HOW TO SELECT SRT

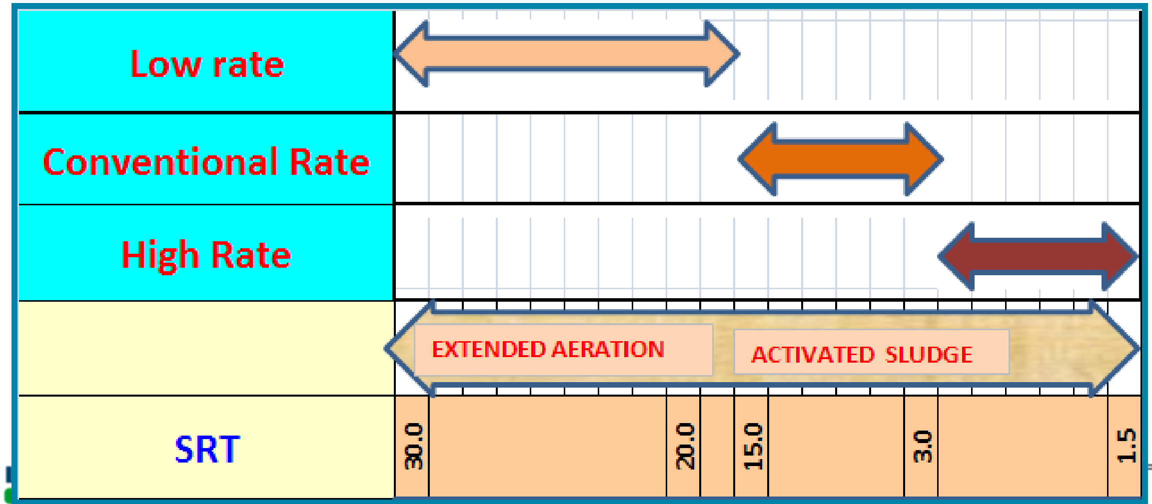
- Selection of design SRT is important as it impacts:
  - solids inventory in the bioreactor.
  - oxygen requirements.
  - sludge quantity and quality.
- The longer the SRT the larger the bioreactor volume, the higher the oxygen consumption, and the lower the sludge production.
- The longer the SRT the lower the biodegradable solids fraction.
- The longer the SRT the higher the volatile suspended solids in sludge and the lower the potential for odors.

HOW TO SELECT SRT

SRT is selected based on the following treatment requirements/Objectives:

- Wastewater Treatment without Nitrification (Carbonaceous BOD removal only).
- Wastewater Treatment with Nitrification.
- Wastewater Treatment with Nitrification & Denitrification
- Wastewater Treatment with Nitrification, Denitrification and sludge stabilization.

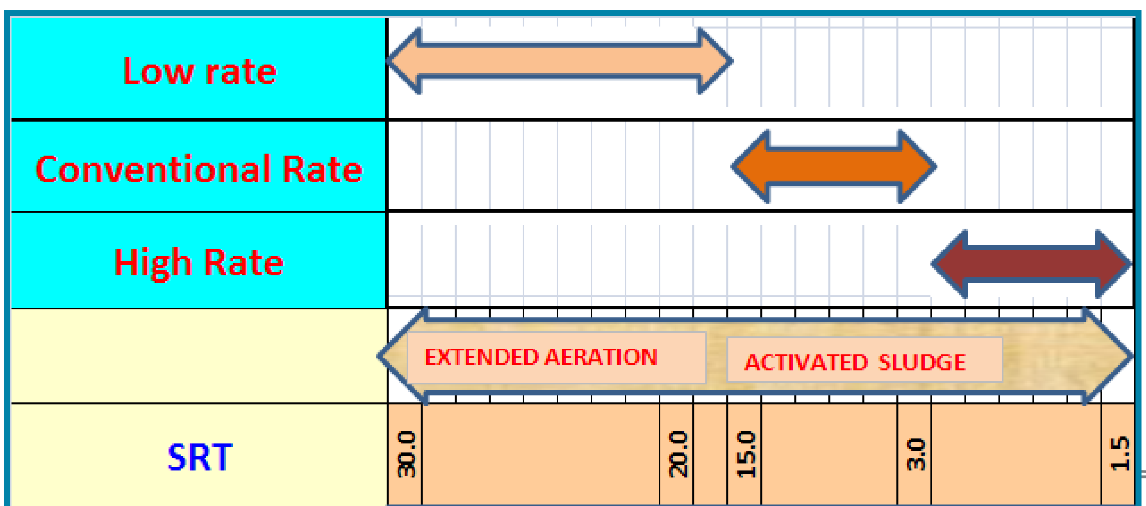
CLASSIFICATION OF ACTIVATED SLUDGE PROCESSES ON SRT



CONSULTANTS

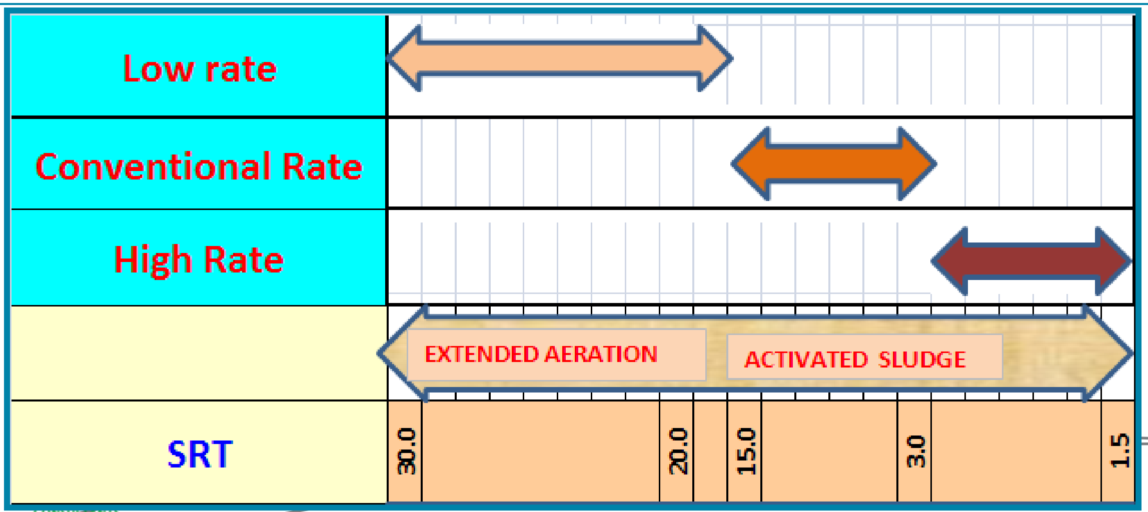
HIGH-RATE ACTIVATED SLUDGE PROCESSES

- SRT <3 days.
- Remove only BOD,COD and TSS.
- Small bioreactor volume.
- Low oxygen consumption.
- Minimum design SRT should be 1.5 days.



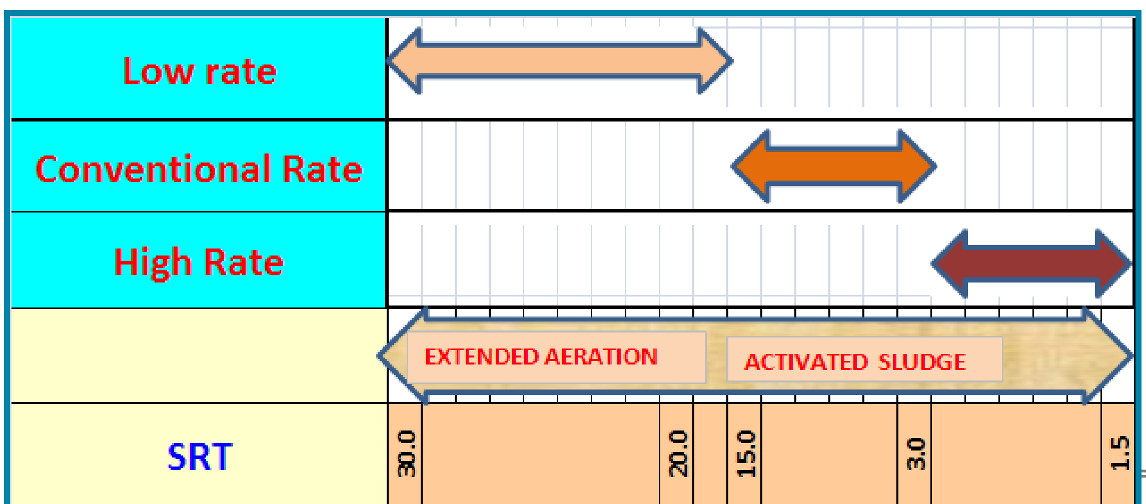
CONVENTIONAL ACTIVATED SLUDGE PROCESSES

- SRT=3-15 days
- Advantages:
  - Ease of operation.
  - Reduced sludge production.
- Disadvantages:
  - Increased oxygen consumption for carbon removal.
  - Potential for unwanted nitrification at warm temperature and long SRT.
  - Nitrification increases oxygen demand significantly.



LOW RATE ACTIVATED SLUDGE PROCESSES

- SRT>15 days
- Extended Aeration.
- Advantages:
  - Very stable operation.
  - Production of reduced quantities of stable sludge.
- Disadvantages:
  - High oxygen demand.
  - Large bioreactor volume and secondary clarifier area.



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SRT SELECTION FOR CARBON REMOVAL WITHOUT NITRIFICATION

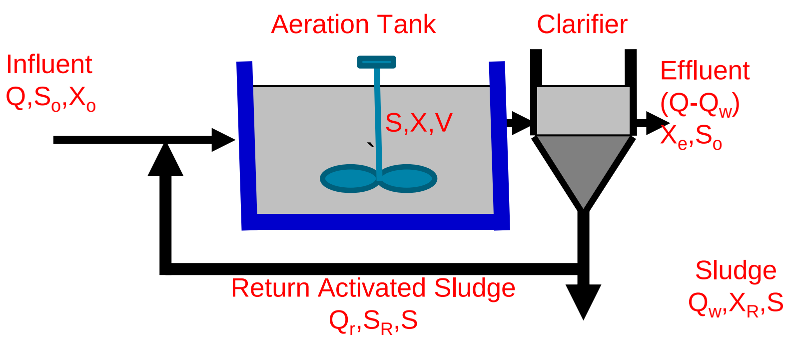
- It is difficult to avoid nitrification in many cases.
- Nitrification will result in unavoidable increase in oxygen demand.
- The designer should consider additional aeration capacity beyond what is needed for carbon removal.
- The only way to control nitrification is through the control of the operating SRT and DO.
- If nitrification can’t be prevented the required oxygen demand should be considered.

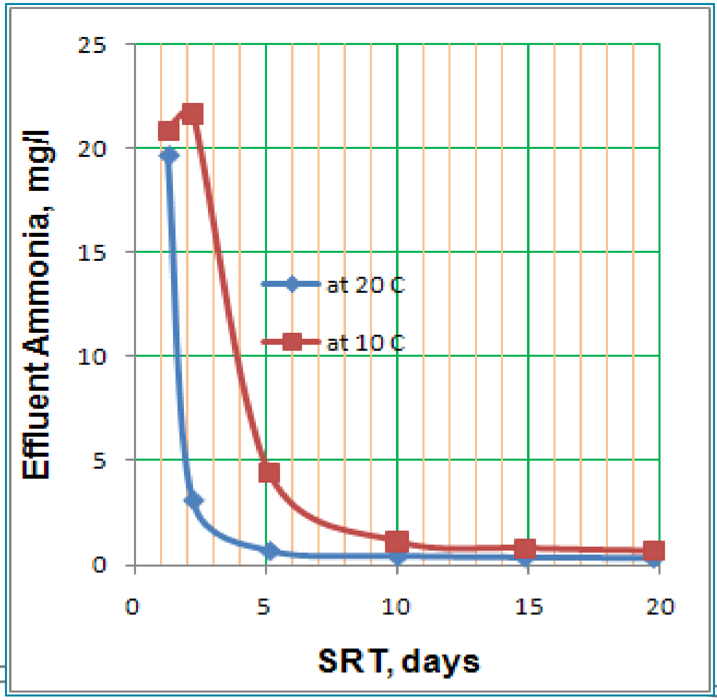
SRT SELECTION FOR CARBON OXIDATION WITH NITRIFICATION

- Nitrification is effected by the bacteria capable of oxidizing ammonia to nitrate.
- Bacteria capable of nitrification are called nitrifiers.
- Nitrifiers have slower growth rate in comparison with heterotrophic bacteria responsible for carbon oxidation.
- Longer SRT is required to prevent washout and maintain adequate population for nitrification.
- Nitrification Requirements.
  - Presence of ammonia.
  - Appropriate temperature
  - Adequate alkalinity.
  - pH near neutral
  - DO of 2 mg/l(optimal condition)
  - Sufficient SRT

COMPLICATIONS WITH PARTIAL NITRIFICATION

- Because nitrification is dependent on the growth rate of autotrophs, the only way to get partial nitrification is to hover precisely at SRT, that is, removing autotrophs from the system at the same rate as they are added to the system via growth. This is not easy to do in practice.
- The SRT at which the system would need to be run at 20 ºC in order to prevent nitrification would be < 2 days.
- The chart shows how quickly a small change in SRT influence effluent ammonia, and how low the SRT would need to be in order to prevent nitrification.





DESIGN SRT FOR NITRIFICATION(METCALF & EDDY METHOD) METHOD-1

$$\frac{1}{SRT_t} = \mu_n - k_{dn}$$

$$SRT_t = \frac{1}{\mu_n - k_{dn}}$$

$$\mu_n = \mu_{mn} \times \frac{N}{K_N + N} \times \frac{DO}{K_O + DO}$$

$$SRT_{des} = SF \times SRT_t$$

$$SF = \frac{Peak\_TKN\_Load}{Average\_TKN\_Load}$$

Where

SRT_a = Theoritical SRT , days.

SRT_{des} = Design SRT, days.

μ_n = specific growth rate for nitrifiers

k_{dn} = specific decay rate for nitrifiers

μ_{mn} = maximum specific growth rate for nitrifiers

N = ammonia concentration in the effluent,mg/l

K_N = half-velocity constant for ammonia conc., mg/l.

DO = DO concentration, mg/l

K_o = half-velocity constant for DO concentration, mg/l

SRT Table Method-1

Fifth Edition Update

WASH OUT & DESIGN SRT FOR NITRIFICATION METHOD-2

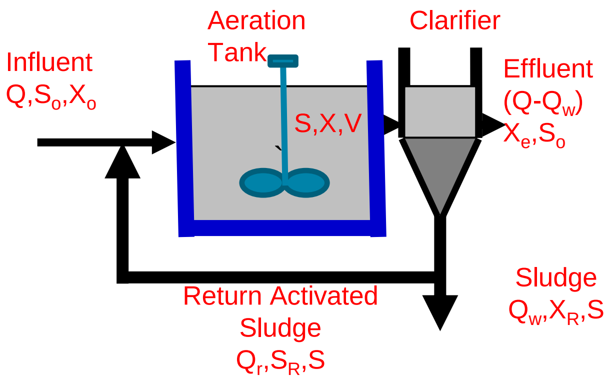
- Washout SRT is a condition that occurs when SRT is too low to allow autotrophic bacteria to accumulate.
- A safety factor of 2-2.5 should be applied to washout SRT to maintain a nitrifier inventory that is adequate to prevent washout.

$$\frac{1}{SRT_w} = \mu_n - k_{dn}$$

$$SRT_w = \frac{1}{\mu_n - k_{dn}}$$

$$\mu_{nw} = \mu_{mn} \times \frac{DO}{K_O + DO}$$

$$SRT_{des} = 2.5 \times SRT_w$$



Where
SRT_w = Washout SRT , days.
SRT_{des} = Design SRT, days.
μ_{nw} = specific growth rate for nitrifiers

SRT Table Method-2

SRT Calculations

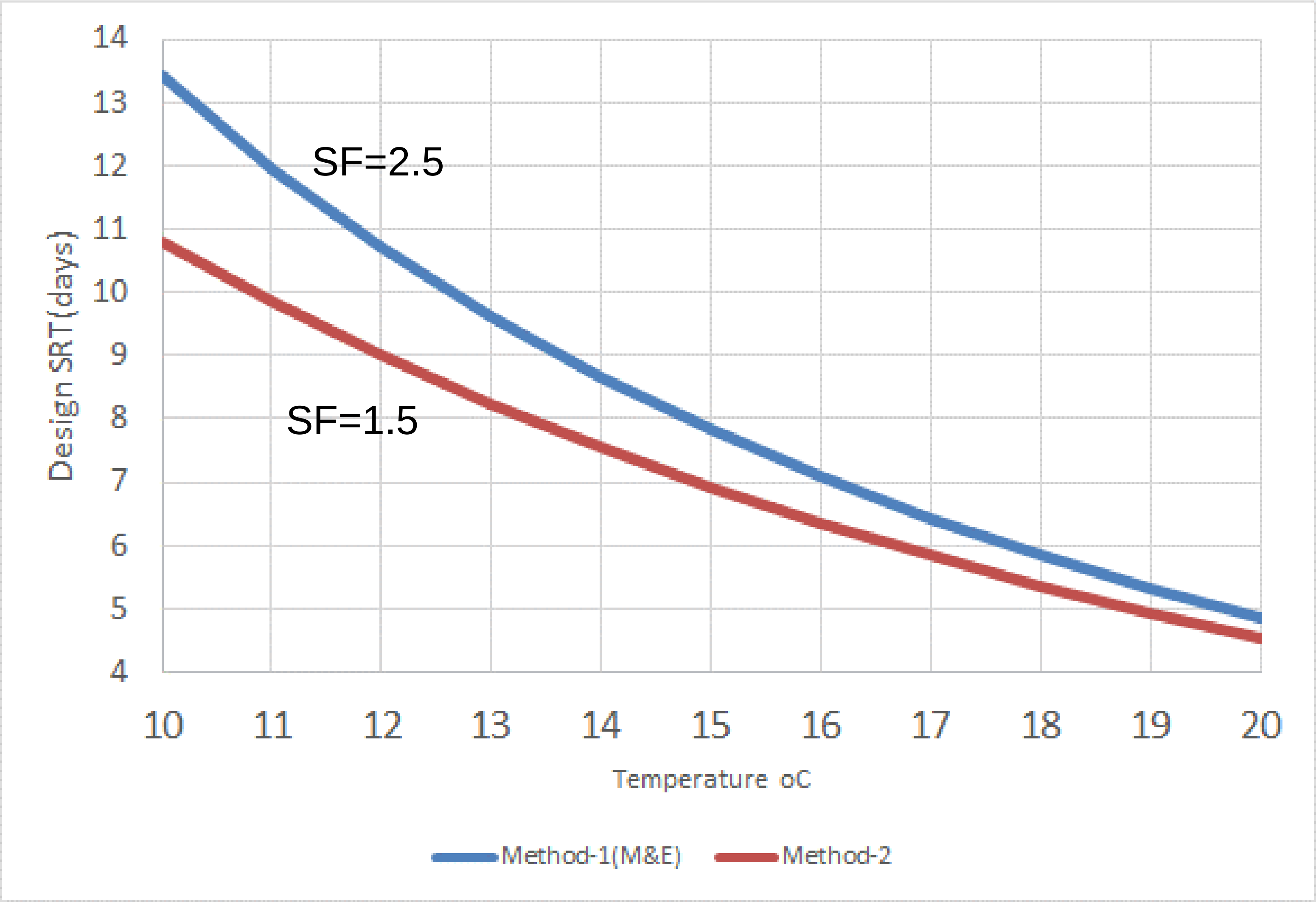
SRT REQUIRED TO MEET AMMONIA LIMIT

- The selected SRT in Method -2 should be checked with the required theoretical SRT to meet effluent ammonia limit.
- The SRT required to meet the effluent ammonia limit is:

$$\frac{1}{SRTa} = \mu_{mn} \times \frac{N}{K_N + N} \times \frac{DO}{K_O + DO} - k_{dn}$$

Where
SRT_a = SRT required to meet ammonia limit
μ_{mn} = maximum specific growth rate
N = effluent ammonia concentration
K_N = half-velocity constant for ammonia conc.
DO = DO concentration
K_O = half-velocity constant for DO concentration

DESIGN SRT CHART FOR NITRIFICATION



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SLUDGE AGE(SRT) AS PER ATV GERMAN STANDARDS

Treatment Objective	Size of the Plant	
	up to 20,000 PE	up to 100,000 PE
Wastewater Treatment w/o Nitrification	5	4
Wastewater Treatment withNitrification (Temperature 10°C)	10	8
Wastewater Treatment with Nitrification & Denitrification (Temperature 10°C)		
Vd/Vat=0.2	12	10
Vd/Vat=0.3	13	11
Vd/Vat=0.4	15	13
Vd/Vat=0.5	18	16
Wastewater Treatment with Nitrification, Denitrification, & Sludge stabilization	25	Not Recommended

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SRT IMPACT ON PROCESS PERFORMANCE AND EFFLUENT QUALITY

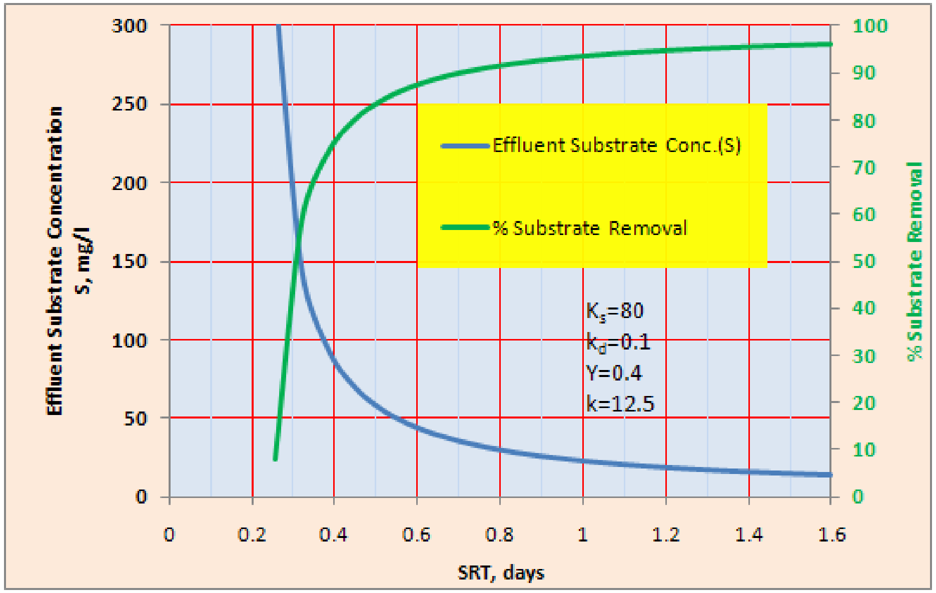
$$S = \frac{K_S\left[1 + k_d SRT\right]}{SRT(Yk - k_d) - 1}$$

$$\mu_m = kY$$

$$S = \frac{K_S\left[1 + k_d SRT\right]}{SRT(\mu_m - k_d) - 1}$$

% BOD Removal

- The effluent substrate concentration from the reactor is a direct function of SRT.
- There is a certain value of SRT below which waste stabilization doesn’t occur.
- This critical SRT value is minimum SRT.
- SRTmin is the resident time at which the cells are washed out or wasted from the system faster than they can reproduce.
- Effluent soluble BOD is unaffected by either the temperature or the SRT(At temp. above 10 and SRT>3)

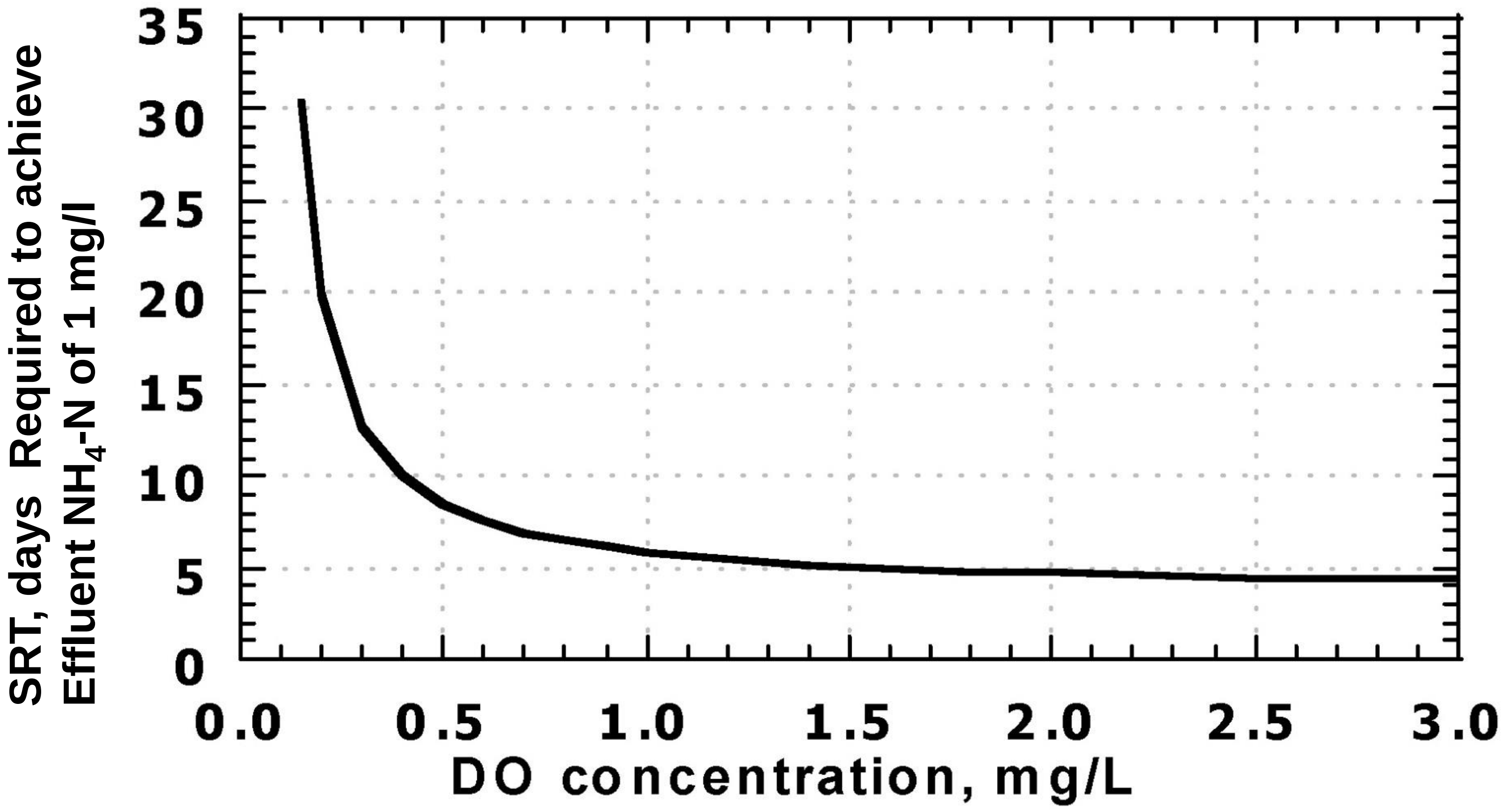


- Variations in effluent BOD are the result of variation of the particulate BOD, which is function of the effluent TSS.
- SRT has direct impact on effluent ammonia as nitrification is much more sensitive to temperature and SRT.
- Nitrification will occur when SRT is greater than the SRT corresponding with the maximum growth rate of nitrifying bacteria(Washout SRT)

WHAT IF I CAN'T ACHIEVE THE SRT NECESSARY TO NITRIFY?

- Alternatives to achieve Nitrification:
  - Build more aeration tanks.
  - Add fixed media to the existing aeration tanks(Integrated Fixed Film Activated Sludge, IFAS).
  - Add nitrifying filters.

EFFECT OF DO CONCENTRATION ON SRT



OBSERVED SLUDGE YIELD

OBSERVED YIELD ESTIMATION

- Observed yield represents the mass of gross solids produced per unit mass of substrate consumed.
- Observed yield directly impact:
  - Bioreactor size.
  - Solids production estimate.
- Methods used for estimation of sludge production:
  - Estimate of observed sludge production yield from published data from similar wastewater treatment facilities.
  - Estimation based on actual activated sludge process design in which wastewater characterization is done and the various sources of sludge production are considered and accounted for.

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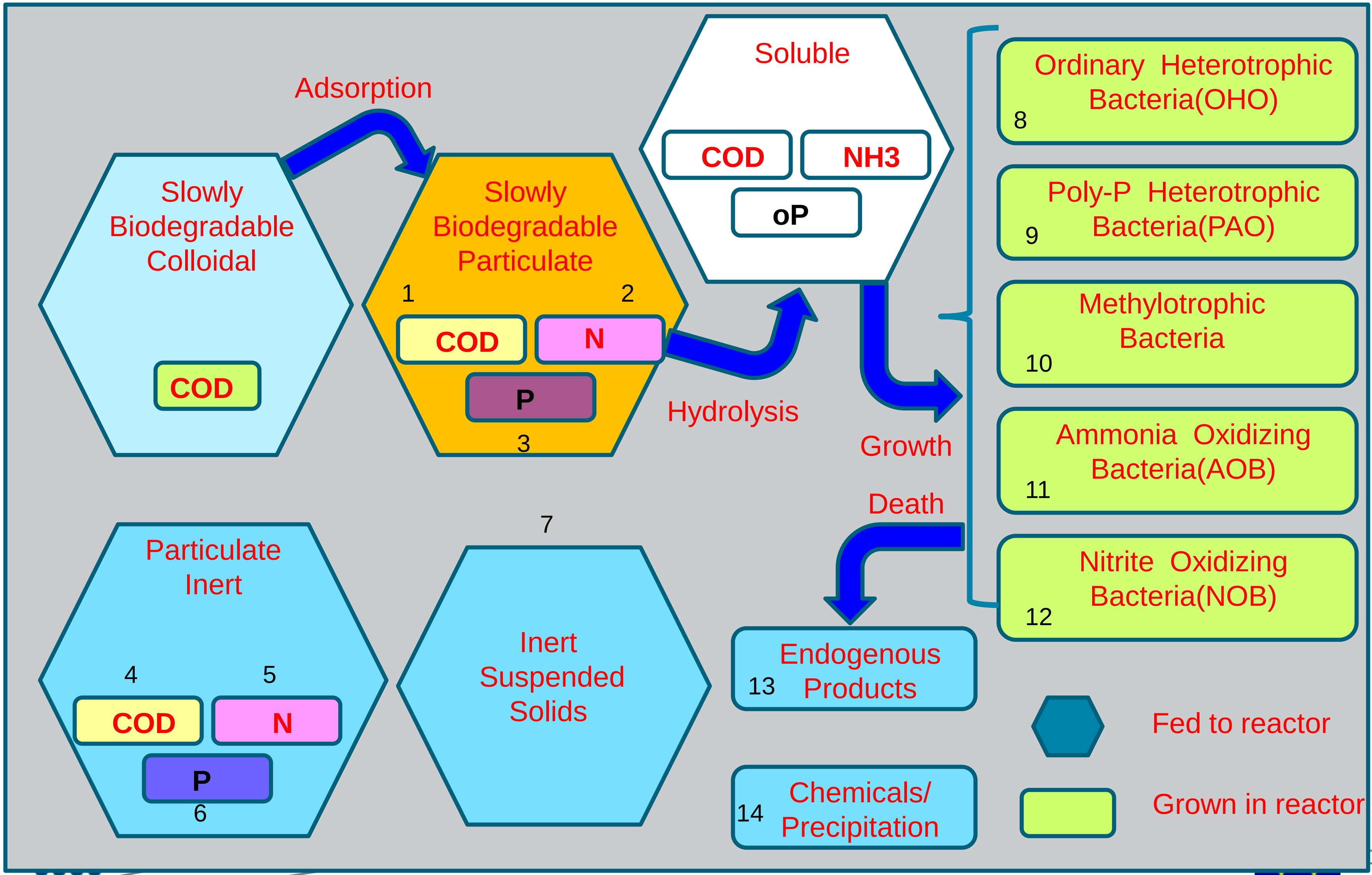
SOLIDS PRODUCTION
MLSS COMPOSITION



SOLIDS PRODUCTION(OBSERVED YIELD)

- Observed yield at existing plants is typically calculated by dividing the rate of the mass of total solids that leaves a plant as waste sludge and as effluent TSS by the rate of mass of biochemical oxygen demand that is biologically degraded.
- Solids produced is related to substrate removed.
- One of the most important parameter used in the conventional design of activated sludge design.
- Observed yield critically effects sizing of bioreactors and solids handling processes.
- Observed yield is required explicitly in the equations used in the conventional design methods.
- Observed yield is obtained either from historical plant data or, when historical data are unavailable or for new plant, determined through relationships:
  - Metcalf & Eddy equations
  - Pitter & Chudoba method
  - Daigger and Buttz method

SOLIDS PRODUCTION ESTIMATION-METCALF & EDDY

$$P_{X,VSS} = \frac{Q \times Y \times (S_0 - S)}{1 + k_d \times SRT} + \frac{f_d \times k_d \times Q \times Y(S_0 - S) \times SRT}{1 + k_d \times SRT} + \frac{Q \times Y_n \times NO_x}{1 + k_{dn} \times SRT} + Q \times nbVSS$$

A
Heterotrophic Biomass

B
Cell Debris

C
Nitrifying bacteria biomass

D
Non-biodegradable VSS in influent

$$P_{X,TSS} = \frac{A}{f_{VSS}} + \frac{B}{f_{VSS}} + \frac{C}{f_{VSS}} + D + Q \times ISS$$

$$TSS = VSS + ISS$$

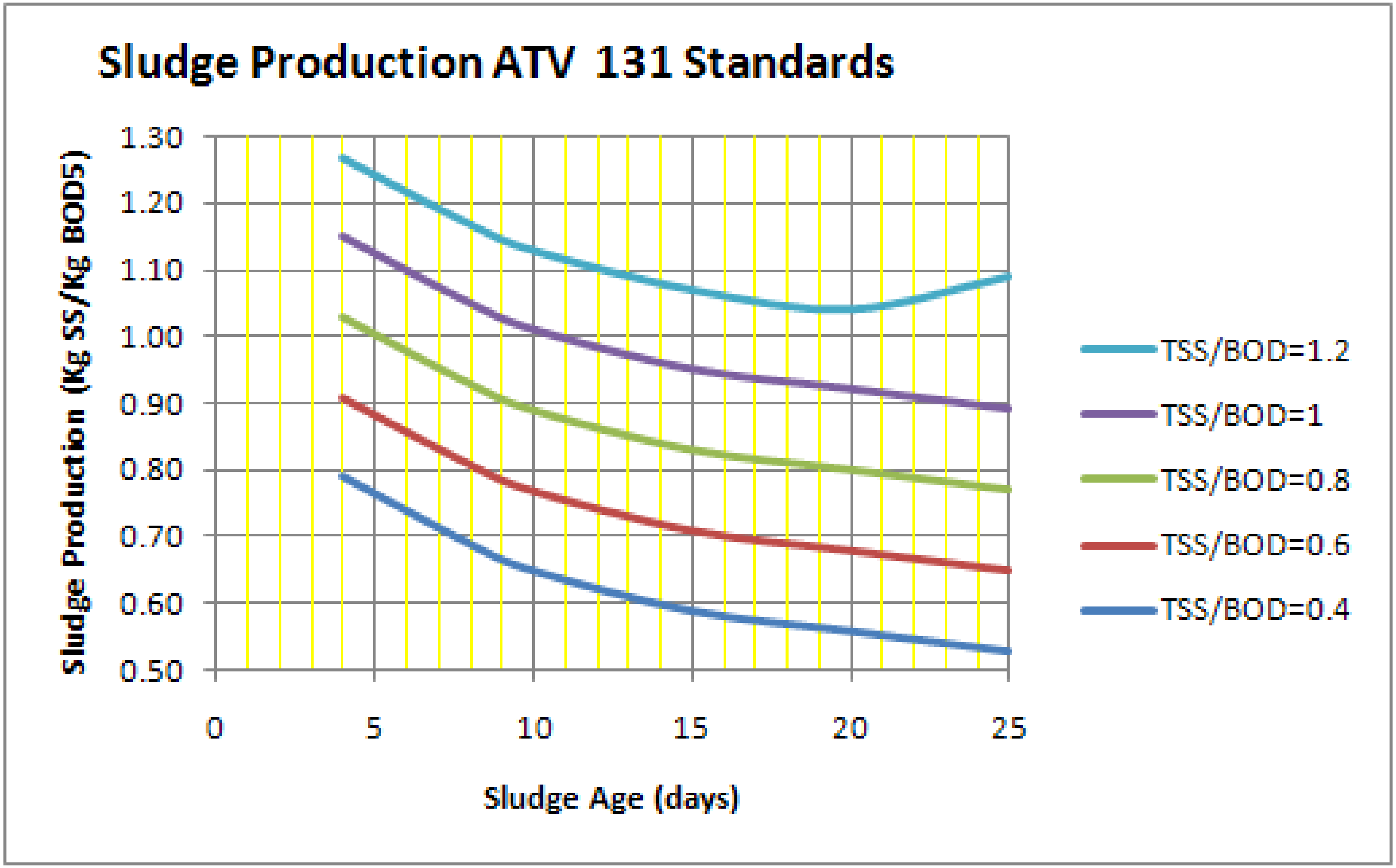
Where

$P_{X,VSS}$	= net waste activated sludge produced, kg VSS/day.
$P_{X,TSS}$	= net waste activated sludge produced, kg TSS/day.
Q	= Average influent flow
Y	= Biomass yield for heterotrophic bacteria
Y_n	= Biomass yield for nitrifiers
S_0	= influent substrate concentration (mg/l)
S	= effluent substrate concentration (mg/l)
k_d	= endogenous decay coefficient, 1/day
k_{dn}	=endogenous decay coefficient for nitrifying organisms, 1/day
SRT	= sludge age, days
f_d	= fraction of biomass that remains as cell debris
nbVSS	= non-biodegradable volatile suspended solids concentration n the influent, mg/l
No_x	= concentration of NH4-N in the influent flow that is nitrified, mg/l
f_{VSS}	= the VSS fraction of the total biomass(default 0.85).

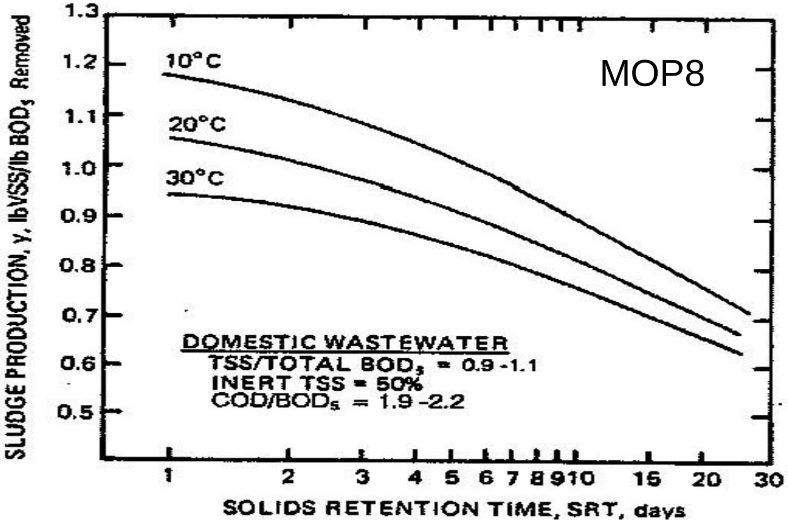
Source : Metcalf &Eddy chapter 8, page 682

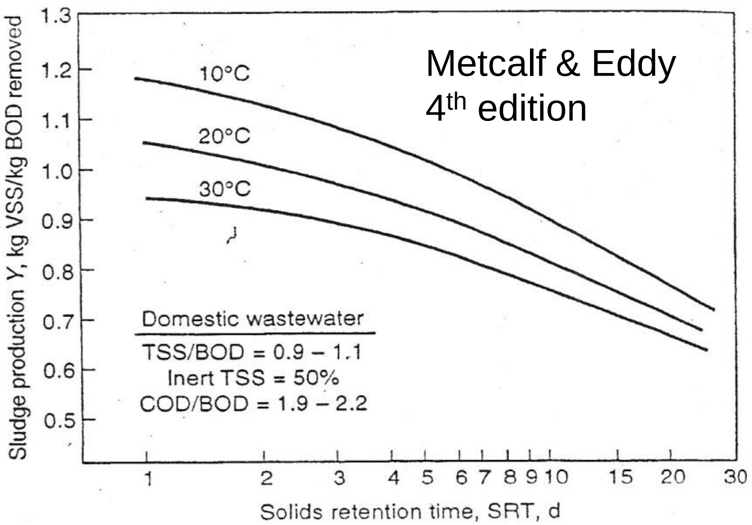
Solids Production

SOLIDS PRODUCTION IN GERMAN ATV STANDARDS



CONFUSION REGARDING SLUDGE PRODUCTION IN CURVES GIVEN IN AMERICAN REFERENCES





- The American wastewater industry reference for quantifying sludge production has been the Water Environment Federation Manual of Practice No. 8(MOP8), Design of Municipal WWTPs.
- Different editions of MOP8 have caused confusion as the units on the sludge production have alternated between volatile solids and total solids. The latest edition reported the units in volatile solids.
- Given that VSS/TSS fraction ranges from 0.75 to 0.83 this error in units would introduces a 15 to 25% uncertainty factor.

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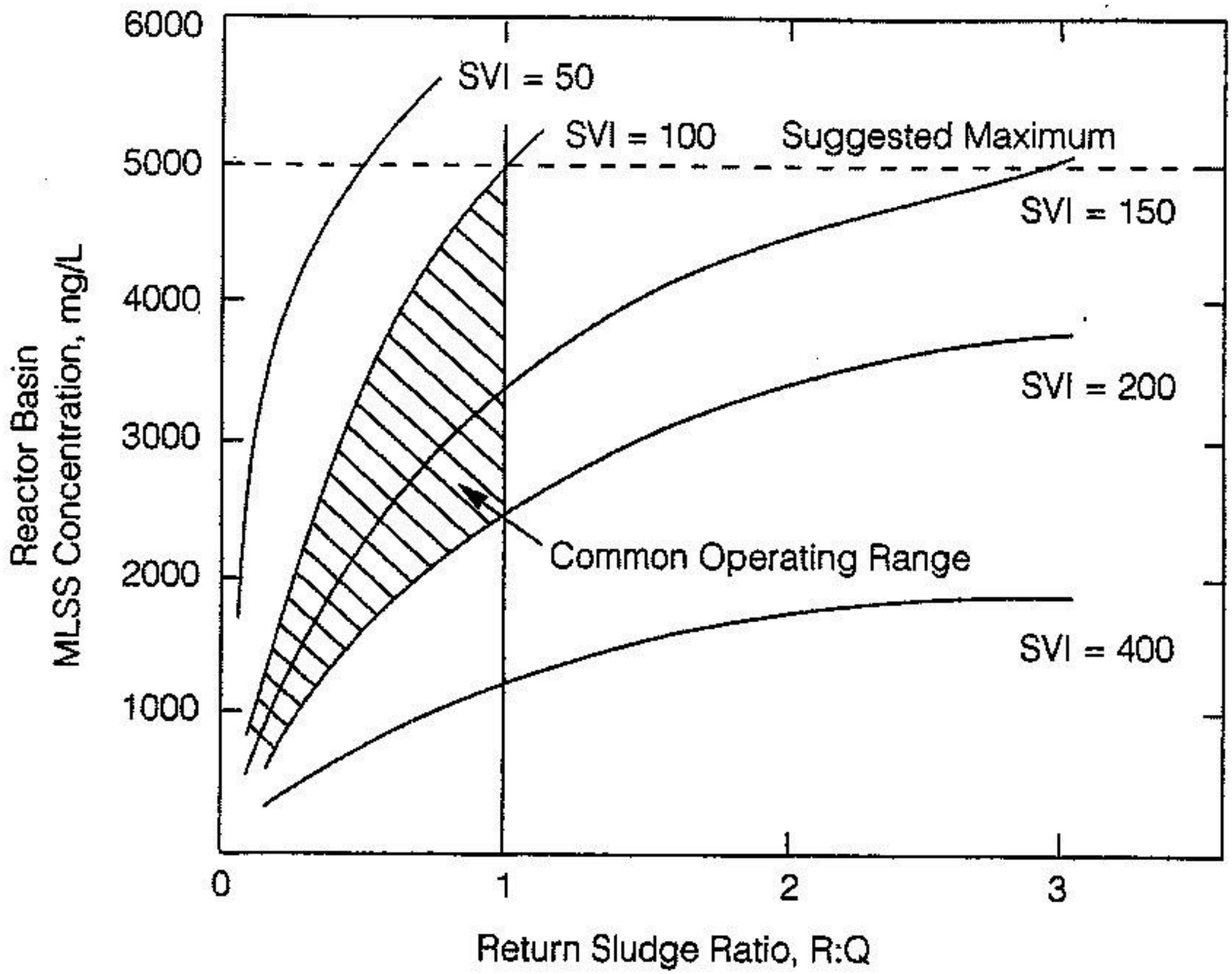
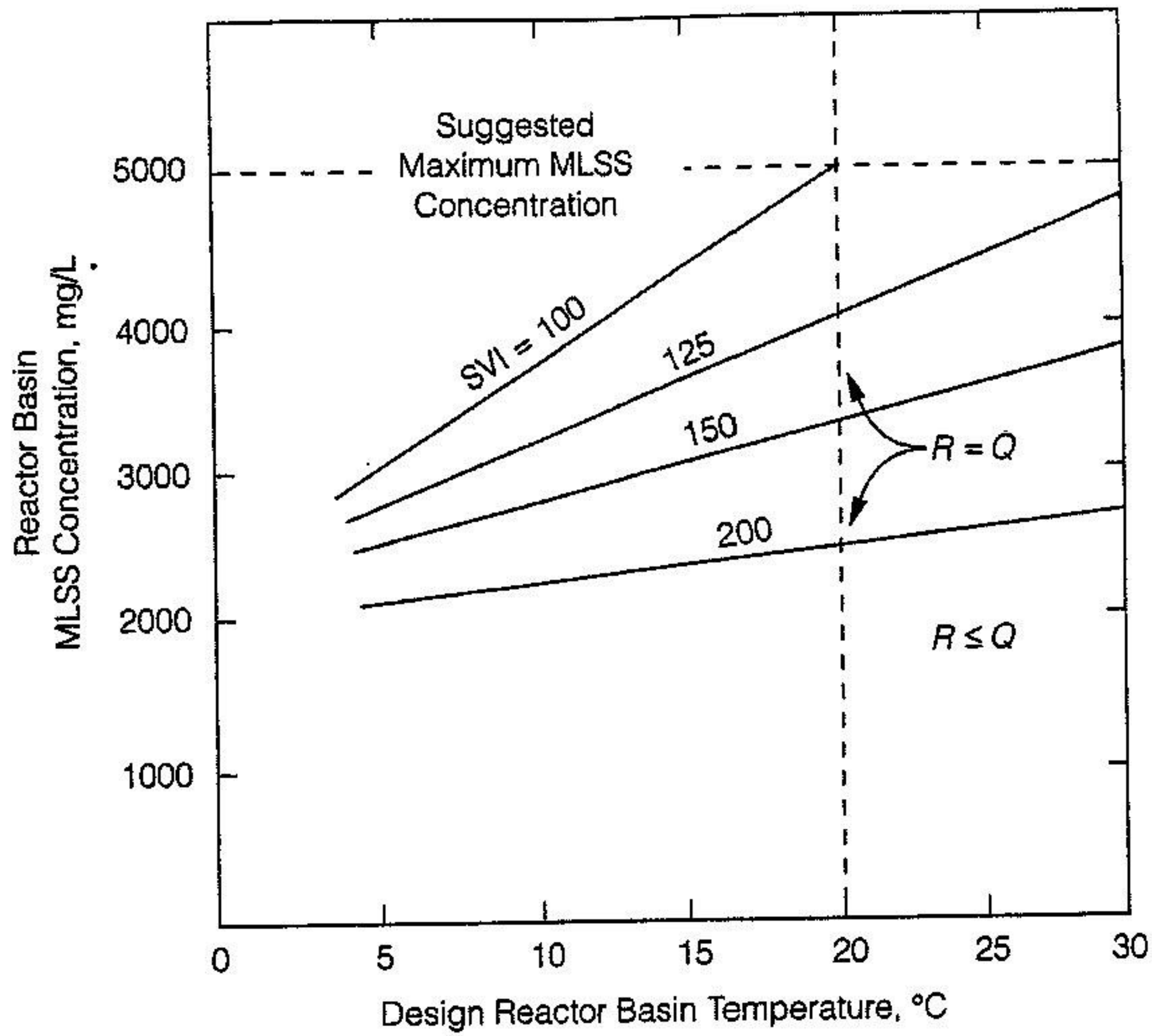
MLSS SELECTION

- Selection of MLSS may be determined by trial and error in the design process.
- Optimizing the aeration tank and clarifier design should be based on:
  - SRT
  - Oxygen transfer limitations
  - Solids settling characteristics
  - Allowable solids loading rate to the secondary clarifier
- Design MLSS concentration range between 1500 and 4000 mg/l for activated sludge plants.
- Solids settling and thickening properties often dictate final selection of MLSS concentration.
- Membrane bioreactors MLSS may reach 10,000 mg/l.
- Design MLSS impact:
  - Bioreactor volume.
  - Secondary clarifier surface area.
- High design MLSS reduces bioreactor volume but increases the solid loading rate to clarifiers.

DESIGN MLSS VERSUS SLUDGE VOLUME INDEX(SVI)



DESIGN MLSS VERSUS TEMPERATURE & SLUDGE VOLUME INDEX(SVI)



SELECTION OF OTHER OPERATING PARAMETERS

- Dissolved Oxygen(DO).
  - A minimum of 2mg/l must be maintained for carbon oxidation.
  - For nitrification, DO consideration are incorporated into the selection of SRT for nitrification.
- pH
  - A pH of 7 to 9 standard unit is assumed. Adjustmentys to the nitrification SRT are needed at pH below 7.
- Temperature
  - For carbon oxidation, temperature are incorporated into the selection of SRT and net yield.
  - For nitrification, temperature are incorporated into the selection of SRT for nitrification

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OXYGEN REQUIREMENTS

- The oxygen required for the biodegradation of carbonaceous material is determined from a mass balance using the bCOD concentration of treated wastewater and the amount of wasted biomass.
- IF all bCOD is oxidized to CO2 and H_2O, the oxygen demand would be equal to the bCOD concentration.
- Bacteria only oxidized a portion of the bCOD to provide energy and use a portion of the bCOD for cell growth.
- Oxygen is also consumed for endogenous respiration.

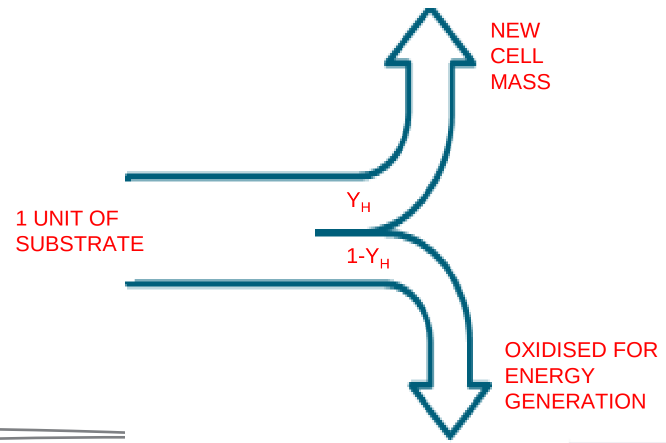
$$Oxygen\_used = bCOD\_removed - COD\_of\_waste\_sludge$$

COD of cell tissue = 1.42 g COD/g VSS

Without nitrification

$$R_o = Q(S_o - S) - 1.42 P_{X,bio}$$

Where
$P_{X,bio}$ = wasted biomass as VSS, kg /day.
Q = Average influent flow
S_o = influent substrate concentration (mg/l)
S = effluent substrate concentration (mg/l)



OXYGEN REQUIREMENTS WITH NITRIFICATION

- When nitrification is included in the process, the total oxygen requirements will include the oxygen required for removal of carbonaceous material plus the oxygen required for ammonia and nitrite oxidation to nitrate.

$$R_o = Q(S_o - S) - 1.42 P_{X,bio} + 4.33 Q(NO_x)$$

Where

R_o	= total oxygen required, g/d
$P_{X,bio}$	= wasted biomass as VSS, g /day.
Q	= Average influent flow
S_o	= influent substrate concentration (mg/l)
S	= effluent substrate concentration (mg/l)
NO_x	= nitrogen oxidized, g/d.