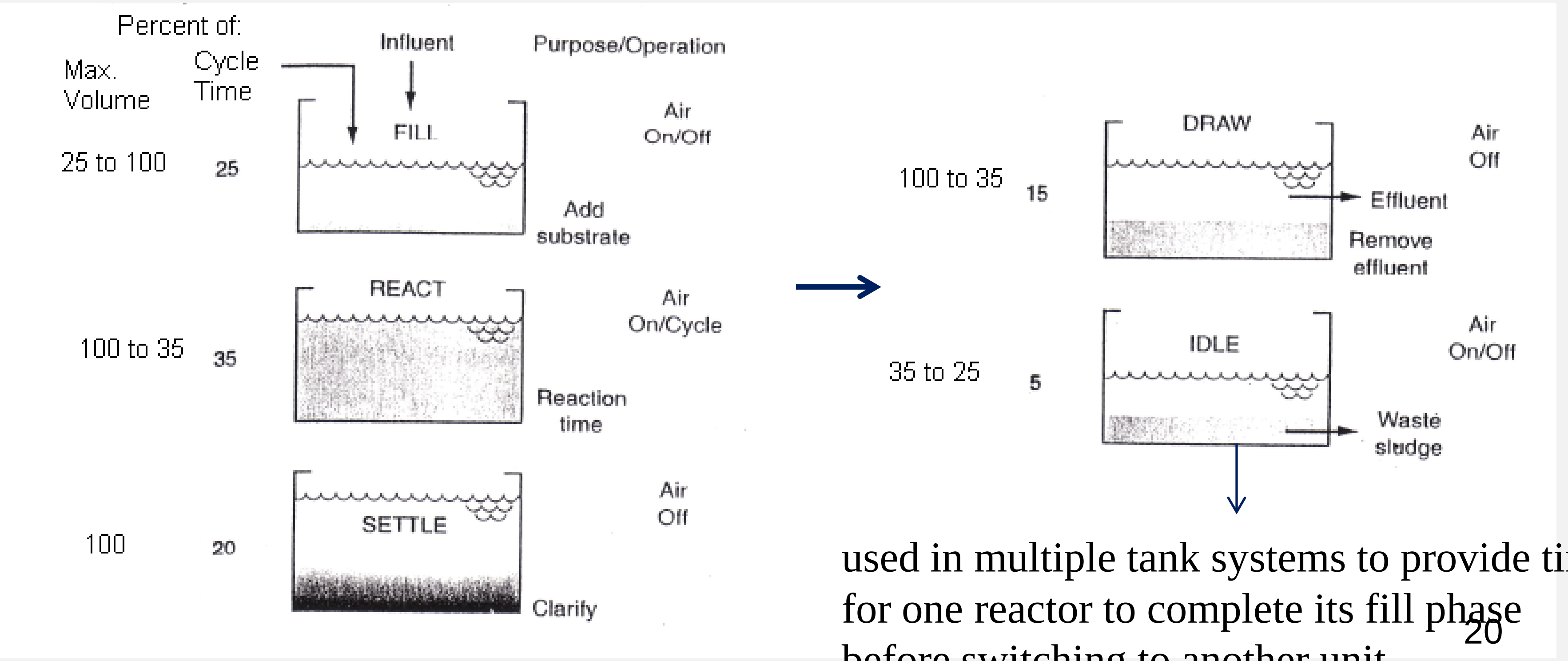


Biolac is a proprietary process that combines long solids retention times with submerged aeration in earthen basins. Fine bubble membrane diffusers are attached to floating aeration chains that are moved across the basin by the air released from the diffusers. Aeration basins are typically 2.4 to 4.6 m (8 to 15 ft) deep. The process can be designed for nitrification since the SRT ranges from 40 to 70 d. The F/M ratio ranges from 0.04 to 0.1 and the MLSS range is from 1500 to 5000 mg/L. A variation of the standard process, known as the "wave oxidation modification," allows biological nitrification and denitrification to occur simultaneously by using timers to cycle the air flowrate to each aeration chain. Either an internal or external clarifier can be used

SEQUENCING BATCH REACTOR PROCESS(SBR)

- Same as activated sludge, but all steps of the process take place sequentially in one tank

- All SBR systems have 5 steps in common;



used in multiple tank systems to provide time for one reactor to complete its fill phase before switching to another unit

SEQUENCING BATH REACTOR PROCESS(SBR) (continue)

A typical cycle may consists of (3h fill, 2h aeration, 0.5h settlle, 0.5h decant)

For continuous flow operations;

- at least 2 SBR tanks
- one tank receives flow while the other completes its treatment cycle

Time for a complete cycle;

Single tank system: time between begining of fill and the end of idle.

Multiple tank systems: time between begining of fill for the first reactor and the end of adle for the last reactor

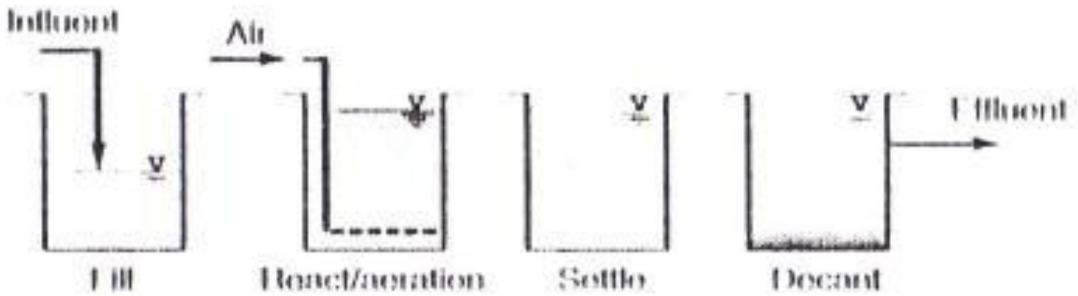
SEQUENCING BATH REACTOR PROCESS(SBR) (continue)

- A unique feature of the SBR system → no need for RAS system
- Sludge wasting usually occurs during the react phase so that a uniform discharge of solids occurs
- Aeration → Jet aerators, coarse bubble diffusers with submerged mixers

Ref: Metcalf & Eddy, 2004

Sequentially operated systems

(n) Sequencing batch reactor (SBR)



The SBR is a fill and draw type of reactor system involving a single complete-mix reactor in which all steps of the activated-sludge process occur. For municipal wastewater treatment with continuous flow, at least 2 basins are used so that one basin is in the fill mode while the other goes through react, solids settling, and effluent withdrawal. An SBR goes through a number of cycles per day; a typical cycle may consist of 3-h fill, 2-h aeration, 0.5-h settle, and 0.5-h for withdrawal of supernatant. An idle step may also be included to provide flexibility at high flows. Mixed liquor remains in the reactor during all cycles, thereby eliminating the need for separate secondary sedimentation tanks. Decanting of supernatant is accomplished by either fixed or floating decanter mechanisms. The τ's for SBRs generally range from 18 to 30 h, based on influent flowrate and tank volume used. Aeration may be accomplished by jet aerators or coarse bubble diffusers with submerged mixers (see Sec. 5–12 in Chap. 5). Separate mixing provides operating flexibility and is useful during the fill period for anoxic operation. Sludge wasting occurs normally during the aeration period

Process Kinetics

During react period→ batch kinetics apply

Q = 0

The substrate concentration is much higher initially then would be present in CMAS systems and the substrate decreases gradually as it is consumed by the biomass.

$$\frac{ds}{dt}\forall = QS_0 - QS + r_{su}V$$

$$r_{su} = -\frac{\mu_M XS}{Y(K_s + S)}$$

$$\frac{ds}{dt} = -\frac{\mu_M XS}{Y(K_s + S)}$$ Integrate wrt to time

$$K_s Ln\frac{S_0}{S_t} + (S_0 - S_t) = X(\frac{\mu_M}{Y})t$$

For nitrifiers;

$$K_N Ln\frac{N_0}{N_t} + (N_0 - N_t) = X_n(\frac{\mu_{Mn}}{Y_n})(\frac{DO}{K_0 + DO})t$$

Process Design

Because of the many design variables involved, an iterative approach is necessary in which key reactor design conditions are first assumed.