M&E APPROACH TO BNR DESIGN

A. Calculating Aerobic Sludge Age (SRT_a)

Writing in terms of ASM Model Notations

$$\mu_A = \hat{\mu}_A = \left(\frac{S_{NH}}{K_{NH} + S_{NH}}\right)\left(\frac{S_0}{K_{0,n} + S_0}\right) - b_A$$

$$\hat{\mu}_{A,T} = \mu_{A,20}(1.07)^{T-20}$$

$$SRT_a = \frac{1}{\mu_{A,T} * SF}$$

B. Biological Sludge Production ($P_{x,bio}$)

Effluent BOD Concentrations, S:

$$S = K_s \frac{(1 + b_{H,T} SRT_a)}{SRT_a(\mu_{H,T} - b_{H,T}) - 1}$$

$$b_{H,T} = b_{H,20}(1.04)^{T-20}$$

$$\mu_{H,T} = \mu_{H,20}(1.07)^{T-20}$$

$$P_{x,bio} = \underbrace{QY_H \frac{(S_0 - S)}{1 + b_{H,T} SRT_a}}_{P_{X,H}} + \underbrace{QY_H f_d b_{H,T} \frac{SRT_a (S_0 - S)}{1 + b_{H,T} SRT_a}}_{P_X\text{-particulates formed from decay of heterotrophs}} + \underbrace{QY_A \frac{NO_X}{(1 + b_{A,T} SRT_a)}}_{P_{X,A}}$$

$$NO_X = \text{Oxidized TKN} = \underbrace{TKN_{in} - TKN_{eff}}_{TKN_{oxid}} - \underbrace{0.12(P_{x,bio}/Q)}_{X_{orgN,WAS}}$$

C. Total Sludge Production ($P_{x,TSS}$)

$$P_{X,TSS} = \frac{P_{X,bio}}{0.85} + Q.nbVSS + Q(TSS_0 - VSS_0)$$

$$\frac{MLVSS}{MLSS} = \frac{P_{X,VSS}}{P_{X,TSS}}$$

$$nbVSS = (1 - \frac{bpCOD}{pCOD})VSS$$

$$VSS_0 = 0.65TSS_0$$

bpCOD=27%

pCOD = 40%

Choose X_T

$$\forall_a = \frac{(P_{X,TSS} + P_{X,PO_4})}{X_T} SRT_a$$

$X_R = 2X$

$$\frac{X}{X_R} = \frac{R}{1+R}, R = 1$$

$$IR = \frac{NO_X}{S_{NO_3N_{eff}}} - (1+R)$$

$$SDNR_{20} = 0.19 \frac{gNO_3N/d}{gMLVSS}$$

See the Table in Appx I

$$\frac{1}{(F/M)_a} = \frac{\forall_a.MLVSS_{biomass}}{Q(S_0 - S)} = Y_H \frac{SRT_a}{1 + b_{H,T} SRT_a}$$

$$MLVSS_{biomass} = \frac{Y_H SRT_a Q(S_0 - S)}{\forall_a (1 + b_{H,T} SRT_a)}$$

Total NO_3N recirculated is denitrified.

Required NO_3N removal = $Q(R+IR).NO_3N_{eff}$

Assume a retention time for anoxic tank, $t_{R,DN}$

$$\forall_{DN} = \frac{Q}{24} * t_{R,DN}$$

NO$_3$N removed = $\forall_{DN}$ *SNDR$_T$*MLVSS$_{biomass}$

$$\forall_T = \forall_{DN} + \forall_a$$

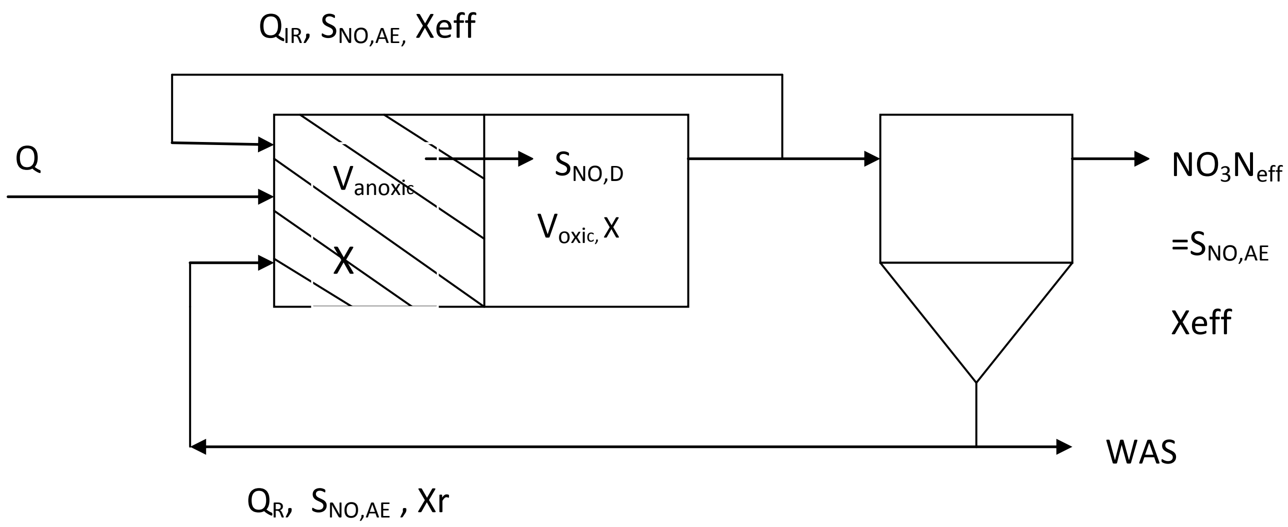
$$SRT_T = \frac{X_T * \forall_T}{P_{X,TSS}}$$

Derivation of Dependence of $S_{NO3Neff}$ on Internal Recirculation (IR)

$$TN_{in} = TKN_{in} + NO_3N_{in}$$

Assume $NO_3N_{in} = 0$

TKN nitrogen to be oxidized = $(TN_{in} - TKN_{eff}) - X_{orgN,WAS} = (1 + R + IR)(S_{NO,AE} - S_{NO,D})$



$$IR = \frac{(TKN_{in} - TKN_{eff} - X_{orgN,WAS})}{S_{NO,AE} - S_{NO,D}} - (1 + R)$$

Assume optimized anoxic volume and $S_{NO,D}$=0

$$IR = \frac{NO_X}{NO_3 N_{eff}} - (1+R)$$

Nitrate to be denitrifed = Q(R+IR)*NO_3N_{eff}

Derivation of $\frac{1}{F/M} = \frac{Y_H SRT}{1+b_{H,T} SRT}$

Rate of substrate utilization:

$$r_{su} = \frac{\mu_H}{Y_H} X_{BH} = -\frac{Q(S_0 - S)}{\forall_T} \quad \text{......} 1$$

$$r_g = \mu_H X_{BH} - b_{H,T} X_{BH} = Y_H r_{su} - b_{H,T} X_{BH} \quad \text{......} 2$$

Making a microorganism mass balance for a completely mixed flow reactor with recycle:

$$\cancelto{0}{\forall_T \frac{dX_{eff}}{dt}} = \cancelto{0}{Q_{in} X_{in}} - (Q_W X_{BH} + Q_{eff} X_e) - \forall_T r_g \quad \text{......} 3$$

At steady-state, and for X_{in}=0, substituting r_g from Eq 2 in Eq3;

$$\frac{Q_W X_{BH} + Q_{eff} X_e}{\forall_T X_{BH}} = Y_H \frac{r_{su}}{X_{BH}} - b_{H,T} \quad \text{.......4}$$

$$\frac{1}{SRT} = Y_H \frac{r_{su}}{X_{BH}} - b_{H,T} \quad \text{.......5}$$

Substituting r_{su} from Eq1;

$$X_{BH} = -\frac{Q(S_0 - S)}{\forall_T} * \frac{Y_H SRT}{1 + b_{H,T} SRT} \quad \text{.......6}$$

$$\boxed{\frac{1}{F/M} = -\frac{\forall_T X_{BH}}{Q(S_0 - S)} = \frac{Y_H SRT}{1 + b_{H,T} SRT}} \quad \text{.......7}$$

From definiton of SRT;

$$\boxed{P_{X,T} = \frac{\forall_T X}{SRT} = \frac{Y_H Q(S_0 - S)}{(1 + b_{H,T} SRT)}}$$

Appendix I

rbCOD/bCOD	10	20	30	40	50
F/Mb					
0.1	0.03	0.03	0.03	0.03	0.03
0.2	0.058	0.058	0.058	0.058	0.058
0.3	0.08	0.08	0.08	0.08	0.08
0.4	0.11	0.11	0.11	0.11	0.11
0.5	0.13	0.132	0.133	0.134	0.135
0.6	0.14	0.15	0.153	0.155	0.16
0.7	0.16	0.165	0.17	0.18	0.185
0.8	0.17	0.18	0.185	0.19	0.2
0.9	0.18	0.19	0.205	0.215	0.23
1	0.195	0.205	0.22	0.225	0.245
1.1	0.2	0.22	0.23	0.25	0.26
1.2	0.21	0.23	0.25	0.26	0.28
1.3	0.215	0.235	0.26	0.275	0.29
1.4	0.22	0.245	0.27	0.29	0.31
1.5	0.225	0.255	0.28	0.297	0.32
1.6	0.23	0.26	0.29	0.315	0.33
1.7	0.23	0.265	0.295	0.32	0.34

1.8	0.233	0.267	0.3	0.335	0.36
1.9	0.234	0.27	0.31	0.345	0.365
2	0.235	0.275	0.315	0.35	0.37