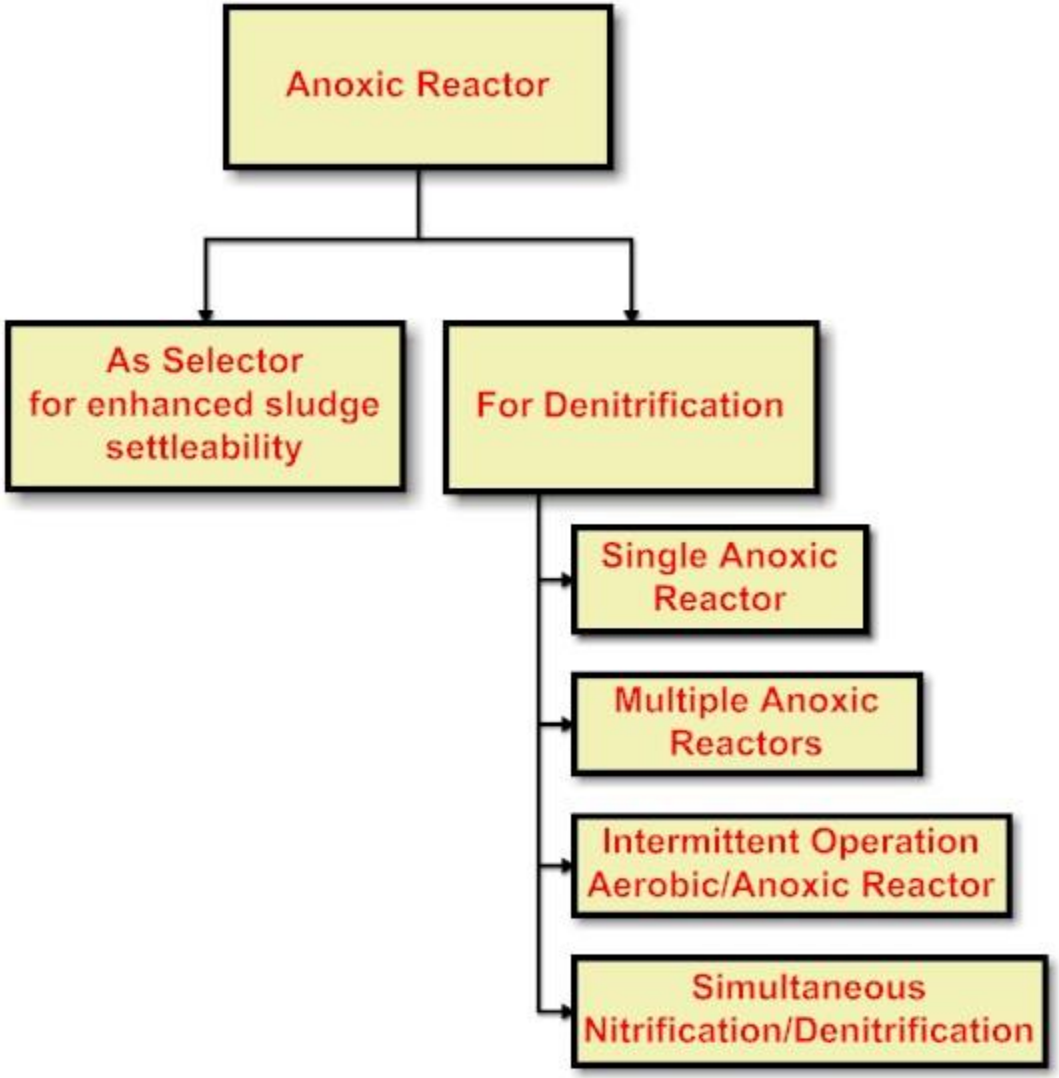
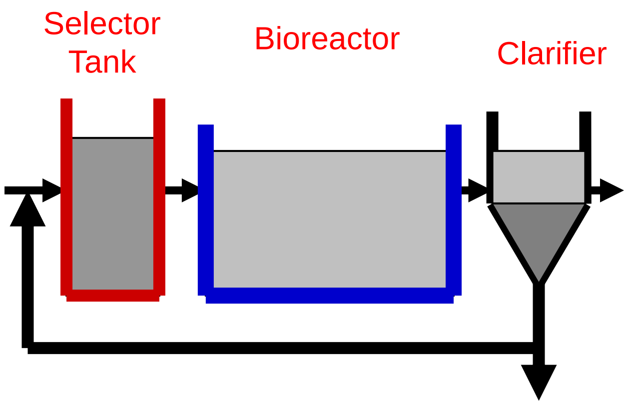
ANOXIC BIOREACTOR SIZING

ANOXIC BIOREACTORS



SELECTOR TANK

- Small tanks located upstream of the aeration tanks that receive the wastewater for treatment and the returned RAS to limit the growth of organisms that do not settle well. They are called selectors because they select the floc forming organisms.
- Selectors are naturally incorporated into the biological nitrogen and phosphorus removal processes.



- Purpose
  - Provides initial zone of high F/M ratio.
  - Encourages rapid uptake of substrate
  - Promotes growth of floc formers
  - Anoxic or anaerobic conditions inhibit growth of filamentous bacteria.
  - Improve the settlement

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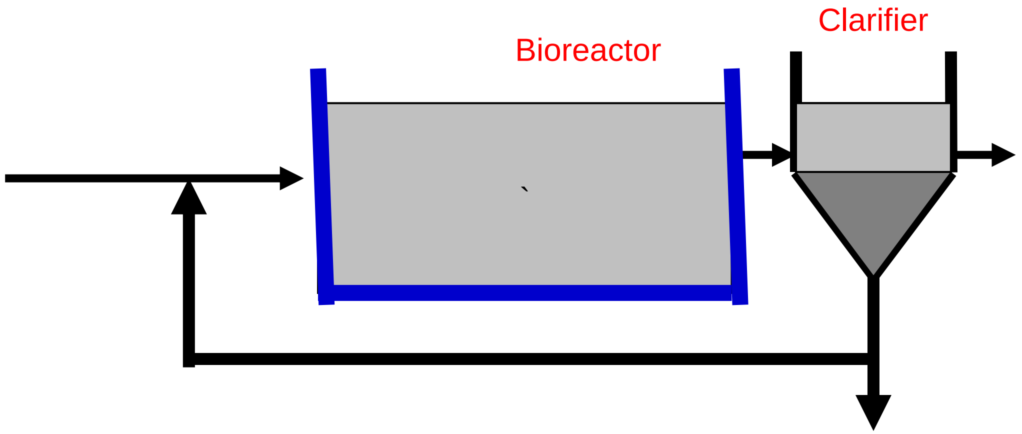
PREVENTION OF ACTIVATED SLUDGE BULKING

- The biggest cause of sludge bulking is that caused by the growth of filamentous bacteria in the aeration tank.
- The filamentous bacteria grow because they have the correct environmental conditions to favor their grow. Most filaments can only grow in aerobic conditions.
- The best remedial methods involve changing the conditions so that other bacteria, the floc forming bacteria, are encouraged to grow.
- It has been found that to encourage the growth of floc formers the F/M ratio at the beginning of treatment needs to be high.



DESIGN FOR ANOXIC SELECTOR

- Anoxic selector shall be sized on the assumption that all biodegradable substrate be removed within the selector volume under high F/M ratio.
- Recommended design F/M=2 to 5 Kg BOD_5/kg MLSS.d.
- Multiple zones within the selector are recommended to provide an F/M gradient and to reduce the potential for substrate breakthrough.
- Selectors can be aerobic where it has the advantage that the volume is part of the carbon removal and/or nitrification aerobic volume.

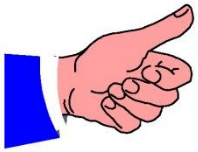
DENITRIFICATION CAPACITY/POTENTIAL

- The maximum denitrification capacity is determined by:
  - The available amount of bsCOD or BOD in influent wastewater to the anoxic zone.
  - Amount of bsCOD or BOD required for nitrate reduction (bsCOD/NO3-N ratio).

$$\frac{bsCOD}{\mathrm{NO_3-N}} = \frac{2.86}{1-1.42Y_n}$$

$$Y_n = \frac{Y}{1+k_d SRT}$$

Where
$bsCOD/NO_3$-N = required ratio of bsCOD to NO_3-N, g bsCOD/g NO3-N.
Y_n = net biomass yield, g VSS/g bsCODr
Y = biomass yield for heterotrophic bacteria(0.4 g VSS/g bsCOD).
k_d = endogenous decay coefficient for heteretrophic bacteria, g VSS/g VSS.d.



A general rule of thump is that 4 kg of wastewater BOD is needed per kg of NO3-N to be removed through biological treatment(EPA Nutrient Control Design Manual). As-Samra WWTP is designed for avearge value of 3 g.

MAXIMUM DENITRIFICATION CAPACITY

$$Maximun\_Denitrification\_Capacity = \frac{rbCODa}{Required\_ratio\_of\_bsCOD / NO_3 - N}$$

$$DC_m = \frac{rbCOD_a}{\left[\frac{bsCOD}{NO_3 - N}\right]}$$

$$\frac{bsCOD}{NO_3 - N} = \frac{2.86}{1 - 1.42 Y_n}$$

Where
bsCOD/NO_3-N = required ratio of bsCOD to NO_3-N, g bsCOD/g NO3-N.
$rbCOD_a$ = available rbCOD in the influent, mg/l, kg/day.
DC_m = maximum denitrification capacity, mg NO_3-N/l, kg NO_3-N/day.

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ANOXIC REACOR SIZING
DESKTOP DESIGN APPROACH

$$NO_r = V_{nox} \times SDNR \times MLVSS$$

$$V_{nox} = \frac{NO_r}{SDNR \times MLVSS}$$

$$SDNR = \frac{NO_{rr}}{MLVSS}$$

$$NO_{rr} = \frac{NO_r}{V_{nox}}$$

multiply NO_{rr} in mg N/l.h by 24 to get g N/m3.d

SDNR is the nitrate reduction rate in the anoxic tank normalized to the MLVSS concentration or it is the mass of nitrate-N denitrified in the anoxic zone per unit time per unit biomass in the reactor

Where:

NO_r = amount of nitrate removed in the anoxic tank, g/d.

NO_{rr} = nitrate removal rate in the anoxic tank, $g/m_3.d$.

SDNR = specific denitrificaion rate, g NO3-N/g MLVSS.d

MLVSS = mixed liquor volatile suspended solids concentration, mg/l, g/m3.

V_{nox} = anoxic tank volume, m3.

REPORTED TYPICAL SDNR VALUES

Type	Metcalf & Eddy		EPA Nutrient Control Design Manual		AS-Samra WWTP Design @ 17 °C
	g NO_3-N/g MLVSS.d	mg NO_3-N/g MLVSS.h	g NO_3-N/g MLVSS.d	mg NO_3-N/g MLVSS.h	mg NO_3-N/g MLVSS.h
Pre-anoxic tanks	0.04 - 0.42	1.67 - 17.50	0.05 - 0.15	2.08 - 6.25	3.56
Post-anoxic tanks	0.01 - 0.04	0.42 - 1.67	0.01 - 0.04	0.42 - 1.67	1.87
With methanol added			0.10 - 0.25	4.17 - 10.42	

$SDNR_{20}$ =3.85 mg NO3-N/g MLVSS.h
SDNR20=3.85*24/1000=0.09 g NO3-N/g MLVSS.d

EMPIRICAL RELATIONSHIP FOR SDNR CALCULATIONS

$$SDNR = 0.03 \times \left[\frac{F}{M}\right] + 0.029$$

For Bardenpho process at 18 °C with no primary treatment

$$SDNR_{20} = 0.03 \times \left[\frac{F}{M}\right] \times \left[\frac{F_b}{0.3}\right] + 0.029$$

Adjusted for SRT and wastewater characteristics

$$F_b = \frac{\left[\dfrac{Y_H}{1 + k_{dt} \times SRT}\right]}{\left[\dfrac{Y_H}{1 + k_{dt} \times SRT}\right] + Y_I}$$

$$k_{dt} = k_d \times 1.029^{(T-20)}$$

Influent inert VSS(Y_I) typical values

Type	Value
With primary treatment	0.1-0.3
Without primary treatment	0.3-0.5

Derivation Vnox

Where:
$SDNR_{20}$ = specific denitrificaion rate at 20 °C, g NO3-N/g MLVSS.d
F/M = anoxic zone food to microorganisms ratio, g BOD applied/g MLVSS.d in the anoxic zone
F_b = active biomass fraction of MLVSS
Y_H = heterotrophic biomass synthesis yield, g VSS/ g VSS.d.
k_d = endogenous decay rate at 20 °C, g VSS/g VSS.d
k_{dt} = endogenous decay rate at MLVSS temperature, g VSS/g VSS.d
Y_I = Influent inert VSS fraction, g VSS inert/g BOD.

SDNR CORRECTION FOR TEMPERATURE & IR

$$SDNR_T = SDNR_{20} \times \theta^{(T-20)}$$

$$SDNR_{adj} = SDNR_{IR1} - 0.0166\, In\left[\frac{F}{M_b}\right] - 0.0078$$

For IR = 2

$$SDNR_{adj} = SDNR_{IR1} - 0.029\, In\left[\frac{F}{M_b}\right] - 0.012$$

For IR = 3-4

θ = temp. Coefficient (1.026)

F/M_b = BOD F/M ratio based on anoxic volume and active biomass concentration, g/g.d.

T = Temperature

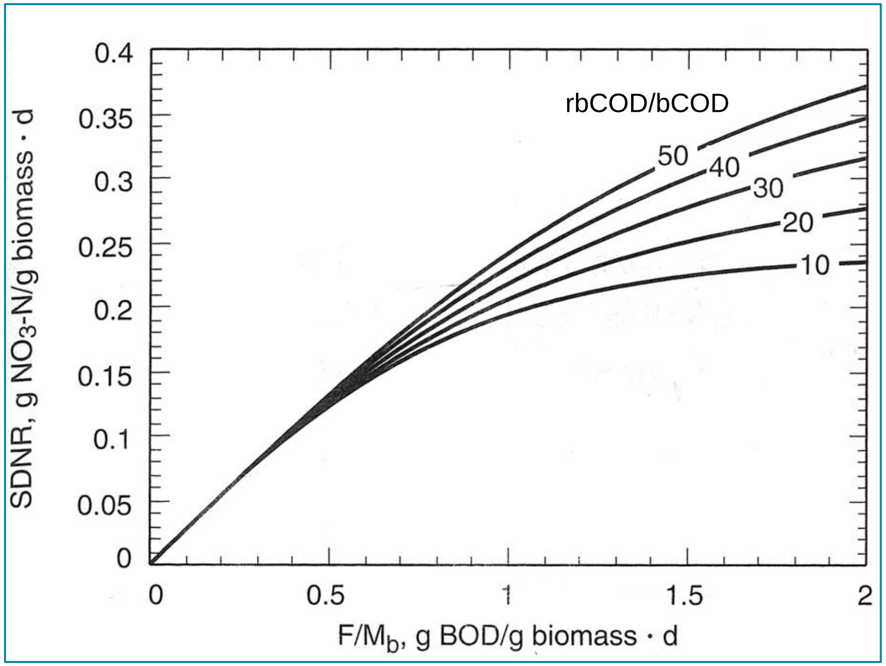
$SDNR_T$ = specific denitrificaion rate at T temperature, g NO3-N/g MLVSS.d

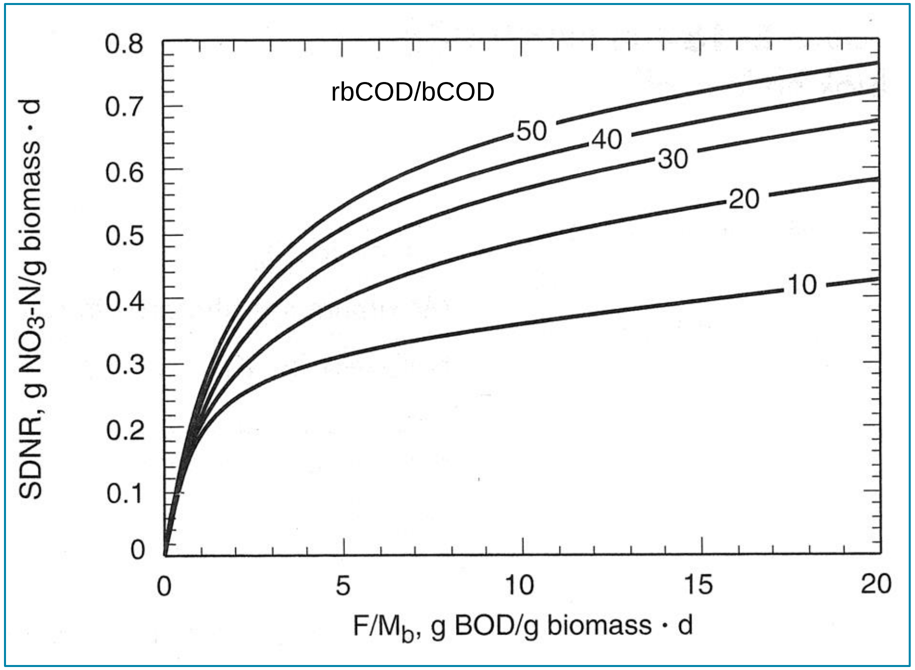
$SDNR_{20}$ = specific denitrificaion rate at 20 ºC, g NO3-N/g MLVSS.d

$SDNR_{adj}$ = SDNR adjusted for the effect of internal recycle, g NO3-N/g MLVSS.d

$SDNR_{IR1}$ = SDNR value at internal recycle ratio of 1, g NO3-N/g MLVSS.d

SDNR VERSUS F/M_b & rbCOD





$$\frac{F}{M_b} = \frac{QS_o}{(V_{nox})X_b}$$

The curves are a result of model simulations using ASM1 Model which couldn't be verified based on BioWin simulation.

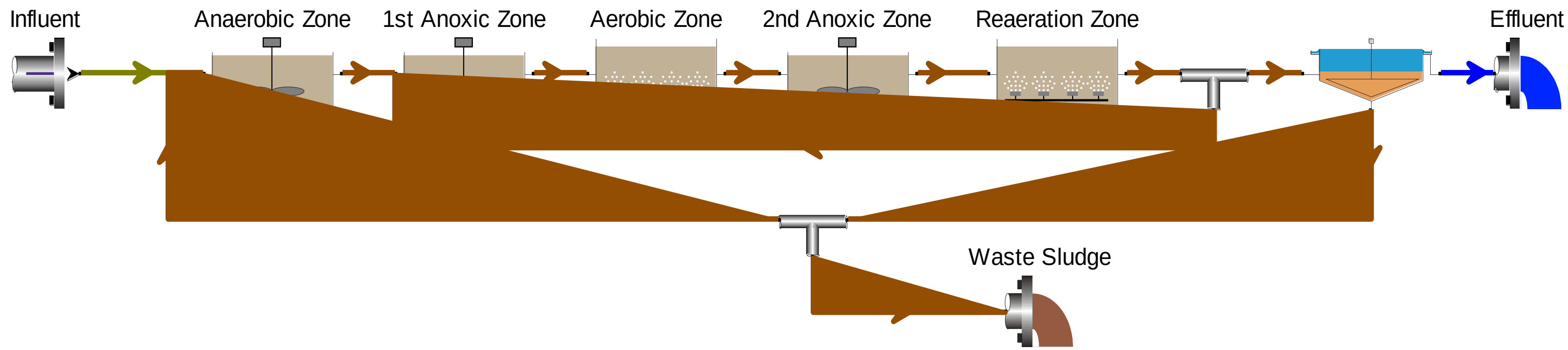
Where
F/M_b = BOD F/M ratio based on active biomass concentration, g BOD/g biomass.d
Q = influent flowrate, m3/d.
S_o = Influent BOD concentration, mg/l
X_b = anoxic zone biomass concentration, mg/l.

Source: page 755, Metcalf & eddy

CONCERNS OVER USING EMPIRICAL SDNR EQUATIONS

- Empirical relationships are limited in applications and can provide only rough estimate of SDNR, because SDNR depends on the following factors that are site and design specific:
  - Fraction of active biomass in the mixed liquor.
  - rbCOD concentration in the anoxic zone.
  - Temperature.
  - SRT.
- The use of Stensel equations has resulted in over sizing of anoxic tanks. Simulation models provide an alternative method for SDNR estimation and anoxic reactor sizing. The simulation model methodology eliminates many of the limitations of the empirical methods.
- It is recommended to use the empirical methods for conceptual stage of the projects and to use simulation model beyond the conceptual stage.

POSTANOXIC ENDOGENOUS DENITRIFICATION



- After nitrification the rbCOD is depleted, and depending upon SRT, most of the bpCOD is likely to be depleted.
- The electron donor that creates the demand for nitrate reduction is mainly form activated sludge endogenous respiration.
- SDNR ranged from 0.01 to 0.04 g NO3-N/g MLVSS under endogenous respiration.

$$SDNR_b = \frac{1.42 \times k_d \times \eta}{2.86} = 0.5 \times k_d \times \eta$$

Where:
1.42 = g O_2/g biomass VSS
2.86 = g O_2 equivalent /g NO_3-N
η = fraction of biomass that can use NO3-N in place of O2 as an electron acceptor, 0.5-0.85.
k_d = biomass endogenous decay coefficient, 1/d.

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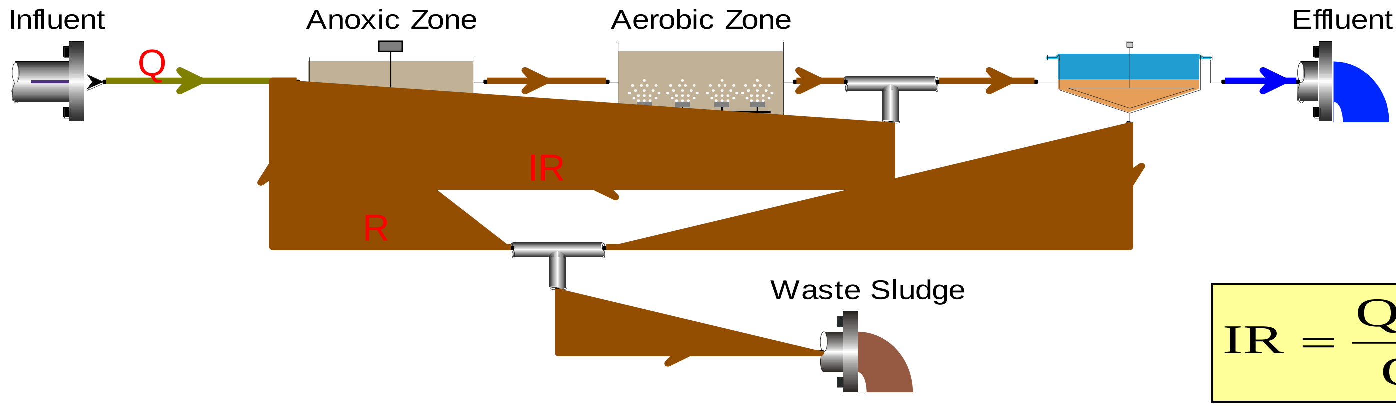
MLSS INTERNAL RECYCLE(IR)



$$IR = \frac{Q_{IR}}{Q}$$

$$R = \frac{Q_R}{Q}$$

- The nitrogen removal and effluent nitrate-N concentration that can be achieved by a single anoxic zone is limited by the practical limits of the MLSS recycle(IR). IR ratios above 4 are impractical.
- MLSS recycle returns most of this nitrate to anoxic zone

This portion can only be denitrified

$$IR = \frac{NO_x}{N_e} - 1 - R$$

$$\%Nremoval = \left[\frac{NO_x - N_e}{NO_x}\right] \times 100$$

$$\%Nremoval = \frac{IR + R}{IR + R + 1} \times 100$$

IR = internal recycle ratio.
R = RAS recycle ratio.
NO_x = concentration of nitrate produced in aeration tank,mg NO_3-N/l
N_e = effluent NO_3-N concentration ,mg/l
% N removal = % nitrogen removal of produced nitrate, %

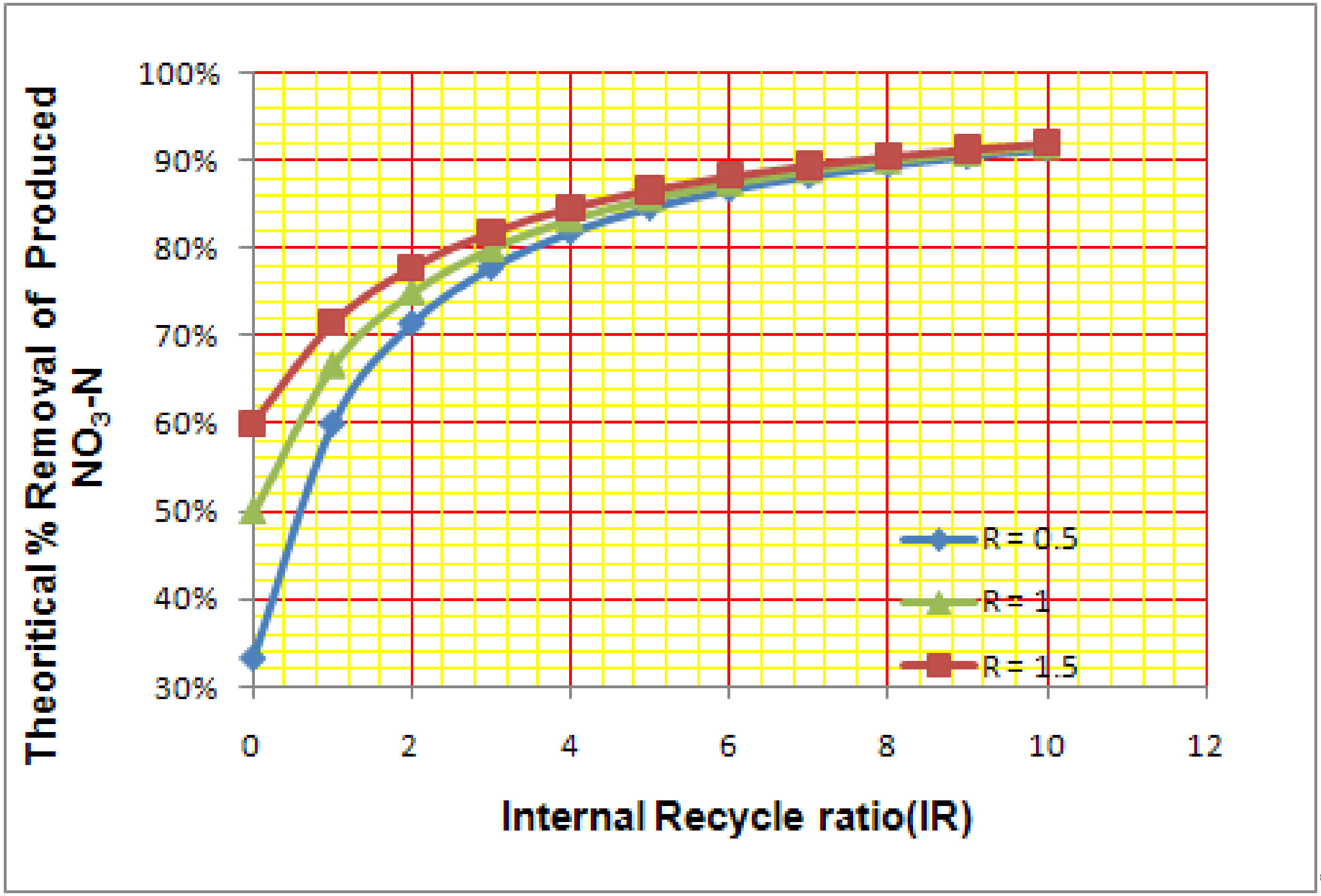
For example
IR=3, R=Q

$$\%Nremoval = \frac{3+1}{3+1+1} \times 100 = \frac{400}{5} = 80\%$$

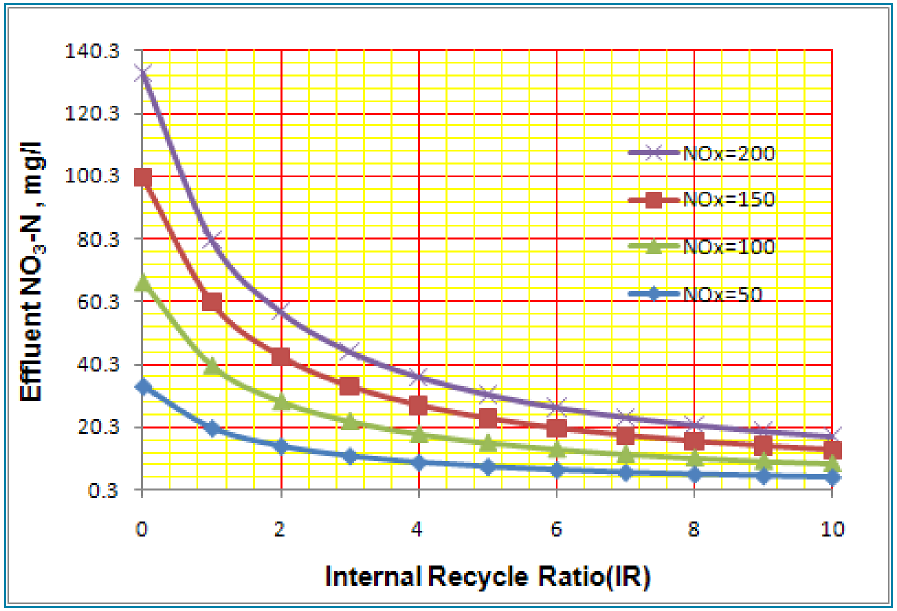
% N REMOVAL VERSUS IR & RAS

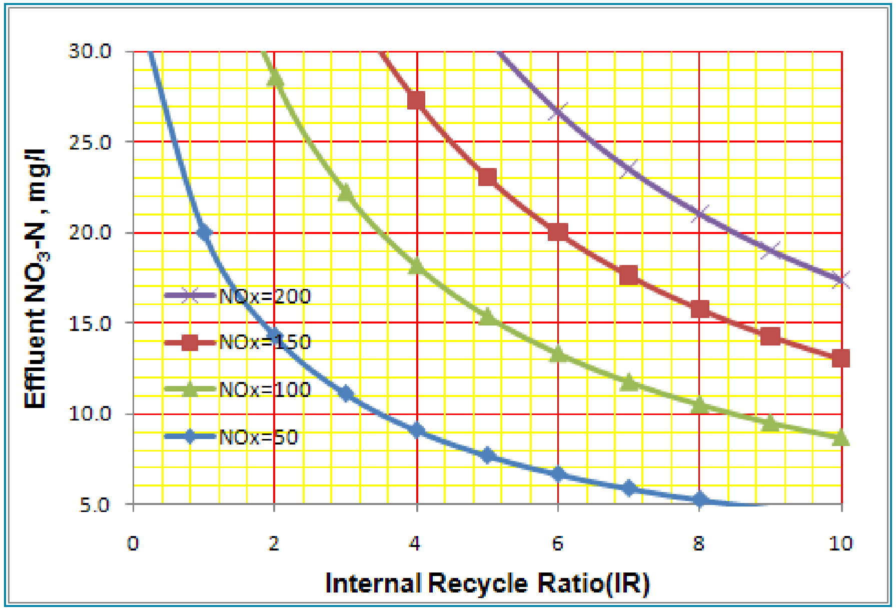
$$\% Nremoval = \left[\frac{NO_x - N_e}{NO_x}\right] \times 100$$

$$\% Nremoval = \frac{IR + R}{IR + R + 1} \times 100$$



EFFECT OF INTERNAL RECYCLE RATIO(IR) ON EFFLUENT NITRATE CONCENTRATION





$$IR = \frac{NO_x}{N_e} - 1 - R$$

$$N_e = \frac{NO_x}{IR + R + 1}$$

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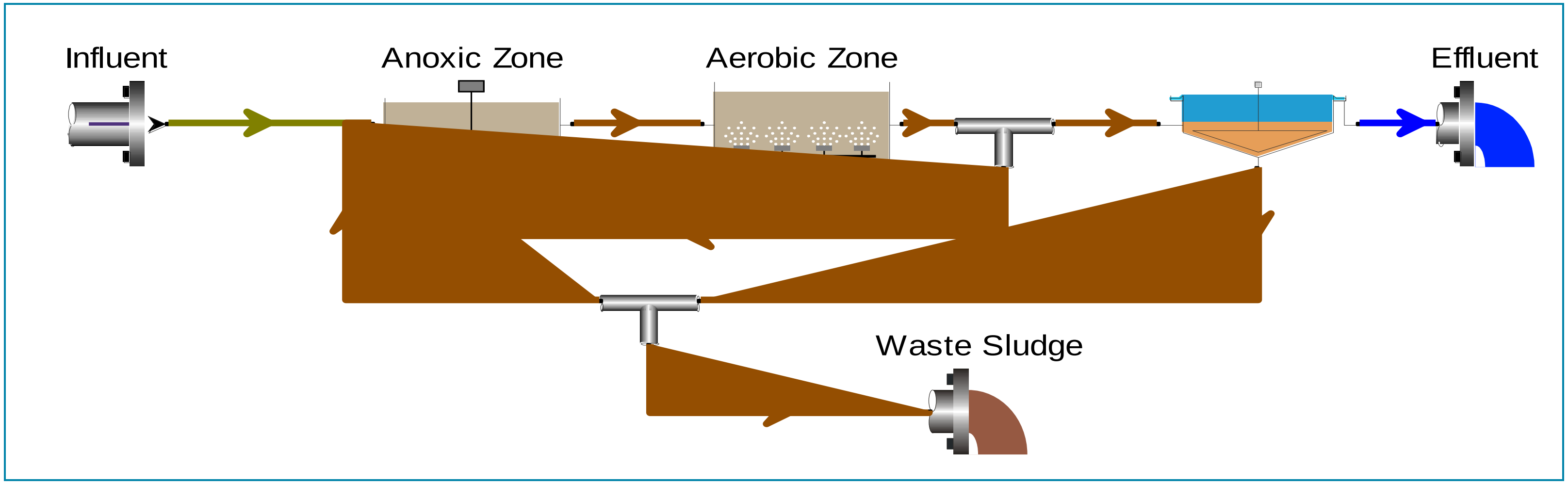
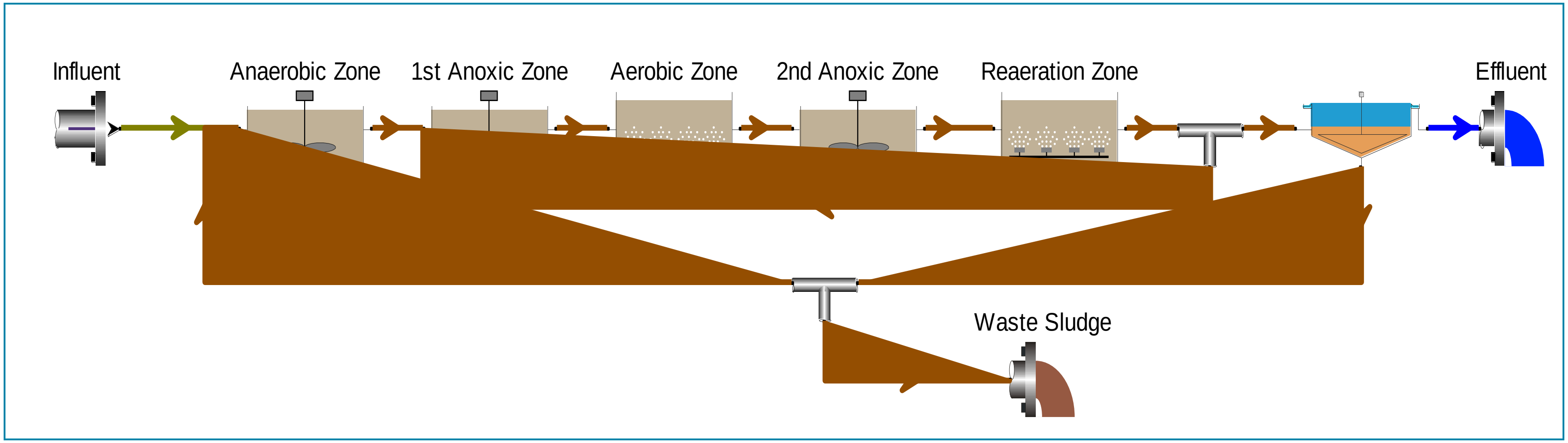
NITROGEN REMOVAL – SEPARATE REACTOR
MODIFIED LUDZACK - ETTINGER (MLE) PROCESS

- MLE Configuration is probably simplest configuration for Biological Nitrogen Removal
- Provides nitrification and denitrification (through Anoxic Zone and Internal MLSS recycle)
- Energy Recovery as Nitrate Provides An Alternative Oxygen Source
- Denitrification capacity is function of the of readily available carbon material(BOD,COD) and the practical return MLSS.



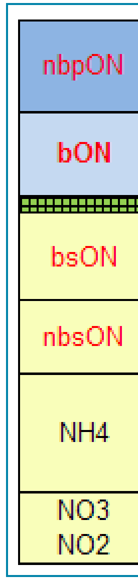
5-STAGE BARDENPHO PROCESS WITH BIOLOGICAL PHOSPHORUS REMOVAL

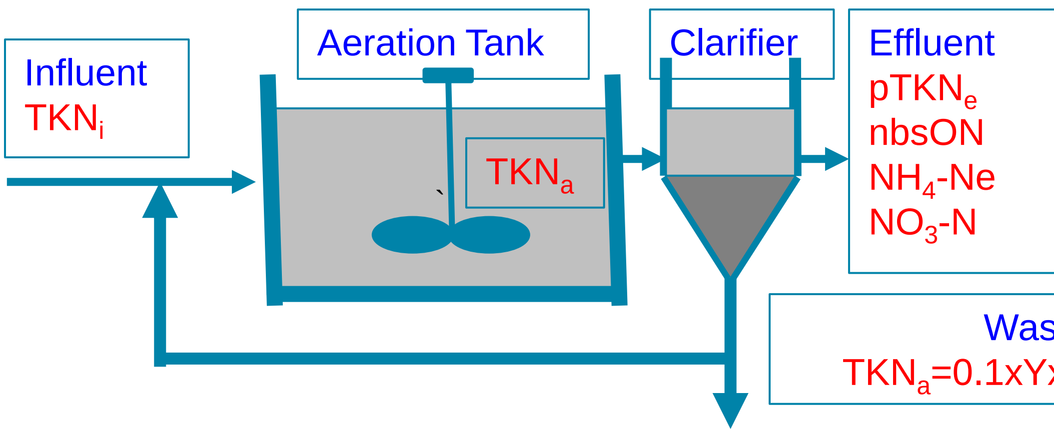
- Includes biological P removal
- Key to Bio-P removal is the anaerobic zone.
- Nitrification and Denitrification
- Second Anoxic zone relies on carbon material produced in the endogenous phase.



NITROGEN MASS BALANCE

- The mass balance should be based on the influent TKN to the activated sludge process.
- Ammonia available for nitrification is equal to the TKN to the secondary treatment minus the following:
  - Soluble organic nitrogen exiting the aeration tank. Estimation of the soluble organic nitrogen was discussed in the wastewater characterization lectures. In the absence of data it can be assumed as 1.5% of the TKN in the raw wastewater.
  - Effluent particulate TKN
  - Nitrogen used for growth of the carbonaceous removing bacteria. This is estimated about 10% of the volatile fraction of the mixed liquor solids.
- Denitrified nitrogen is equal to the nitrified nitrogen less the effluent NO_3-N.





$$TN_e = NH_4\_N_e + NO_3\_N_e + pTKN + nbsON$$

$$TKN_e = NH_4\_N_e + pTKN + nbsON$$

Waste Sludge
TKN_a=0.1xYxBOD$_r$x(VSS/TSS)

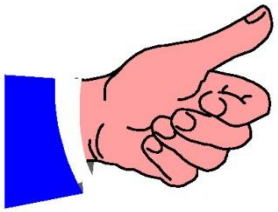
$$NH_4\_N_n(nitrified) = TKN_i - nbsON - NH_4\_N_e - TKN_a$$

$$NO_3\_N(denitrified) = NH_4\_N_n - NO_3\_N_e$$

NITROGEN BALANCE
WHERE DOES NITROGEN END UP In A NITRIFYING PLANT

- In the sludge
- In the effluent
- In the atmosphere

HOW MUCH NITROGEN IS IN THE SLUDGE?



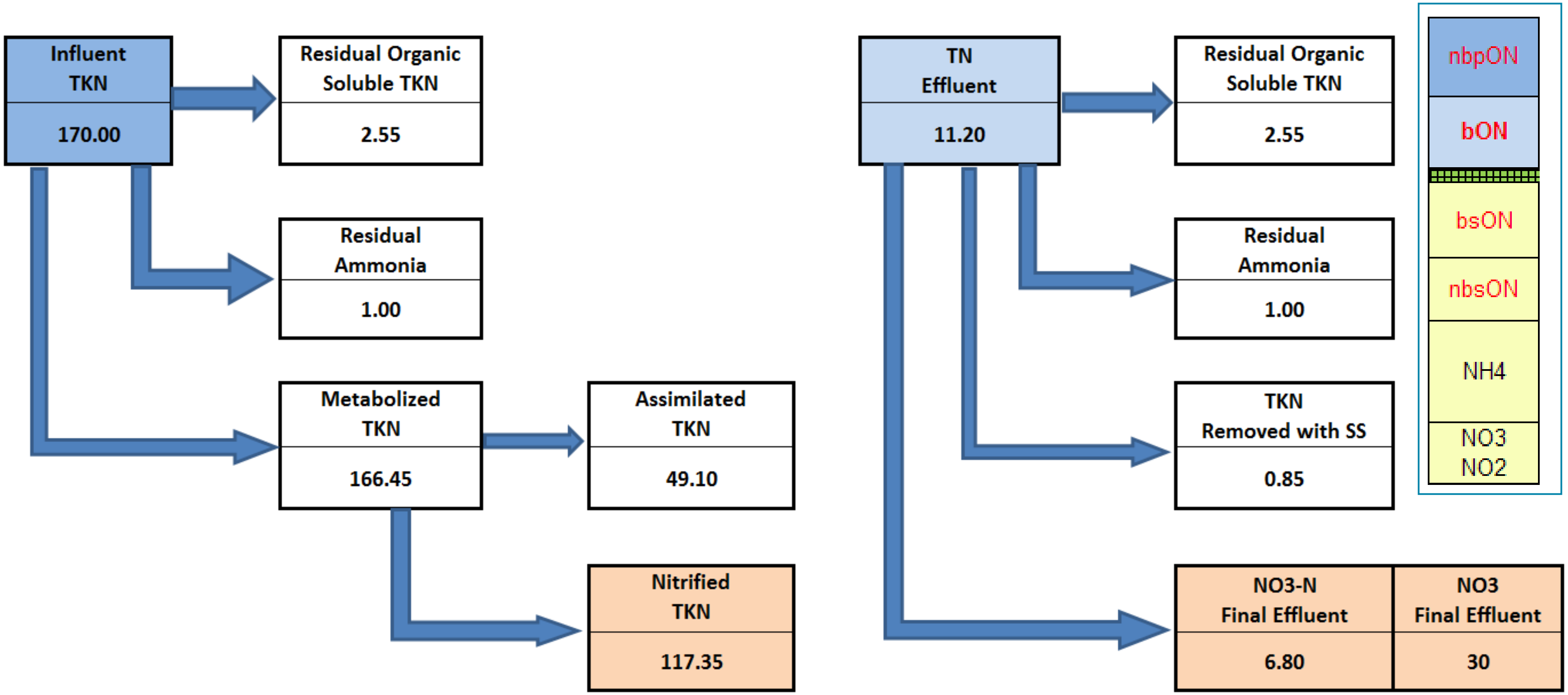
Rule of Thumb

Primary Sludge	- About 2.5% of total solids is Nitrogen
Secondary Sludge	- 10% of total solids is Nitrogen on VSS basis.

Nitrogen Mass Balance		
Item	**Unit**	**Value**
Influent Flow	m3/day	12,433
Influent TKN to Bioreactor	mg/l	170.0
NO3 in Final Effluent	mg/l	30
NO3-N in Final Effluent	mg/l	6.8
Residual TKN (Nonbiodegradable Soluble Organic Nitrogen)		
Assumed Percentage of the influent TKN	mg/l	1.5%
Calculated Concentration	mg/l	2.6
Assumed concentration	mg/l	**2.6**
Residual Ammonia		
Effluent NH4-N limit	mg/l	**1.0**
TKN in Effluent SS		
Effluent TSS	mg/l	10
VSS/TSS		0.85
Effluent VSS	mg/l	8.5
Nitrogen content of biomass(VSS)	mg N/mg VSS	0.1
TKN in SS Effluent	mg/l	**0.85**
Nitrogen used for growth of the carbonacious removing organisms		
Total BOD Removed in the Bioreactor	Kg BOD/day	11960
Net Yield	Kg TSS/Kg BOD removed	0.6
Total waste sludge volatile suspended solids	Kg VSS/day	6100
Nitrogen content of biomass(VSS)	mg N/mg VSS	0.1
TKN load assimilated in waste sludge	Kg N/day	610
TKN concentration assimilated in waste Sludge	mg/l	**49.1**
NH4-N available for Nitrification	mg/l	**117.4**
NO3-N available for Denitrification	mg/l	**110.6**
% N removal required		94.2%

Nitrogen Balance

NITROGEN MASS BALANCE CONCENTRATION(mg/l)

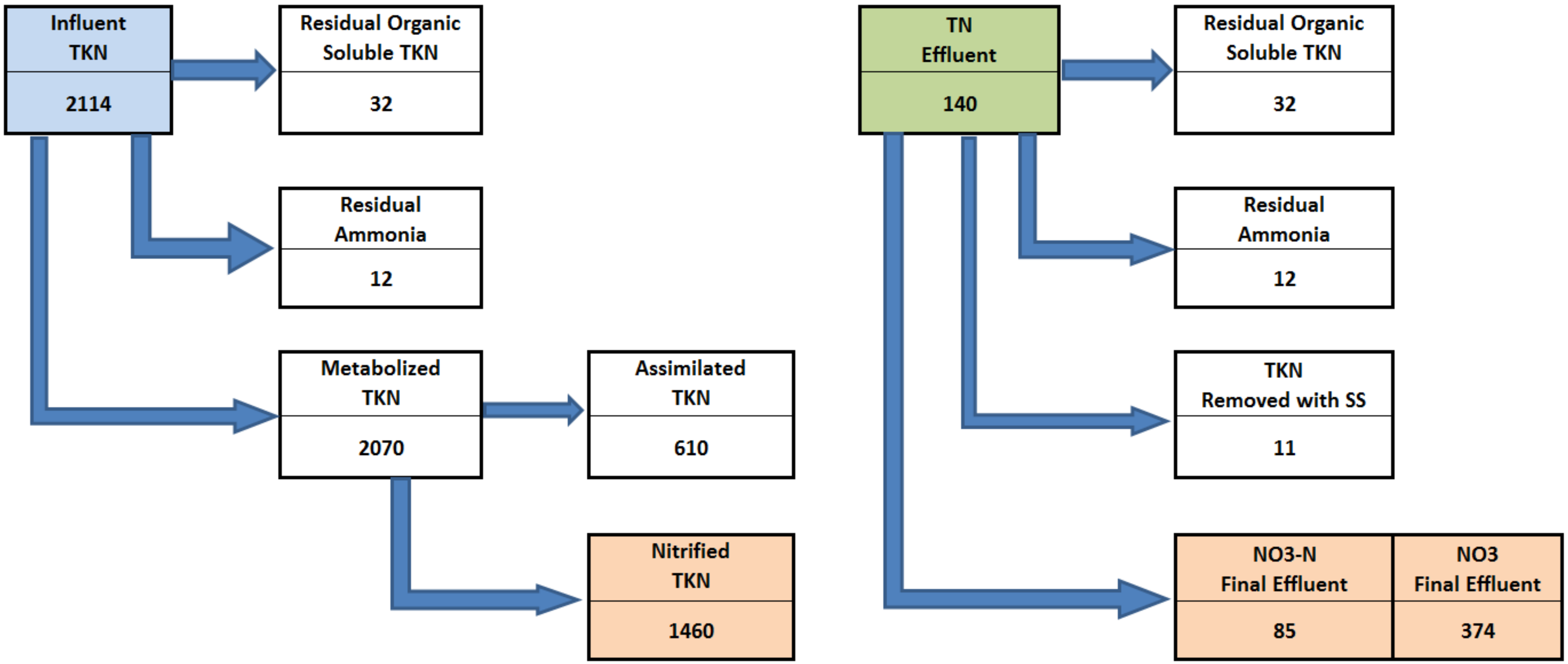


Nitrified TKN	**117.35**	mg/l
Denitrified TKN	**110.55**	mg/l

$$NH_4\_N_n(nitrified) = TKN_i - nbsON - NH_4\_N_e - TKN_a$$

$$NO_3\_N(denitrified) = NH_4\_N_n - NO_3\_N_e$$

NITROGEN MASS BALANCE LOADS(kg/day)



Nitrified TKN	1460.00	Kg/day
Denitrified TKN	1375.00	Kg/day

$$NH_4\_N_n(nitrified) = TKN_i - nbsON - NH_4\_N_e - TKN_a$$

$$NO_3\_N(denitrified) = NH_4\_N_n - NO_3\_N_e$$

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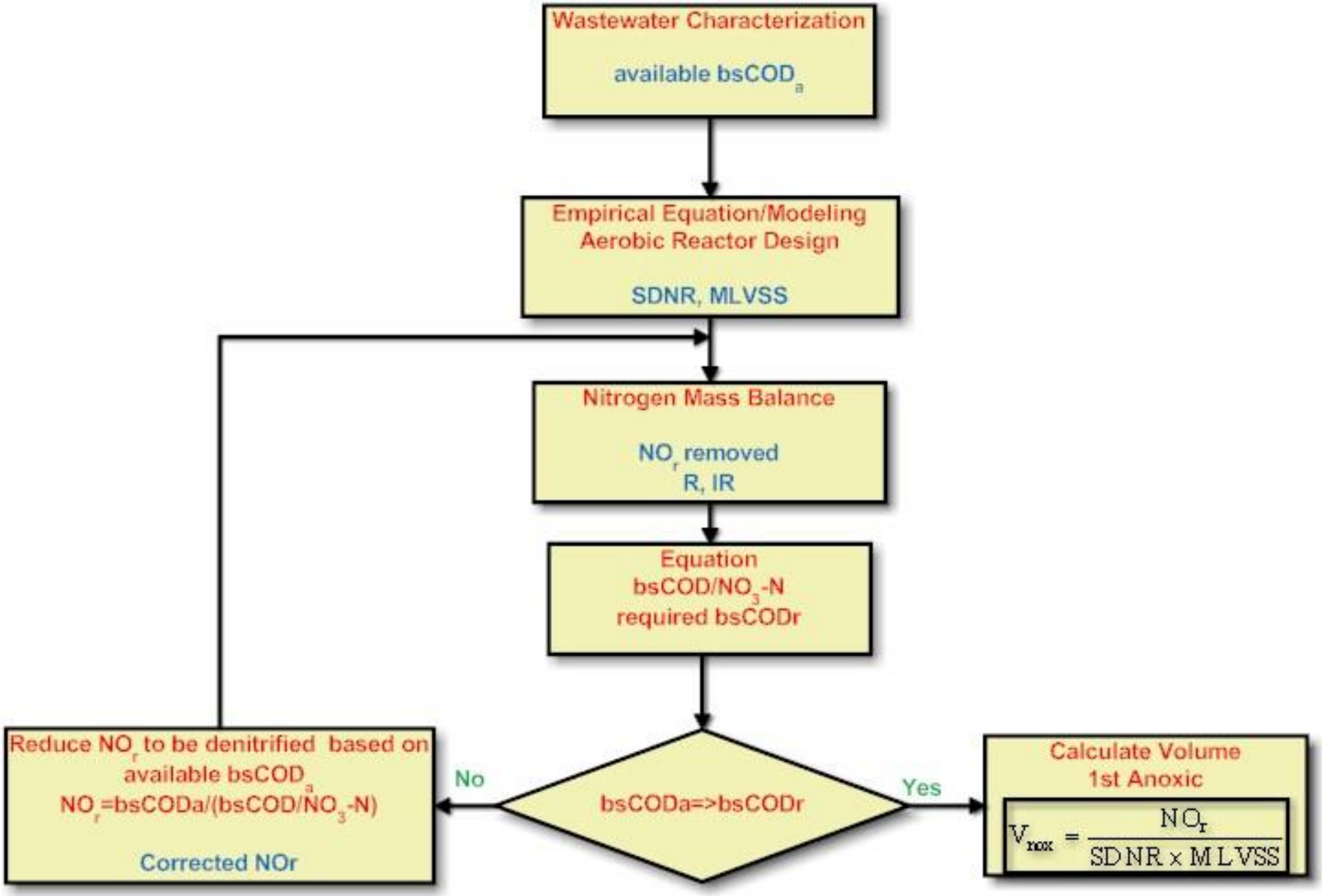
FIRST ANOXIC REACTOR SIZING DIAGRAM



EXAMPLE
AEROBIC & ANOXIC REACTORS SIZING

AEROBIC(AERATED) BIOREACTOR SIZING

PAGE NO.: 20 of 38

$MLSS := 3000$ — Assumed Mixed liquor suspended solids , mg/l

$MLVSS := MLSS \times \%MLVSS$

$= 3000 \times \%MLVSS$

$= 2250.0$ — Calculated Mixed liquor volatile suspended solids , mg/l

$SRT := 5.5$ — Sludge age calculated/assumed above

$$V_{aerobic} := \frac{BOD\_Load_{rMM} \times Y_{obs} \times SRT}{MLSS \times 0.001}$$

Volume of the aerobic zone of the bioreactors,m3

$$= \frac{36854.0 \times 0.65 \times 5.5}{3000 \times 0.001}$$

$= 43917.0$

F/M Gradient Method

First & 2^{nd} Anoxic Sizing

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SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Thank you for your attention.

This Project is funded by the European Union

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- For further information

- Website
- www.swim-h2020.eu E: info@swim-h2020.eu

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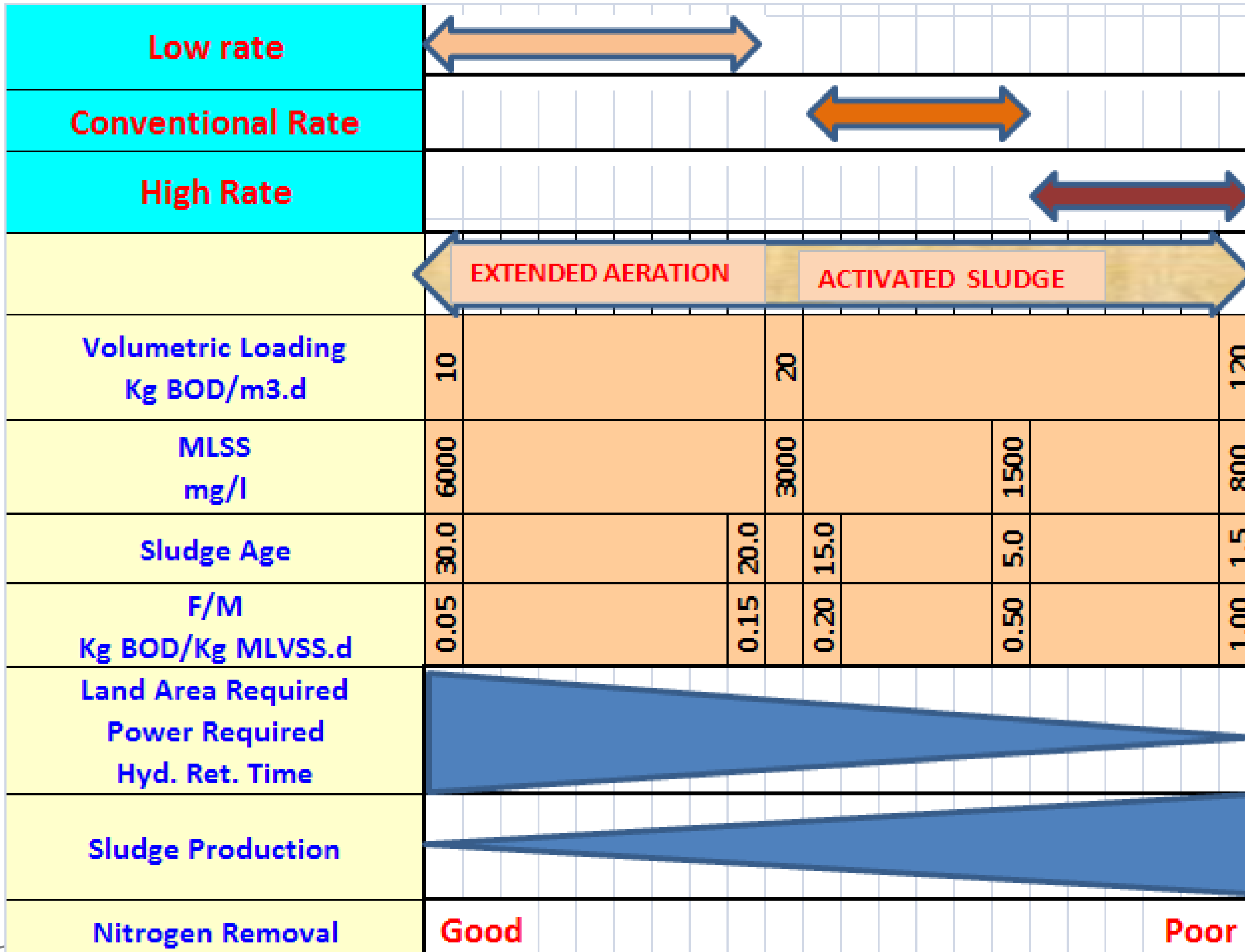
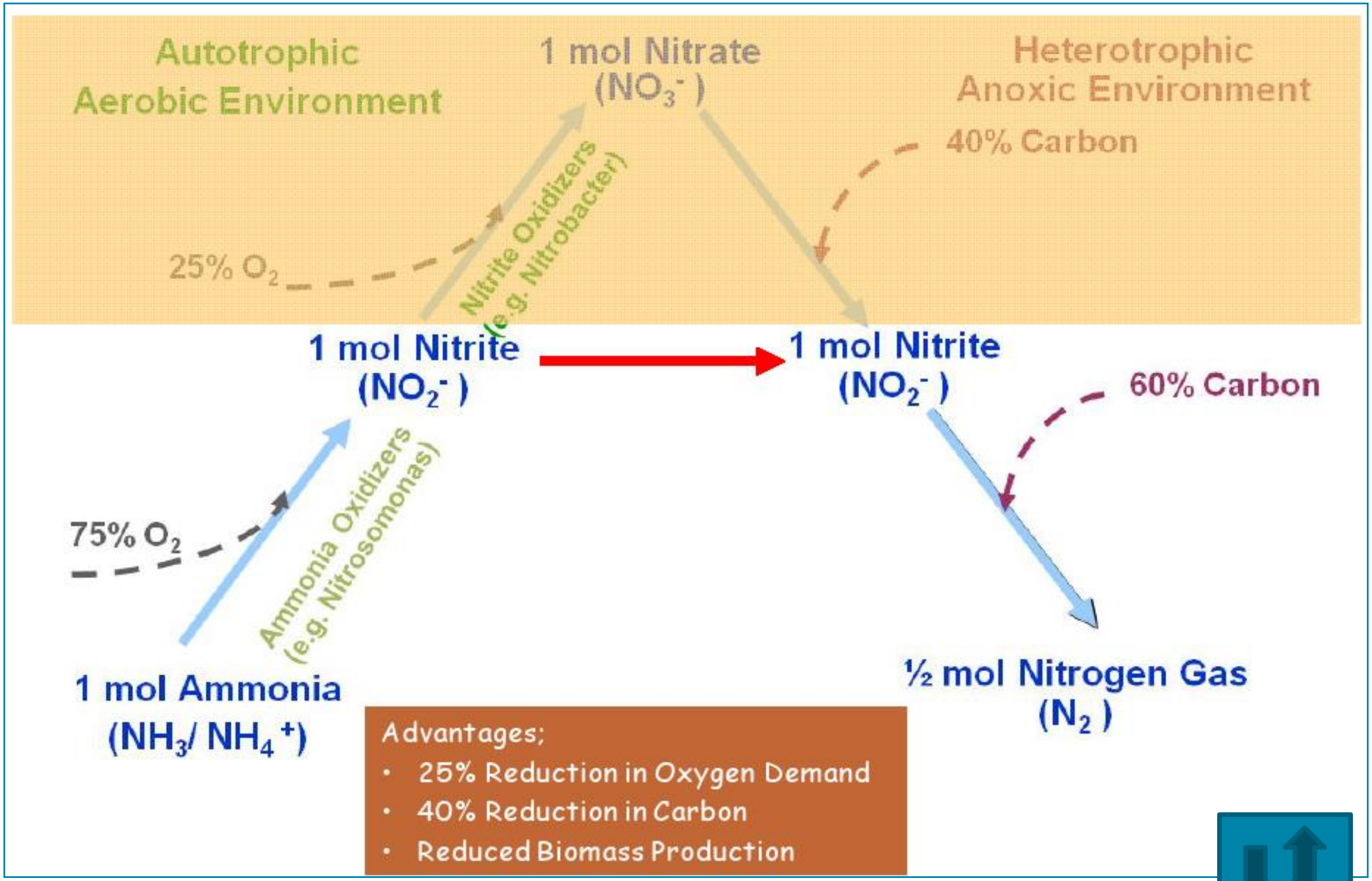
APPENDIX

ACTIVATED SLUDGE PROCESSES CLASSIFICATION



TWO-STEP NITRIFICATION DENITRIFICATION SHARON PROCESS

Single Reactor High Activity Ammonia Removal Over Nitrite



ACTIVATED SLUDGE KINETIC COEFFICIENTS FOR HETEROTROPHIC BACTERIA

Coefficient		Unit	Value @ 20 °C		Temp. Correction (θ Value)	
			Range	Typical	Range	Typical
Maximum specific bacterial growth rate	μ_m	gVSS/g VSS.d	3-13.2	6	1.03-1.08	1.07
Half-velocity constant	K_s	mg BOD/l	25-100	60	1	1
		mg bsCOD/l	10-60	40	1	1
		mg bCOD/l	5-40	20	1	1
True yield /Synthesis yield coefficient)	Y	mgVSS/mg BOD	0.4-0.8	0.6		
		mgVSS/mg bCOD	0.3-0.5	0.4		
Endogenous decay coefficient	k_d	g VSS/g VSS.day	0.06-0.2	0.12	1.03-1.08	1.04
Cell debris fraction	f_d	Unitless	0.08-0.2	0.15		

Source: Tale 8-10 Metcalf & Eddy, page 705.

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ACTIVATED SLUDGE KINETIC COEFFICIENTS FOR NITRIFYING BACTERIA

Coefficient		Unit	Value @ 20 °C		Temp. Correction (θ Value)	
			Range	Typical	Range	Typical
Maximum specific growth rate of nitrifying bacteria	μ_{mn}	gVSS/g VSS.d	0.2-0.9	0.75	1.06-1.123	1.07
Half-velocity constant for ammonia concentration	K_n	mg NH4-N/l	0.5-1	0.74	1.06-1.123	1.053
Biomass true yield /Synthesis yield coefficient)	Y_n	mgVSS/mg NH4-N	0.1-0.15	0.12		
Endogenous decay coefficient for nitrifying organisms	k_{dn}	g VSS/g VSS.day	0.05-0.15	0.08	1.03-1.08	1.04
Half-velocity constant for dissolved -oxygen concentration	K_o	mg/l	0.40-0.60	0.5		

Source: Tale 8-11 Metcalf & Eddy, page 705.

UPDATED KINETIC PARAMETERS FOR BOD REMOVAL

Parameter		Unit	Metcalf & Eddy/AECOM Fifth Edition		Metcalf & Eddy Fourth Edition	
			Range	Typical	Range	Typical
Maximum specific substrate utilization rate	k	bsCOD/g VSS.d	4-12	6	2-10	5
Half-velocity constant	Ks	mg/l BOD	20-60	30	25-100	60
		mg/l bsCOD	5-30	15	10-60	40
True yield /Synthesis yield coefficient)	Y	mg VSS/mg BOD	0.4-0.8	0.6	0.4-0.8	0.6
		mg VSS/mg COD	0.4-0.6	0.45	0.3-0.6	0.4
Endogenous decay coefficient	b,kd	g VSS/g VSS.d	0.06-0.15	0.1	0.06-0.15	0.1

Source: Metcalf & Eddy/Aecom
Table 7-8,page 593 Fifth Edition
Table 7-9, page 585 Fourth Edition

UPDATED KINETIC PARAMETERS FOR NITRIFICATION & BOD REMOVAL

Parameter	Cryptic Name	Unit	Metcalf & Eddy/AECOM Fifth Edition			Metcalf & Eddy Fourth Edition	
			COD Oxidation	NH4 Oxidation	NO2 Oxidation	Range	Typical
Maximum specific growth rate	μ_{max}	g VSS/g VSS.d	6	0.9	1	0.2-0.9	0.75
Half-velocity constant	K_s	mg/l	8			0.5-1	0.74
	K_{NH4}			0.5			
	K_{NO2}				0.2		
True yield /Synthesis yield coefficient)	Y	g VSS/g substrate oxidised	0.45	0.15	0.05	0.1-0.15	0.12
Endogenous decay coefficient	b,kdn	g VSS/g VSS.d	0.12	0.17	0.17	0.05-0.15	0.08
fraction of biomass that remains as cell debri	f_d		0.15	0.15	0.15		
Half-velocity constant for dissolved -oxygen concentration	K_{O2}	mg/l	0.2	0.5	0.9	0.4-0.6	0.5
Temp. Correction μmax	(θ Value)		1.07	1.072	1.063	1.06-1.123	1.07
Temp. Correction b,kdn			1.04	1.029	1.029	1.03-1.08	1.04
Temp. Correction Kn			1	1	1	1.03-1.123	1.053

Source: Metcalf & Eddy/Aecom
Table 8-14,page 755 Fifth Edition
Table 8-11, page 705 Fourth Edition

EFFECT OF TEMPERATURE ON KINETIC COEFFICIENTS

$$k_T = k_{20} \times \theta^{(T-20)}$$

Where

k_T = reaction rate coefficient at temperature T, ^oC.

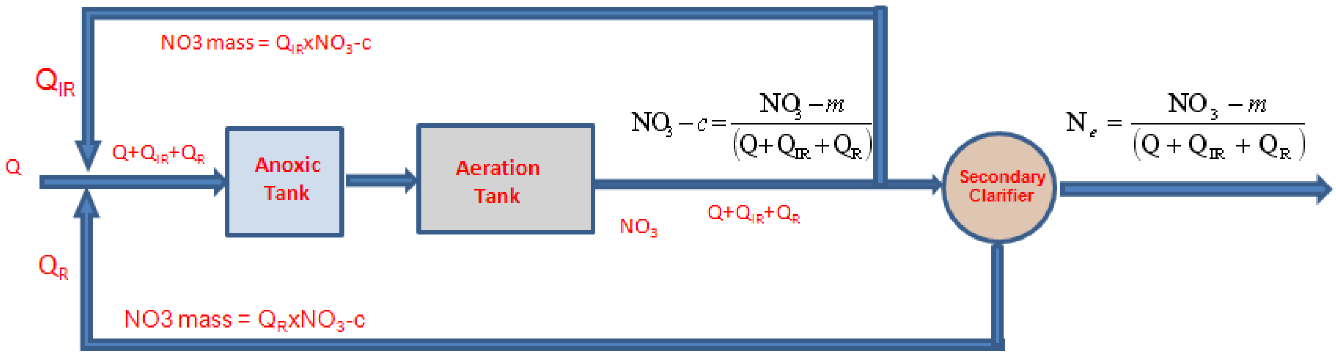
k_{20} = reaction rate coefficient at 20 ^oC.

θ = temperature coefficient(1.02-1.25).

T = temperature, ^oC.

NITROGEN REMOVAL MASS BALANCE

$$Q_{IR}\left[\frac{NO_3-m}{(Q+Q_{IR}+Q_R)}\right]=Q_{IR}\left[\frac{NO_3-m}{Q+IR\times Q+R\times Q}\right]=\frac{Q_{IR}}{Q}\left[\frac{NO_3-m}{1+IR+R}\right]=IR\left[\frac{NO_3-m}{1+IR+R}\right]$$



$$Q_R\left[\frac{NO_3-m}{(Q+Q_{IR}+Q_R)}\right]=Q_R\left[\frac{NO_3-m}{Q+IR\times Q+R\times Q}\right]=\frac{Q_R}{Q}\left[\frac{NO_3-m}{1+IR+R}\right]=R\left[\frac{NO_3-m}{1+IR+R}\right]$$

mass of nitrate produced in aerobic zone **=** nitrate in effluent **+** nitrate in internal recycle **+** nitrate in RAS

$$Q\times NO_3-c=N_e\times Q+N_e\times Q_{IR}+N_e\times Q_R$$

$$IR=\frac{Q_{IR}}{Q}$$

$$Q\times NO_3-c=N_e(Q+Q_{IR}+Q_R)$$

$$R=\frac{Q_R}{Q}$$

$$Q\times NO_3-c=N_e(Q+IR\times Q+R\times Q)$$

$$IR=\frac{NO_3-c}{N_e}-1-R$$

RASSS

$$RASSS = \frac{\left(1+\frac{Q_r}{Q}\right) \times MLSS - ESS}{\frac{Q_W}{Q} + \frac{Q_r}{Q}} \approx \left(\frac{1+R}{R}\right) \times MLSS$$

$$R = \frac{Q_r}{Q}$$

Where:

RASSS: Return activated sludge concentration

Q : Influent flow

ESS: Effluent suspended solids, negligible

Qw : Waste activated sludge flow, negligible

AEROBIC BIOLOGICAL OXIDATION

Oxidation & Synthesis

$$COHNS + O_2 + nutrients \xrightarrow{bacteria} CO_2 + NH_3 + C_5H_7NO_2 + other\_products$$

Organic matter

New cells

Endogenous respiration

cells

$$C_5H_7NO_2 + 5O_2 \xrightarrow{bacteria} 5CO_2 + 2H_2O + NH_3 + energy$$

mw= 113 mw= 160 160/113= 1.42

DERIVATION OF PRE-ANOXIC TANK VOLUME EQUATION

$$NO_r = V_{nox} \times SDNR_t \times MLVSS$$

$$SDNR_{20} = 0.03 \times \left[\frac{F}{M}\right] \times \left[\frac{F_b}{0.3}\right] + 0.029$$

$$F/M = \frac{Q * BOD.i}{V * MLVSS}$$

$$T_c = \theta^{(T-20)}$$

$$SDNR_t = SDNR_{20} \times \theta^{(T-20)}$$

$$NO_r = V \times \left[0.03 \times \left[\frac{Q * BOD.i}{V * MLVSS}\right] \times \left[\frac{F_b}{0.3}\right] + 0.029\right] \times T_c \times MLVSS$$

$$V = \frac{0.0345 \times (1 \times 10^6 \times NO_r - 100 * BOD_i \times F_b \times Q \times T_c)}{MLVSS \times T_c}$$

Where:

F/M = anoxic zone food to microorganisms ratio, g BOD applied/g MLVSS.d in the anoxic zone

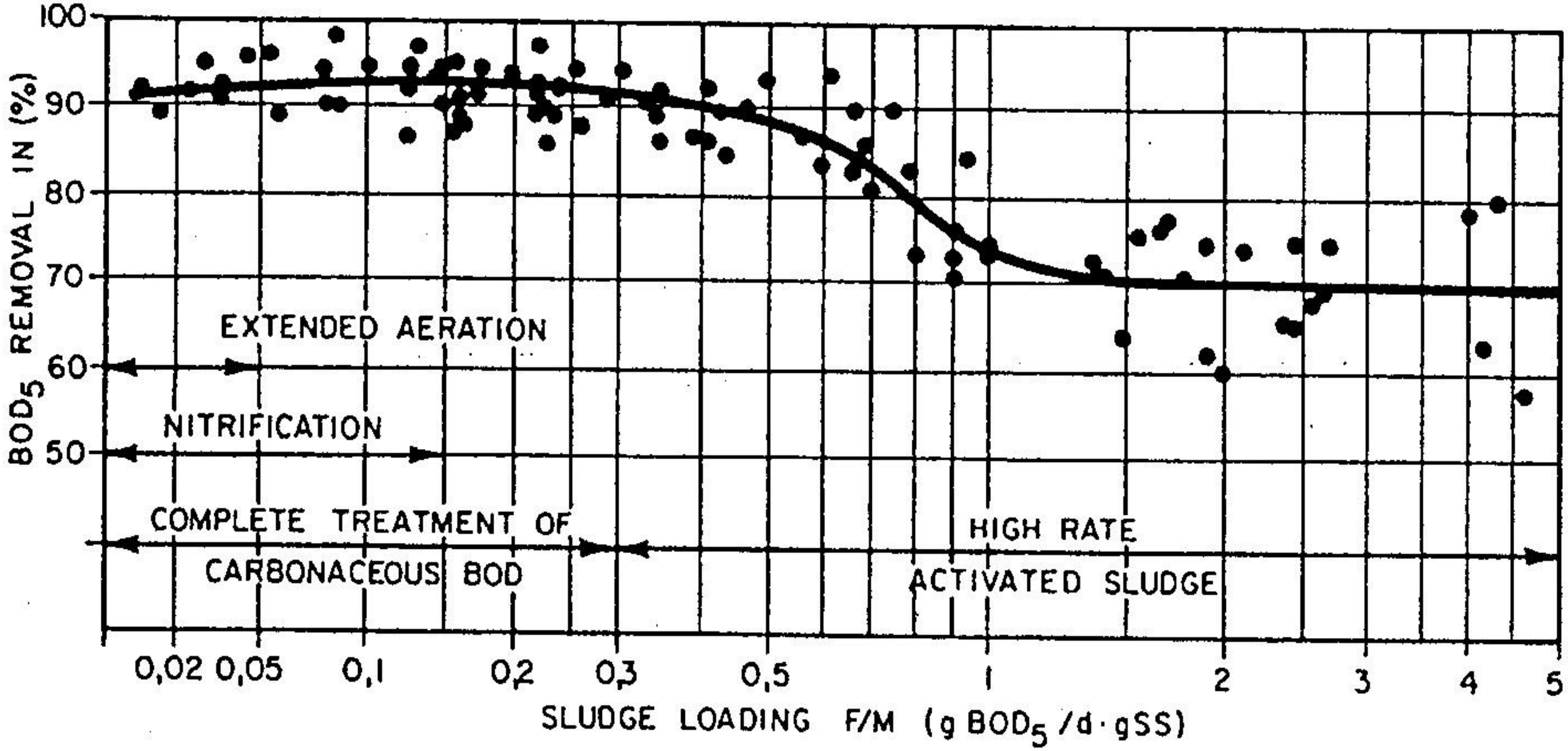
F_b = active biomass fraction of MLVSS

BODi = influent BOD5 concentration mg/l

NOr = Denitrified nitrogen kg/day.

Tc = Temperature correction for SDNR

BOD REMOVAL



SRT 16 6 3 1.5 0.3

$$\frac{1}{SRT} = \left[\frac{F}{M}\right] \times Y_{obs}$$

DESIGN SRT FOR NITRIFICATION
FIFTH EDITION METCALF & EDDY/AECOM

$$\mu_{AOB} = \mu_{\max,AOB} \times \left(\frac{S_{NH}}{K_{NH} + S_{NH}}\right)\left(\frac{S_o}{K_{O,AOB} + S_o}\right) - b_{AOB}$$

$$\frac{1}{SRT_a} = \mu_{na} - k_{dn}$$

$$\mu_{NOB} = \mu_{\max,NOB} \times \left(\frac{S_{NO}}{K_{NO} + S_{NO}}\right)\left(\frac{S_o}{K_{O,NOB} + S_o}\right) - b_{AOB}$$

Where

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

K_N = half-velocity constant for ammonia conc.

DO = DO concentration

K_o = half-velocity constant for DO concentration

SDNR FOR OXIDATION DITCHES DENITRIFICATION

$$SDNR_b = \frac{\eta \times A_n}{2.86 \times Y_n}\left(\frac{1}{SRT}\right)$$

$$Y_n = \frac{Y}{1 + k_d \times SRT}$$

$$A_n = 1 - 1.42 \times Y + \frac{1.42 \times k_d \times Y \times SRT}{1 + k_d \times SRT}$$

Where:

$SDNR_o$ = SDNR in anoxic zones following nitrification & with no exogenous carbon addition, g NO_3-N/g MLVSS.d

An = net oxygen requirement by heterotrophs, g O_2/ g bCOD removed

Yn = net heterotrophic biomass yield, g VSS/ g bCOD removed.

η = fraction of biomass that can use NO_3-N in place of O_2 as an electron acceptor, 0.5-0.85, typical 0.5.

k_d = biomass endogenous decay coefficient, 1/d.

SRT = sludge age, days

Source : M&E chapter 8, page 777

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

Fifth Edition Metcalf & Eddy			
Unit	**Parameter**	**Value at 20°C**	**θ**
1/day	μ_{mn}	0.9	1.072
1/day	k_{dn}	0.17	1.029
mg/l	K_N	0.5	1
mg/l	K_O	0.5	1
mg/l	N	1	
mg/l	DO	2	

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

$$k_T = k_{20} \times \theta^{(T-20)}$$

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

Temp. °C	μ_{mnT} Maximum Specific Growth Rate	k_{dn} Specific Decay Rate	µn Specific Growth Rate	Theoritical SRT SRTa (days)	Design SRT (days) For Safety Factor =		
					1.2	1.5	1.7
10	0.449	0.128	0.239	8.9	10.7	13.4	15.2
11	0.481	0.131	0.257	8.0	9.6	12.0	13.6
12	0.516	0.135	0.275	7.1	8.6	10.7	12.1
13	0.553	0.139	0.295	6.4	7.7	9.6	10.9
14	0.593	0.143	0.316	5.8	6.9	8.7	9.8
15	0.636	0.147	0.339	5.2	6.3	7.8	8.9
16	0.681	0.152	0.363	4.7	5.7	7.1	8.0
17	0.731	0.156	0.390	4.3	5.1	6.4	7.3
18	0.783	0.161	0.418	3.9	4.7	5.8	6.6
19	0.840	0.165	0.448	3.5	4.2	5.3	6.0
20	0.900	0.170	0.480	3.2	3.9	4.8	5.5

CONSULTANTS

DESIGN SRT FOR NITRIFICATION (METHOD-2 WASHOUT SRT)

Method-2

Unit	Parameter	Value at 20°C	θ
1/day	μ_{mn}	0.9	1.072
1/day	k_{dn}	0.17	1.029
mg/l	K_N	0.75	1.053
mg/l	K_O	0.5	1
mg/l	N	1	
mg/l	DO	2	

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

$$k_T = k_{20} \times \theta^{(T-20)}$$

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

Temp. °C	μ_{mnT} Maximum Specific Growth Rate	k_{dn} Specific Decay Rate	μn Specific Growth Rate	Washout SRT SRTw (days)	Design SRT (days) For Safety Factor = 2.5
10	0.449	0.128	0.359	4.3	10.8
11	0.481	0.131	0.385	3.9	9.9
12	0.516	0.135	0.413	3.6	9.0
13	0.553	0.139	0.443	3.3	8.2
14	0.593	0.143	0.474	3.0	7.5
15	0.636	0.147	0.509	2.8	6.9
16	0.681	0.152	0.545	2.5	6.4
17	0.731	0.156	0.584	2.3	5.8
18	0.783	0.161	0.627	2.1	5.4
19	0.840	0.165	0.672	2.0	4.9
20	0.900	0.170	0.720	1.8	4.5