LAWRANCE & McCARTHY METHOD

Calculate θ_{CA}

$$\mu'_{\max A} = \mu e^{0.098(t-15)} \frac{DO}{K_{DO} + DO}\left[1 - 0.833(7.2 - pH)\right]$$

$$\theta_{CA} = \frac{(SF_{kinetic})(SF_{process})}{\mu'_{\max A} - b_A}$$

Choose fraction of Aerobic volume, fv_A

Nitrification

$$\theta_{CT} = \theta_{CA} / fv_A$$

$$f'_{VSS} = f_{VSS} / \left[1 + (1 - f_{VSS})b_H \theta_{CT}\right]$$

$$Y_{obsH} = \frac{Yh}{1 + b_H \;\; f'_{VSS}\, \theta_{CT}}$$

$P_{XH} = Q\ Y_{obsH}\ (S_0 - S)$

$$\forall_T = \frac{\theta_{CT} . P_{XH}}{X_{TVSS}}$$

Denitrification

$U'_{DN} = U_{DN20}\ (1.09)^{t-20}\ (1\text{-}DO)$; $\quad U_{DN20} = 0.042 \frac{mgNO_3N/d}{mgVSS}$

$$\forall_{DN} = \frac{QN_{DN}}{U'_{DN}\ X_{TVSS}}$$

$$\forall'_T = V_{DN} / (1 - fv_A$$

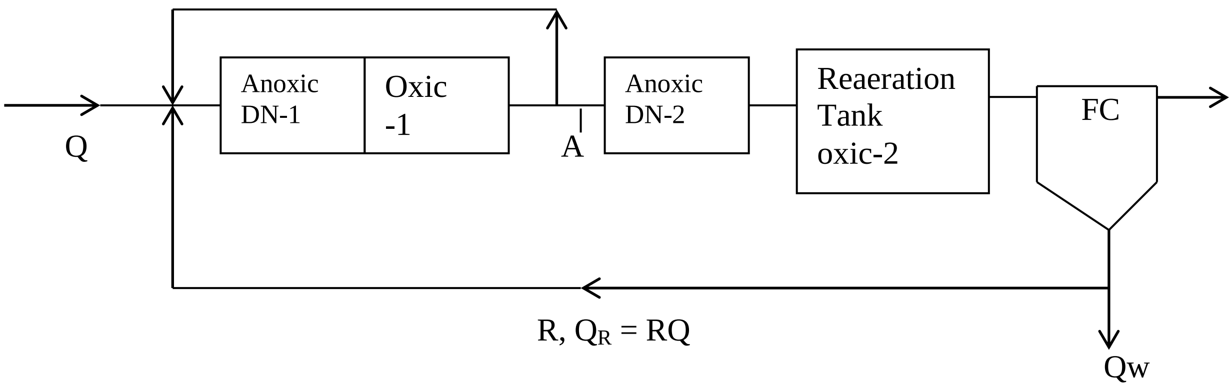
$V_T = \forall_T$

No

Yes

WEF MOD BARDENPHO DESIGN

5 Stage Bardenpho Process



Calculation of the Oxic Volume $\forall_A$

Single Sludge, Seperate Stage

$$\mu'_A = \mu e^{0.098(T-15)} \frac{DO}{K_{DO} + DO}$$

$$\text{Design } \theta_{CA} = \theta_{CA} = \frac{1}{\mu'_A - b_A}$$

$$\text{System } \theta_{CT} = (1.8 - 2.0)\ \theta_{CA}$$

$$Y_{obsH} = \frac{Y_H}{(1 + b_H f_{VSS} \theta_{CT})}$$

$$\theta_{CT} = \frac{\forall_T X_{TVSS}}{Q Y_{obsH}(S_0 - S)}$$

$$\theta_{CA} = \frac{\forall_A X_{TVSS}}{Q Y_{obsH}(S_0 - S)} \quad \rightarrow \quad V_A = \frac{Q\theta_{CA} Y_{obsH}(S_0 - S)}{X_{TVSS}}$$

V_{DN-1} First Anoxic Zone Pre-Denitrification (Exogenous Pre-Denitrification)

$$[NO_3N]_{IR} = \frac{TKN\ to\ Nitrif}{Q + Q_R + Q_{IR}}$$

$[NO_3N]_{IR}$ is also the concentration at the inlet of V_{DN-2} (pt A)

NO_3N to be DN = Q (IR) $[NO_3N]_{IR}$ + $Q_R[NO_3N]_{eff}$

$$r_{DN-1} = \frac{NO_3N\ to\ be\ DN\ in\ the\ 1^{st}\ anoxic\ zone}{\forall_{DN-1} X_{TVSS}}$$

Solve for V_{DN-1} assuming that the DN Rate in the first anoxic pre-DN zone of Bardenpho is given by the eqn:

$$r_{DN-1} = \left[0.03\frac{F}{M} + 0.029\right](1.06)^{tc-20}$$

$$\frac{F}{M} = \frac{Q(S_0 - S)}{\forall_{DN-1} X}$$

Post Denitrification

2nd Anoxic Zone, observed in 2nd anoxic tank of the Bardenpho Process (Endogenous Denitrification)

$$r_{DN-2} = 0.12\theta_{CT}^{-0.706}(1.03)^{tc-20}$$

NO_3 to be DN in $\forall_{DN-2}$ = $TKN_{oxidized}$ – NO_3N removed in $\forall_{DN-1}$ – NO_3N_{eff}

$$X\forall_{DN-2} = \frac{NO_3\ to\ be\ DN\ in\ \forall_{DN-2}}{r_{DN-2}}$$

Additional second anoxic zone tank volume required to take up the DO in the aeration tank effluent.

$$Specific\ OUR = \frac{A_n}{Y_h \theta_{CT}} * MLSS[=]mgO_2 / h / L$$

Add V_{DN-2} = 0.5 mg/L/S_{POUR} * Q_{design}/24

$\forall_{DN-2} = \forall'_{DN-2} + \forall_{DN-2\ Additional}$

Reaeration Tank

Calculate the volume for 45 min retention time at average day/maximum month flow.

COMPARISON OF BNR DESIGN METHODS

THE WEF METHOD

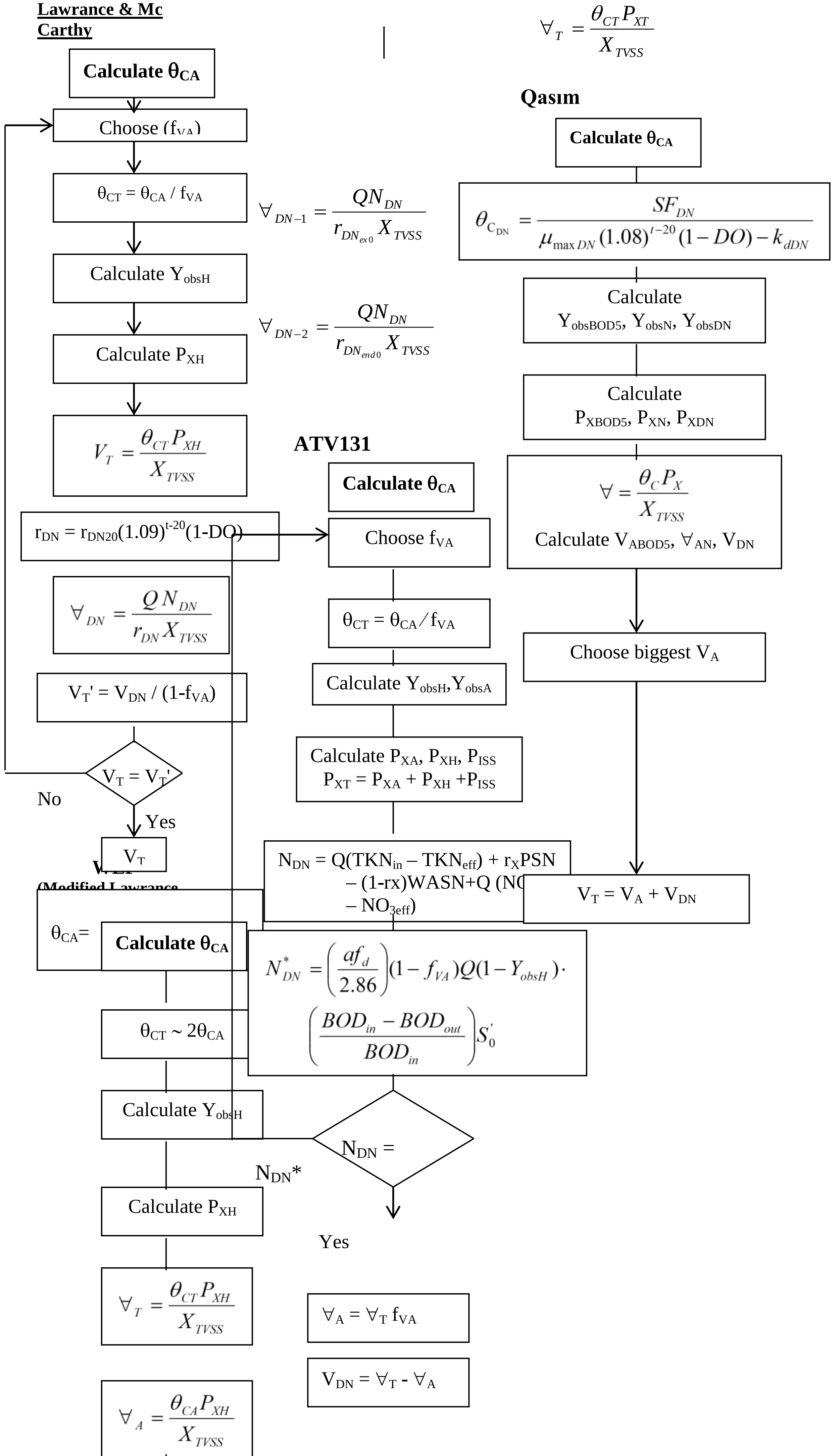
The WEF method is essentially the same as the Lawrence & McCarthy Method only the trial and error solution is not made and θ_{CT} is assumed to be approximately twice of θ_{CA}. In the WEF method two different equations for exogenous and endogenous denitrification rates are used. The nitrate amount to be denitrified includes the internal recirculation ratio. The aerobic volume and the total volumes are calculated using θ_{CA} and θ_{CT} respectively.

COMPARISON OF QASIM & LAWRANCE & MCCARTY METHODS

While Qasım calculates Y_{obs} for denitrification (Y_{obsDN}) and for BOD removal ($Y_{obsBOD5}$) as separate constants using aerobic θ_C, Lawrance & Mc Carthy Method calculates one Y_{obs} for heterotrophic Bacteria using total θ_C (θ_{CT}).

Lawrance & Mc Carthy Method, Qasım's method uses a mean cell residence time equation (θ_{CDN}) for denitrification volume (V_{DN}), calculations and a trial and error solution is used till total volume $\forall_T$ calculated using $\forall_{DN}$ and fraction of aerobic volume equals to the $\forall_T$ calculated using total mean cell residence time θ_{CT} also calculated from θ_{CA} using the assumed fraction of aerobic volume.

Every program should share a carbon and nitrogen balance, oxygen requirements subroutines in addition to oxic and anoxic volumes.


Lawrance & Mc Carthy
Calculate θ_{CA}
Choose (f_{VA})
$\theta_{CT} = \theta_{CA} / f_{VA}$
Calculate Y_{obsH}
Calculate P_{XH}
$V_T = \frac{\theta_{CT} P_{XH}}{X_{TVSS}}$
$r_{DN} = r_{DN20}(1.09)^{t-20}(1-DO)$
$\forall_{DN} = \frac{Q N_{DN}}{r_{DN} X_{TVSS}}$
$V_T' = V_{DN} / (1-f_{VA})$
$V_T = V_T'$
No
Yes
V_T
$\forall_{DN-1} = \frac{QN_{DN}}{r_{DN_{ex0}} X_{TVSS}}$
$\forall_{DN-2} = \frac{QN_{DN}}{r_{DN_{end0}} X_{TVSS}}$
$\forall_T = \frac{\theta_{CT} P_{XT}}{X_{TVSS}}$
Qasım
Calculate θ_{CA}
$\theta_{C_{DN}} = \frac{SF_{DN}}{\mu_{\max DN}(1.08)^{t-20}(1-DO)-k_{dDN}}$
Calculate $Y_{obsBOD5}$, Y_{obsN}, Y_{obsDN}
Calculate P_{XBOD5}, P_{XN}, P_{XDN}
$\forall = \frac{\theta_C P_X}{X_{TVSS}}$
Calculate V_{ABOD5}, $\forall_{AN}$, V_{DN}
Choose biggest V_A
$V_T = V_A + V_{DN}$
ATV131
Calculate θ_{CA}
Choose f_{VA}
$\theta_{CT} = \theta_{CA} / f_{VA}$
Calculate Y_{obsH},Y_{obsA}
Calculate P_{XA}, P_{XH}, P_{ISS}
$P_{XT} = P_{XA} + P_{XH} + P_{ISS}$
$N_{DN} = Q(TKN_{in} - TKN_{eff}) + r_X PSN - (1-rx)WASN+Q (NO$ $- NO_{3eff})$
$N^*_{DN} = \left(\frac{af_d}{2.86}\right)(1-f_{VA})Q(1-Y_{obsH})\cdot \left(\frac{BOD_{in}-BOD_{out}}{BOD_{in}}\right)S_0'$
$N_{DN} =$
$N_{DN}*$
Yes
$\forall_A = \forall_T f_{VA}$
$V_{DN} = \forall_T - \forall_A$
WEF
(Modified Lawrance
$\theta_{CA}=$
Calculate θ_{CA}
$\theta_{CT} \sim 2\theta_{CA}$
Calculate Y_{obsH}
Calculate P_{XH}
$\forall_T = \frac{\theta_{CT} P_{XH}}{X_{TVSS}}$
$\forall_A = \frac{\theta_{CA} P_{XH}}{X_{TVSS}}$

θ_{CA} CALCULATION

$$\mu'_{\max A} = \mu e^{0.098(t-15)} \frac{DO}{DO+K_{DO}}[1-0.833(7.2-pH)]$$
$$\theta_{CA} = \frac{(SFkinetic)(SFprocess)}{\mu'_{\max A} - k_{dA}}$$

Y_{obs} & P_X CALCULATIONS **VOLUME CALCULATIONS**

$\theta_{C_{DN}} = \frac{SF_{DN}}{\mu_{\max DN}(1.08)^{t-20}(1-DO)-k_{dDN}}$ $P_{XDN} = Y_{obsDN}\,Q(N_{DN})$	$\forall_{DN} = \frac{(\theta_{CDN})Px_{DN}}{fx_{DN}X_{TVSS}}$ $f_{XDN} = 0.5$	**NITROGE** $N_{DN} = N_N$- (NO_3N_{eff}) N_N = TKNin-TKNeff-(OrgNassim = 0.122 Y
$Y_{obsBOD_5} = \frac{Y_{BOD_5}}{1+k_{dBOD_5}(\theta_{cA})}$ $P_{XBOD5} = Y_{obsBOD5}$ Q (BOD_5 to satisfy)	$\forall_{ABOD_5} = \frac{(\theta_{CA})Px_{BOD_5}}{fx_H X_{TVSS}}$ $fx_H = 0.94$	**CARBON** BOD_5 to satisfy=(S_0-S)x(BO / for
$Yobs_N = \frac{Y_N}{1+k_{dN}(\theta_{cA})}$ $P_{xN} = Y_{obsN}\,Q(N_N)$	$\forall_{AN} = \frac{(\theta_{CA})Px_N}{(fx_A)(X_{TVSS})}$ $f_A = 0.06$	(BOD_5 for DN) = 0.68 (BOD_5 for / Deoxygen) = 0.68 (1.3) [(
$Y_{obsDN} = Y_{DN}/(1 + k_{dDN}\,\theta_{CDN})$ $Y_{obsBOD5} = Y_{BOD5}/(1 + k_{dBOD5}\,\theta_{CA})$	Choose biggest $\forall_A$ $\forall_T = \forall_{DN} + \forall_A$	

QASIM Ex 13 – 11 IN A NUT SHELL

7 Methods of BNR Design

1. Trial & Error (Lawrance & Mc Carthy)
   Model I, Model II
2. DN Capacity (ATV-131)
3. DN rate eqn (WEF)
4. Cowi Design
5. Kruger DesigN
6. IA WPRC Task Group
7. Qasım Ex 13 - 11