FHE - Module 5 2018 1

# 1 PRIMARY SETTLING

Raw WW

$Q_i = 25\ Ml/d$ ADWF

$S_{ti} = 750\ mgCOD/l$

$N_{ti}$ (TKN) $= 60\ mgN/l$

$N_{ai}$ (FSA) $= 39.1\ mgN/l$

$P_{ti}$ (TP) $= 12,0\ mgP/l$

OP $P_{si} = 7,28$ "

Settled WW

$24.875\ Ml/d$

$S_{ti} = 475\ mgCOD/l$

$N_{ti} = 50,0\ mgN/l$

$N_{ai} = 39,1\ mgN/l$

$P_{ti} = 9,6\ mgP/l$

$P_{si} = 7,28\ mgP/l$

Underflow

0,5 % ADWF

$0,5/100 \times 25 = 0,125\ Ml/d$

$= 125\ m^3/d$

TOC $C_{ti} = 250.8\ mgC/l$

TSuspS $= 416$ mg TSuspS/l

ISuspS $= 60$ mg ISS/l

$C_{ti} = 158,8\ mgC/l$

TSuspS $= 189$ mg SuspS/l

$= 15$ mg ISS/l

| | Raw WW | | Settled WW | | Primary Sludge | |
|---|---|---|---|---|---|---|
| Flow | 25 Ml/d | | 24.875 | | 0,125 Ml/d | |
| | Conc mg/l | Flux kg/d | Conc mg/l | Flux kg/d | Conc mg/l | Flux kg/d |
| COD | 750 | 18750 | 475 | 11816 | 55475 | 6934 |
| TKN | 60,0 | 1501 | 50,0 | 1244,8 | 2050,1 | 256,3 |
| FSA | 39,1 | 977,5 | 39,1 | 972,5 | 39,1 | 4,9 |
| TP | 12,0 | 299,97 | 9,6 | 238,92 | 488,37 | 61,05 |
| OP | 7,28 | | 7,28 | | 7,28 | |
| TOC | 250,8 | 16270,0 | 158,8 | 3949,7 | 18553,0 | 2319,1 |
| TSuspS | 416 | 10410,6 | 189 | 4706,0 | 45637,7 | 5704,7 |
| ISuspS | 60 | 1500 | 15 | 373,1 | 9015,0 | 1126,9 |
| VSuspS | 356 | 8910,6 | 174 | 4329,0 | 36622,3 | 4577,8 |

Q1.2 Raw WW

Total
750

VFA 50 | FBSO 115 | USO 45 | Dissolved 210

Sus; Effluent 45 COD filtered

Settleable Non Settleable

BPO 440 | UPO 100 | Particulate 540

Biodeg | Unbio

Raw WW UPO fraction $f_{S'up} = 0.133$

$S_{upi} (UPO) = f_{S'up} \cdot S_{ti} = 0.133 \times 750$
$= 100$ mg COD/l

$S_{usi} (USO) = f_{S'us} = \frac{45}{750} = 0.060$

$\text{VSS of the UPO} = \frac{\text{COD of UPO}}{f_{cv}} = \frac{100}{1.481}$
$= 67.5$ mg VSS/l

Settled WW COD

Total
475

VFA 50 | FBSO 115 | USO 45 | Dissolved 210

Non Settleable

BPO 255 | UPO 10 | 265 Particulate

$f_{S'up}$ settled WW $= 0.021$
$S_{upi} = f_{S'up} S_{ti} = 0.021 \times 475 = 10$ mg COD/l

NL 09h30

Raw WW TKN

TKN 60.0

orgN 20.9

FSA 39.1

FBSO 3.8 | 4.9 | USO 1.1

BPO 9.25 | UPO 6.75

Biodeg unbio

Filtered Effluent
TKN = 1.48
FSA = 0.38
orgN = 1.10

Dissolved 44.0

Particulate 16.0

$f_{n_{UPO}}$ = N/VSS ratio = 0.10 mgN/mgVSS

$$N_{oupi} = f_n \frac{S_{upi}}{f_{cv}}$$

$$= 0.10 \times \frac{100}{1.48} = 6.75 \text{ mgN/l}$$

Raw WW

VSS 356 | 288.5 BPO | 67.5 UPO | Particulate Settleable + Non Settled

COD 540 | 440 | 100

Settled WW TKN

50.0

FSA 39.1

44.0

FBSO 3.8 | USO 1.1 | Dissolved

6.0

5.33 | 0.67 UPO | Particulate

$$N_{oupi} = \frac{S_{upi}}{f_{cv_{UPO}}} f_n = \frac{10}{1.481} 0.10 = 0.67$$

Raw WW TP

TP $\boxed{12.00}$

Effluent Filtered 4

TP = 7.55

oP = 7.55

org = 0

$\boxed{4.72}$

| OP | | FBSO | | USO | |
|---|---|---|---|---|---|
| $\boxed{7.28}$ | 8.23 | $\boxed{0.95}$ | 1 | $\boxed{0.0}$ | 0.95 Dissolved |
| | 3.77 | $\boxed{2.07}$ | | $\boxed{1.7}$ | Particulate |
| | | BPO | | UPO | |

$$P_{oupi} = \frac{S_{upi}}{f_{cv}} f_p = \frac{100}{1.481} 0.025 =$$

$$= 1.7 \text{ mgP/l}$$

Settled TP

$\boxed{9.60}$

$\boxed{2.32}$ org P

| | | | | | |
|---|---|---|---|---|---|
| $\boxed{7.28}$ | 8.23 | $\boxed{0.95}$ | 0.95 | $\boxed{0.0}$ | Dissolved |
| | 1.37 | $\boxed{1.20}$ | 1.37 | $\boxed{0.17}$ | Particulate |

$$P_{oupi} = f_{puo} \frac{S_{upi}}{f_{cv}}$$

$$= 0.025 \times \frac{10}{1.48} = 0.17$$

Raw WW TOC

$\boxed{250.8}$*

VFA $\boxed{18.75}$* FBSO $\boxed{38.1}$ ✓ USO $\boxed{16.0}$* 71.9 Dissolved

$\boxed{143.9}$ BPO $\boxed{35.0}$ UPO 178.9 ✓ Particulate

$$CH_3COOH + 2H_2O = 2CO_2 + \cancel{8(H^+ + e^-)}$$

$$\cancel{8(H^+ + e)} + 2O_2 = 4H_2O$$

ox ↓ C N P O H $e^-/ch$ ↑ red

1 mole HAc needs 2 mole $O_2$

$2 \times 32 = 64\,g\,O$.

60 g HAc needs 64 g O or COD

1 g HAc needs $64/60 = 1.067$ g O or g COD.

50 mg COD/ℓ HAc ∴ mass $= \frac{50}{1.067} = 46.8$ g HAc/ℓ.

$\frac{50}{64} = 0.78$ mmol HAc/ℓ

TOC: HAc has 2 mol C/mole

∴ has $2 \times 12 = 24$ g C/mol

∴ TOC $= 0.78 \times 24 = 18.75$ mg C/ℓ

$$C_{oupi} = f_c \frac{S_{upi\,UPO}}{f_{cv\,UPO}} = 0.518 \times \frac{100}{1.481} = 35 \text{ mg C/ℓ}$$

Settled WW TOC Total $\boxed{158.8}$

VFA $\boxed{18.75}$ $\boxed{38.1}$ $\boxed{15.0}$ 71.9

$\boxed{83.4}$ $\boxed{3.5}$ 86.9

$$C_{oupi} = f_{cUPO} \frac{S_{upi}}{f_{cv\,UPO}} = 0.518 \frac{10}{1.481}$$

COD PS

$\boxed{55475}$

| VFA | FBSO | USO | |
|---|---|---|---|
| $\boxed{50}$ | $\boxed{115}$ | $\boxed{45}$ | 210 Dissolved |

| BPO | UPO | |
|---|---|---|
| $\boxed{37255}$ | $\boxed{18010}$ | 55265 Particulate |

Find UPO in PS by mass balance – like in table of Q1.1

$$Q_{PS}\,Supi_{PS} = Q_{iRawWW}\,Supi_{RawWW} - Q_{SettledWW}\,Supi_{SettledWW}$$

Flux

$$0.125 \times Supi_{PS} = 25 \times 100 - 24.875 \times 10$$

$$Supi_{PS} = 18010 \text{ mg/l}$$

$$\text{Unbio fraction of the PS} = \frac{18010 + 45}{55475} = 0.325 = 32.5\%$$

So PS is $100 - 32.5 = 67.5\%$ Biodeg.

TKN of PS

Flux Table

$\boxed{2059.1}$

$\boxed{2011.0}$

| FSA | | FSBo | USo | |
|---|---|---|---|---|
| $\boxed{39.1}$ | 44.0 | $\boxed{3.8}$ | $\boxed{1.1}$ | 44.0 |

| 2006.1 | $\boxed{790.0}$ | $\boxed{1216.1}$ |
|---|---|---|

$$N_{oupi}\,PS = f_{nUPO}\,\frac{Supi_{PS}}{f_{cvUPO}} = 0.10\,\frac{18010}{1481} = 1216.1 \text{ mgN/l}$$

10h30 AM

TP of PS

Flux Table

TP

$\boxed{488.4}$

$\boxed{481.1}$

OP

$\boxed{7.28}$ 8.23 $\boxed{99.5}$ $\boxed{90}$

480.13 $\boxed{176.1}$ $\boxed{304.1}$

Particulate

$$P_{OUPPS} = f_P \frac{Sup_{PS}}{f_{CV\,UPO}} = 4025 \frac{18010}{1.481}$$

$=$

TOC of PS

Flux Table

18553

$\boxed{18.8}$ 71.9 $\boxed{38.1}$ $\boxed{15.0}$

18481 $\boxed{12181.8}$ $\boxed{6299.2}$

BPO VPO

$$C_{OUPPS} = f_{CUPO} \frac{Sup_{i\,UPO}}{f_{CV\,UPO}} = 4518 \frac{18010}{1.481}$$

$= 62992$ mg C/l

| Q1.4 Primary Sludge | UPO + BPO | Bulk Table UPO | BPO |
|---|---|---|---|
| COD | | 18010 | 37255 |
| VSS | 36622.3 | 12160.7 | 24461.6 |
| TOC | | 6299.2 | 12181.9 |
| org N | | 1216.1 | 790.0 |
| org P | | 304.0 | 176.0 |
| $f_{cv}$ | | 1.481 | 1.523 |
| $f_c$ | | 0.518 | 0.498 |
| $f_n$ | | 0.100 | 0.0323 |
| $f_p$ | | 0.025 | 0.0072 |

$$VSS \text{ of } UPO = \frac{COD \; UPO}{\underset{f_{cv} UPO}{1.481}} = \frac{18010}{1.481} = 12160.7$$

$$VSS \text{ of } BPO = 36622.3 - 12160.7 = 24461.6 \;\; mg\,VSS/\ell$$

$$C_x H_y O_z N_a P_b = C_{f_c/12} H_{f_h/1} O_{f_o/16} N_{f_n/14} P_{f_p/31}$$

(4) $COD \longrightarrow f_o$

Mass balance $f_h + f_o + f_c + f_n + f_p = 1$ (5)

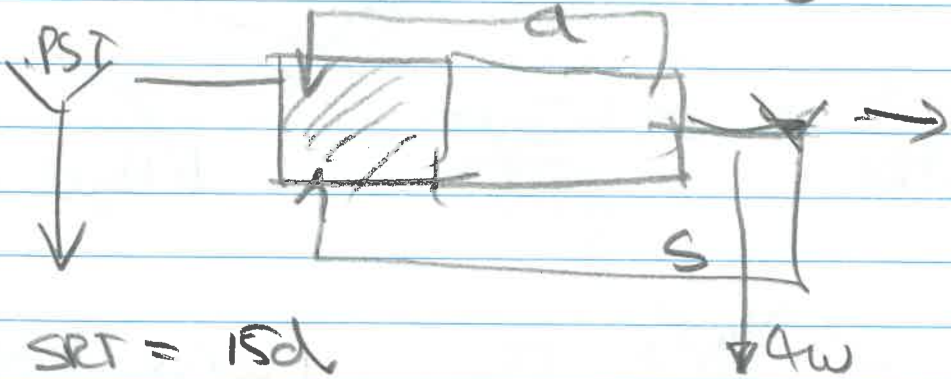
Q2 Activated Sludge PULE

Settled WW $T = 16°C$

$X_t = TSS = 4.5\ g\,TSS/l$

$f_{S'us} = \frac{USO\ COD}{Total\ COD} = 0.095;\ \frac{45}{475}$

$f_{S'up} = \frac{UPO\ COD}{Total\ COD} = \frac{10}{475} = 0.021$




SRT = 15d

Flux Table

2.1 Fluxes COD $= q_i S_{ti} = 24.875 \times 475 = FS_{ti}$
$= 11816$ kg COD/d

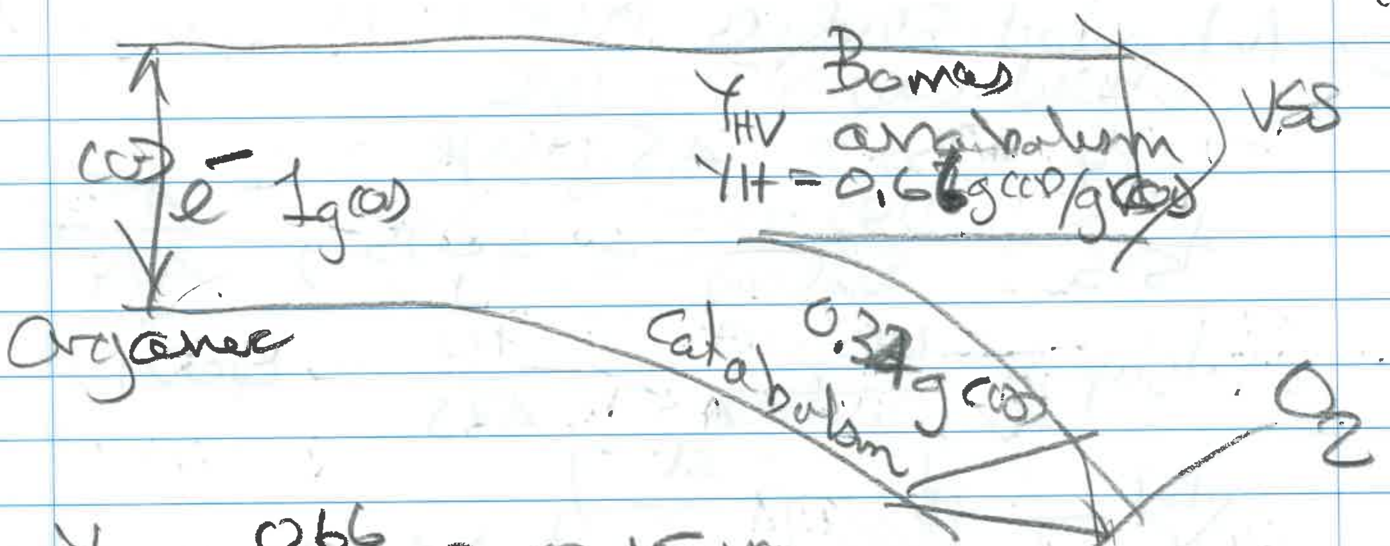
$FS_{bi} = $ Bio COD $= FS_{ti}(1 - f_{S'us} - f_{S'up})$
$= 11816(1 - 0.095 - 0.021) = 10448$ kg COD/d

Flux UPO in VSS $= FX_{Ii} = q_i$ UPO COD conc Supi
$= 24.875 \times 10 / f_{cV}$
$= \underbrace{11816}_{FS_{ti}} \times \frac{0.021}{1.481} = 1681$ kgVSS/d

Flux ISS $= Q_i X_{IOi} = 24.875 \times 15$
$= 373$ kg ISS/d

2.2 16°C $b_{H16} = b_{H20}(1.029)^{16-20}$
$= 0.24(1.029)^{16-20} = 0.214$ /d

$$\frac{Y_{Hv} R_s^{SRT}}{1 + b_{HT} R_s} = \frac{0.45\ gVSS/gCOD\ 15d}{1 + 0.214/d \times 15d} = 1.603\ \frac{gVSS.d}{gCOD}$$




$$Y_H = \frac{0.66}{1.481} = 0.45 \frac{gVSS}{gCOD}$$

$$MX_{\substack{OHO \\ BH}} = \frac{Y_{HV} R_S}{1 + b_{HT} R_S} \qquad FS_{ti} = 1.603 \times 10448$$

$$= 16747 \text{ kg VSS}$$

recall

$$\frac{kgVSS \cdot d}{kgCOD} \; \frac{kgCOD}{d} = kgVSS$$

$$MX_{EB} = f_H \, b_{HT} \, R_s \, MX_{BH}$$

$$= 0.20 \times 0.214 \times 15 \times 16747$$

$$= 10775 \text{ kg VSS}$$

$$MX_I \,(UPO) = FX_{Ii} R_S = 168 \frac{kgVSS}{d} \, 15d$$

$$= 2519 \text{ kg VSS}$$

$$MX_V \,(VSS) = MX_{BH} + MX_{EH} + MX_I$$

$$= 16747 + 10775 + 2519$$

$$= 30021 \text{ kg VSS.}$$

$$MX_{IOi} = FX_{IOi} R_S + f_{iOHO} MX_{BH}$$

$$= 373 \times 15 + 0.15 \times 16747$$

$= 5597 + 2512 = 8109 \text{ kg ISS}.$

$MX_t = VSS + ISS = MX_v + MX_{IO}$

$= 30021 + 8109 = 38135 \text{ kg TSS}.$

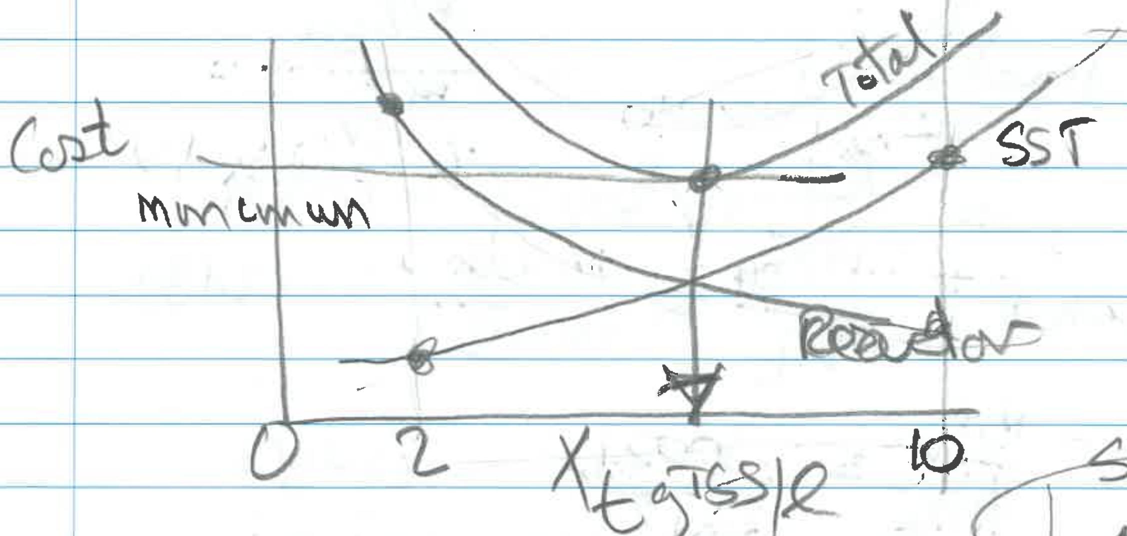
2.3 $V_p = \frac{MX_t}{X_t} = \frac{38{,}135 \text{ kgTSS}}{4.5 \text{ kg/m}^3} = 8473 \text{ m}^3$

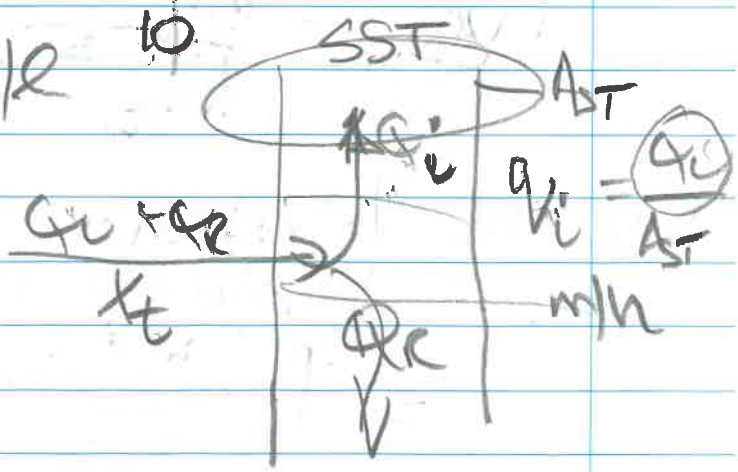
or $8{,}473$ Ml

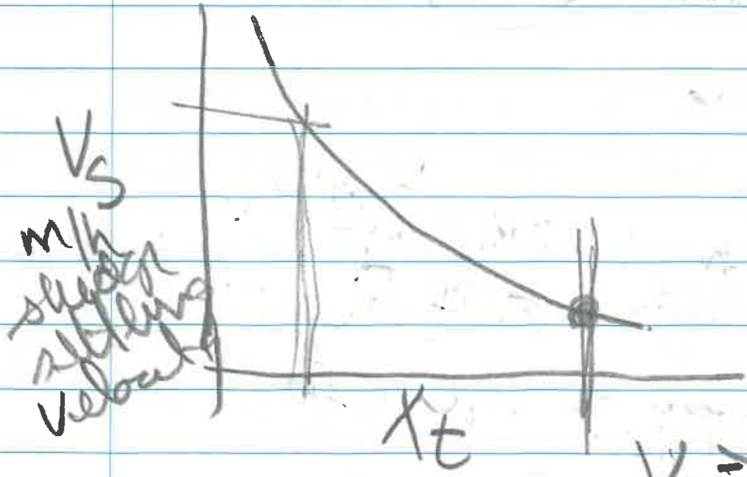
$HRT = \frac{V}{Q_i} = \frac{8.473}{24.875} = 0.34 \text{ d}$

$8.14 \text{ h}$

?



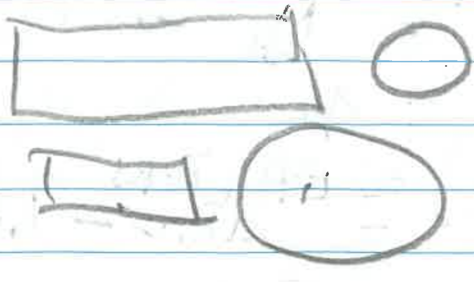




$V_s \geq q_i = \frac{Q_i}{A_{ST}}$

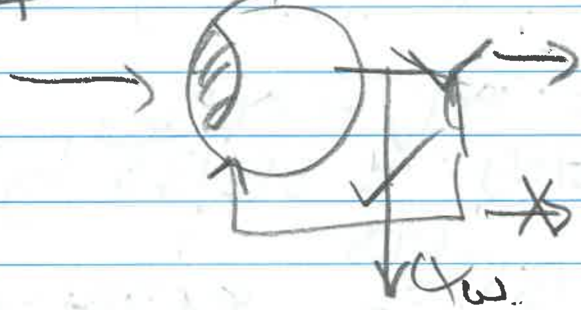
11h35 ML

Low $X_t$ 2

High $X_t$ 10



Q2.4




$R_S = SRT = \dfrac{MX_t \text{ kgTSS}}{FX_t \text{ kgTSS/d}}$

$FX_t = \dfrac{MX_t}{R_S}$

$= \dfrac{38135}{15} = 2542$ kgTSS/d

$Q_w = \dfrac{V}{R_S}$ or $\dfrac{8473}{15}$

$= 565\ m^3/d$

$Q_w = FX_t / X_t = \dfrac{2542}{4.5} = 565\ m^3/d$

Q2.5 Active fraction $f_{avOHO} = \dfrac{MX_{BH}}{MX_V} =$

$= 16747 / 30021 = 0.558$

$f_{atOHO} = \dfrac{MX_{BH}}{MX_t} = \dfrac{16747}{38135} = 0.439$

$\dfrac{VSS}{TSS} = \dfrac{MX_V}{MX_t} = \dfrac{30021}{38135} = 0.787$

Q2.6 $N_S$ = nitrogen conc in influent required for sludge production mgN/l influent

$= f_n \dfrac{MX_V}{R_S Q_i} \quad \dfrac{\text{mgN}}{\text{mgVSS}} \quad \dfrac{\text{kgVSS}}{d \cdot Ml/d} = \text{mgN/l}$

$= 0.10 \dfrac{30021}{15 \times 24.875} = 8.0$ mgN/l influent

Effluent TKN $= N_{te}$ no nitrification

$= N_{ti} - N_S = 50 - 8.0$

no nitrification $= 42.0$ mgN/l

Effluent FSA ($N_{ae}$) = Eff TKN − $N_{ouse}$

$= 42.0 - 1.1 = 40.9$ mgN/l

Influent FSA = 39.1 mg N/l
So effluent FSA = 40.9 mg N/l
Go to TKN block diagram.

$$\underbrace{39.1}_{FSA} + \underbrace{\underbrace{3.8}_{FBSO} + \underbrace{5.33}_{BPO}}_{\text{org N from influent}} - \underbrace{\left(\overset{N_s - N_{oupi}}{8.0 - 0.67}\right)}_{\text{N taken up from FSA to produce OHO + End Residue}} = 40.9!$$

Q2.7 Oxygen Demand

$$FO_c \; kgO/d = FS_{bi}\left\{\underbrace{(1 - f_{cv}Y_{Hv})}_{\text{catabolic growth}} + f_{cv}(1-f_H)\,b_{HT}\frac{Y_{Hv}R_s}{1+b_{HT}R_s}\right\}$$

$$= 10448\left\{(1-1.481\times0.45) + 1.481(1-0.2)\,0.214\times1.603\right\}$$

= 7732 kgO/d organic removal.

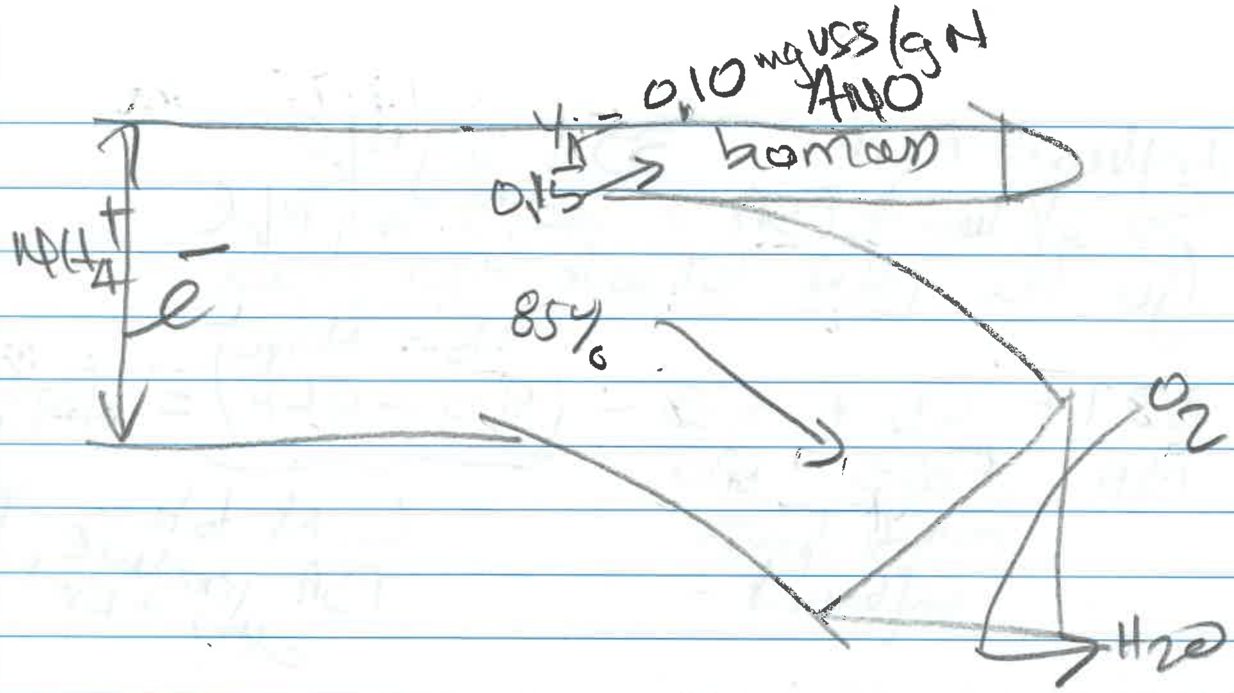
$FO_n$ for complete nitrification ie. all FSA → $NO_3^-$

$$= 4.57\,\underbrace{Q_i}_{24.875}\;\underbrace{\text{effluent FSA}}_{40.9 \text{ mgN/l}}$$

$$= 4649 \text{ kgO/d}$$

$$FO_t = FO_c + FO_n = 7732 + 4649 = 12381 \text{ kgO/d}$$

$$OUR = \frac{FO_t\,10^6}{V_{reactor}\,24\times10^3} = \frac{12381}{8472\times24\times10^3}\;\frac{mgO}{l.h} =$$




$$NH_4^+ + 3H_2O \rightarrow NO_3^- + 10H^+ + 8e^-$$

$$8(H^+ + e^-) + 2O_2 = 4H_2O$$

1 mole FSA as N needs 64 g O (2×32)

1 g N needs $64/14 = 4.57$ g O/g N

Q2.8 $C_5H_7O_2N_{0.9}P_{0.1}$ biomass

$$f_p = \frac{0.1\times 31}{12\times 5 + 7 + 2\times 16 + 0.9\times 14 + 0.1\times 31} = \frac{3.1}{114.7}$$

$= 0.027$ g P/g VSS ok but we use 0.025 g P/g VSS.

$$P_s = f_p \frac{MX_V}{R_s Q_i} = 0.025 \frac{30021}{15\times 24.875}$$

$= 2.0$ mg P/ℓ (notice $\frac{1}{4}$ of $N_s$!)

$\frac{1}{4}$ of $f_n$

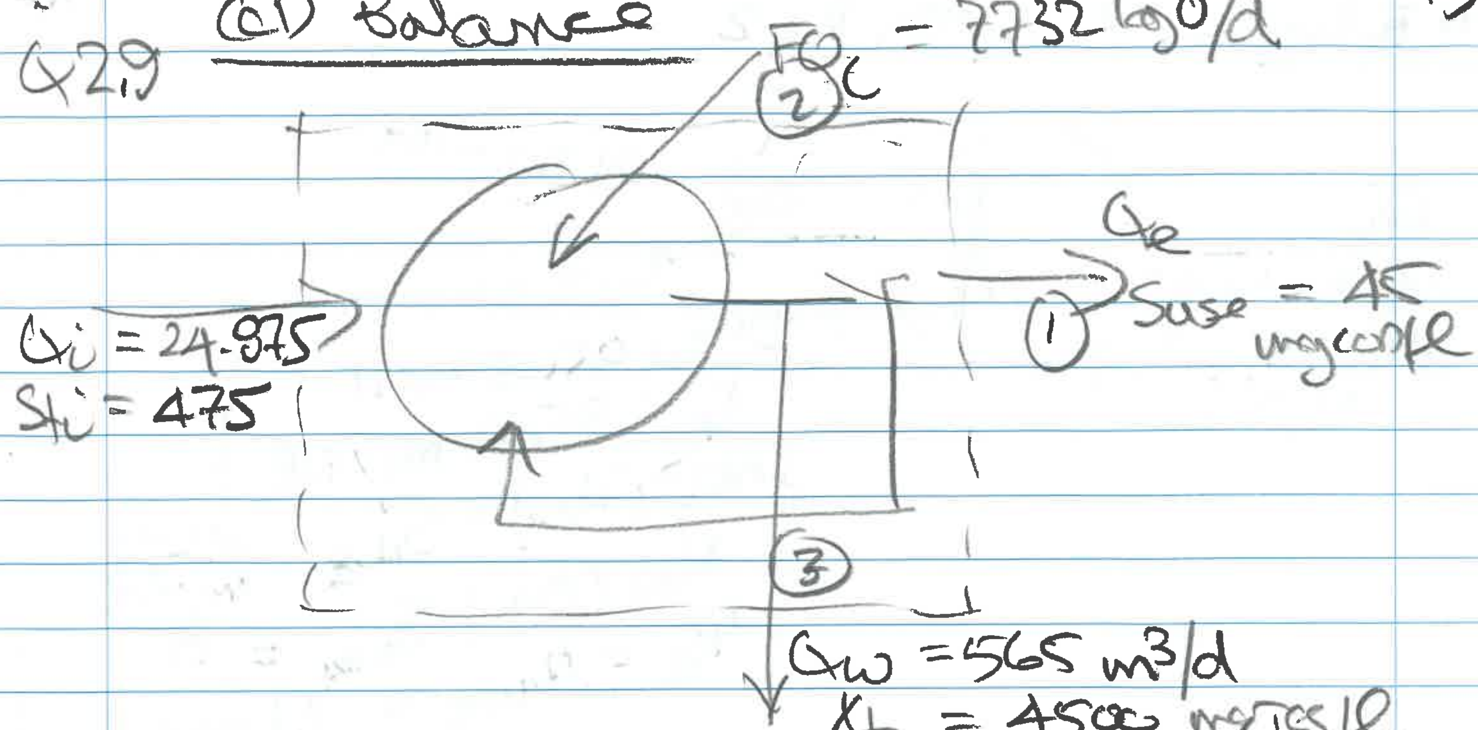
$$P_{te} = P_{ti} - P_s = 9.6 - 2.0 = 7.6 \text{ mg TP-P/ℓ}$$

$P_{se}$ OP in effluent $= P_{te} - P$ in USO

$= 7.6 - 0$ (from block diagram)

$P_{se} = 7.6$ mg OP-P/ℓ

Q2.9 COD Balance




$X_t = 4500$ mgTSS/l

$X_v = \frac{VSS}{TSS}\, 4500$

$= 0.787 \times 4500$

$= 3542$ mgVSS/l

COD in $= Q_i S_{ti}$

$= 24.875 \times 475$

$= 11816$ kg COD/l

(1) Effluent COD $= Q_e S_{use} = (Q_i - Q_w) S_{use}$

$= (24.875 - 0.565)\ 45$

$24.310 \times 45 = 1094$ kg COD/d

(2) $FO_c = 7732$ kgO/d or kg COD/d

(3) Waste flow: $= Q_w (S_{use} + f_{cv} X_v)$

$= 0.565\,(45 + 1.481 \times 3542)$

$= 2986$ kg COD/d

Total COD out $= \underset{1}{1094} + \underset{2}{7732} + \underset{3}{2986}$

$= 11815$ kg COD/d

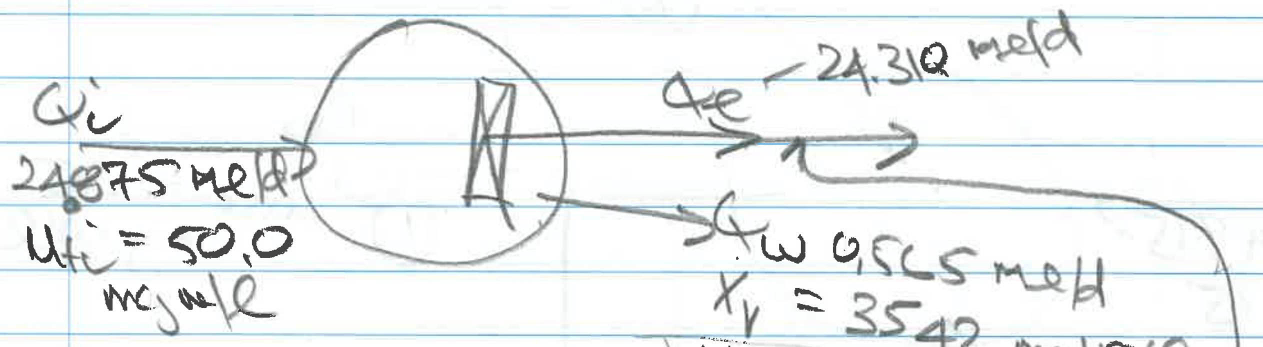
COD balance % $= \frac{\text{COD out}}{\text{COD in}} \times 100 = \frac{11815}{11816}\, 100$

$= 99.99\%$ Error ~ 0.01%

Acceptable error $< \pm 0.1\%$ or $\frac{1}{1000}$

12h30 NL
End day 1

N Balance 27/2/18 start Day 2 




$NO_3^-$ ($N_{ne}$) = $S_{NO_3}$ = 40.9 mgN/l
$N_{ae}$ (FSA) | $S_{NH4}$ = 0
$N_{te}$ = $N_{ouse}$ = 1.1 mgN/l

$$Q_i N_{ti} \overset{?}{=} Q_w(X_v f_n + \underset{TKN}{N_{te}} + \underset{NO_3}{N_{ne}}) + Q_e(\underset{TKN}{N_{te}} + \underset{NO_3}{N_{ne}})$$

$$24.875 \times 50 \overset{?}{=} 0.565(3542 \times 0.1 + 1.1 + 40.9) + 24.31(1.1 + 40.9)$$

$$1244.9 \text{ kgN/d} \overset{?}{=} 223.8 + 1021.0 = 1244.8 \text{ kgN/d}$$

$$N \text{ balance } \% = \frac{N_{out}}{N_{in}} 100 = \frac{1244.8}{1244.9} 100$$

$$= 100.0 \quad < 0.1\% \checkmark$$

P Balance

$$Q_i P_{ti} \overset{?}{=} Q_w(X_v f_p + P_{te}) + Q_e(P_{te})$$

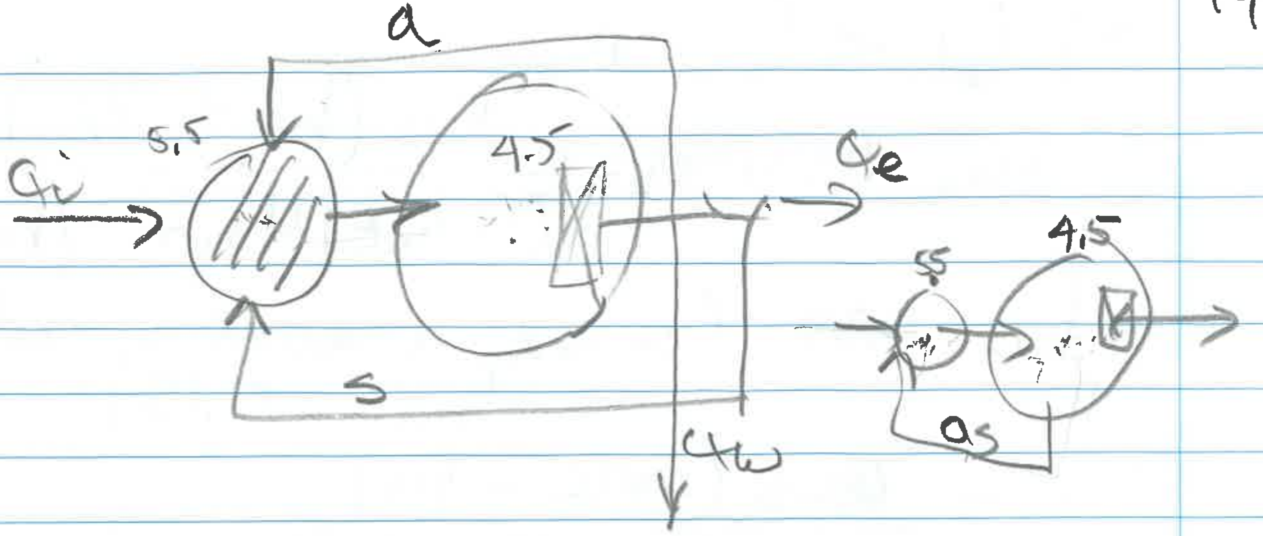
$$P_{te} = \underset{0.0}{P_{ouse}} + OP \quad P_{se} = S_{PO4}$$

$$24.875 \times 9.6 \overset{?}{=} 0.565(3542 \times 0.025 + 7.6) + 24.31 \times 7.6$$

$$238.8 \overset{?}{=} 54.3 + 184.5 = 238.8 \text{ kg P/d}$$

P balance = 100%

Q3




$\mu_{Am20}$ ANO = 0.45/d  0.3 to 0.8/d

$\mu_{Am16} = \mu_{Am20}(1.123)^{T-20}$

$= 0.45(1.123)^{16-20} = 0.283/d$

$K_{n16} = K_{n20}(1.123)^{16-20} = 0.63$ mg FSA-N/ℓ
1.0

$b_{A16} = b_{A20}(1.029)^{16-20} = 0.036/d$
└ 0.04/d

Safety factor $= S_f = 1.25$.

$f_{xm}$ = max unaerated sludge mass fraction

$= 1 - \frac{S_f(b_{AT} + 1/R_s)}{\mu_{AmT}}$  \$\$\$\$\$

$= 1 - \frac{1.25(0.036 + 1/15)}{0.283} = 0.548$

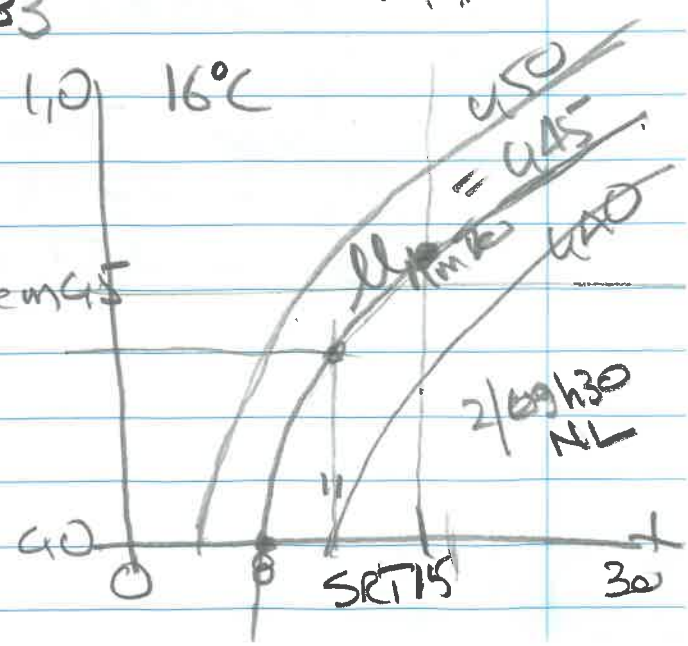
$MX_t$ = 38135 kg TSS

So 54.8% of $MX_t$ can be unaerated and still nitrify well.

Max (FSA Effl) $= \frac{K_{nT}}{S_f - 1}$

$f_{xt} = f_{xm}$  $= \frac{0.63}{1.25-1}$

= 2.52 mg FSA-N/ℓ



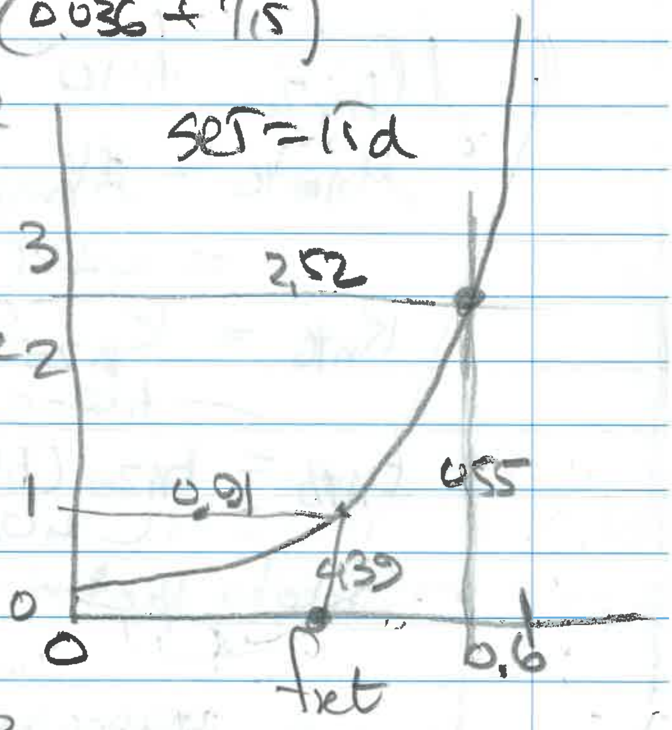
If $f_{xt} < f_{xm}$ then

$$N_{ae}\ (\text{Eff FSA}) = \frac{K_{nT}(b_{AT} + 1/R_s)}{(1-f_{xt})\mu_{AmT} - (b_{AT} + 1/R_s)}$$

$f_{xt} = 0.39$ (in Q4 anaerobic reacta $f_{xa} = 0.15$)

$$= \frac{0.63(0.036 + 1/15)}{(1-0.39)\,0.283 - (0.036 + 1/15)}$$

$= 0.91$ mg FSA-N/l




Effluent TKN = FSA + Org N

$N_{te} = N_{ae} + N_{ouse}$

$0.91 + 1.1 = 2.0$ mg TKN-N/l

Nitrification Capacity

$N_c = N_{ti} - N_s - N_{te}$

$= 50.0 - 8.0 - 2.0$

$= 40.0$ mg $NO_3$-N/l

$FO_n = 4.57 \times Q_i N_c = 4.57 \times 24.875 \times 40$

$= 4547$ kgO/d

$f_{xt} = f_{xm}$ Then $N_{te} = 2.52 + 1.1 = 3.62$ mg N/l

$N_c = 50 - 8 - 3.62 = 38.4$

$FO_n = 4.57 \times 24.875 \times 38.4 =$

Less

Q3.2 Readily Biodeg COD fraction with respect to the influent Biodeg COD say "Unit i"

$$f_{SbS\text{-}soluble}\ (\text{COD}\ L_{bio}) = \frac{VFA + FBSO}{VFA + FBSO + BPO}$$

Readily / soluble

Biodeg COD

$$= \frac{50+115}{50+115+255} = 0.393$$

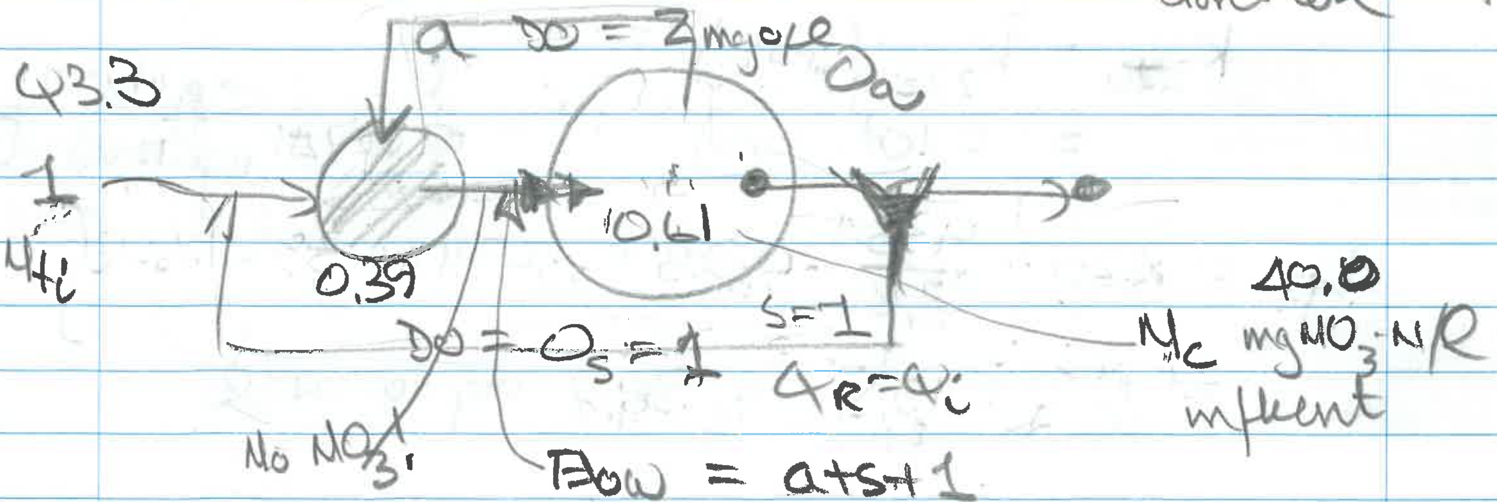
$$f_{Sb'S} \neq f_{S'bS} = \frac{VFA + FBSO}{VFA + FBSO + BPO + UPO + USO}$$

wrt Biodg COD

wrt total COD

$$f_{S'bS} = \frac{50+115}{475} = 0.347$$ don't use

Q3.3



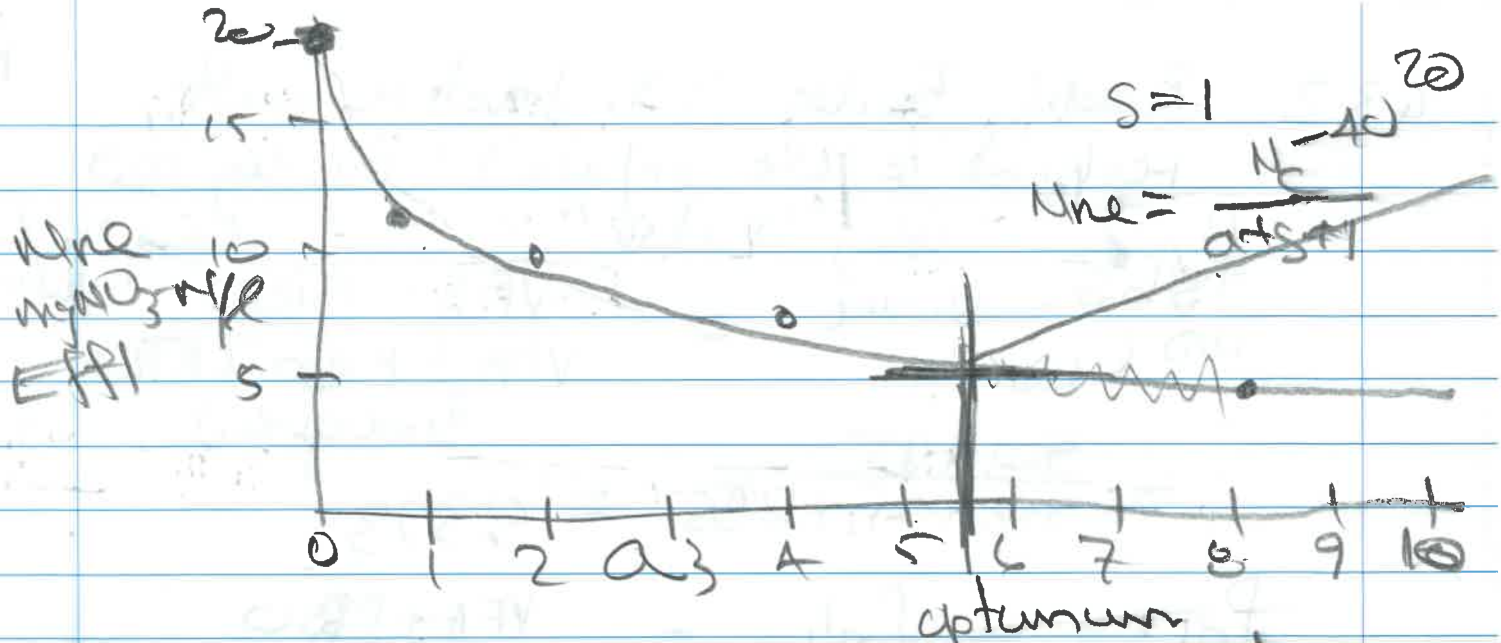

$$\text{Nitrate in aerobic conc} = \frac{N_c\,1}{a+s+1}$$

Nitrate load on anoxic =

$$a\left\{\frac{N_c}{a+s+1} + \frac{O_a}{2.86}\right\} + s\left\{\frac{N_c}{a+s+1} + \frac{O_s}{2.86}\right\}$$

But Anoxic has a certain denitrification potential $D_{p1}$ (primary anoxic)

$$N_{ne} = \frac{N_c}{a+s+1}$$ on condition that $NO_3$ from anoxic is zero!




$a_{opt}$ is when $NO_3$ load on anoxic = $D_{p1}$

$$D_{p1} = S_{bi}\left\{\underbrace{\frac{(1-f_{cv}Y_{Hv})}{2.86} f_{sb's}}_{RBCOD} + \underbrace{K_{2T}\, f_{xd1}\frac{Y_{Hv}R_s}{1+b_{HT}R_s}}_{BPO}\right\}$$

$$K_{2T} = K_{220}(1.08)^{T-20}$$
$$= 0.101(1.08)^{16-20} = 0.0741\ \frac{mg\ NO_3\text{-}N}{mg\ OHVSS.d}$$

$$D_{p1} = 420\left\{\frac{0.334}{2.86}0.393 + 0.0741 \times 0.39 \times 1.603\right\}$$
$$= \underset{RBCOD}{19.2} + \underset{BPO}{19.5} = 38.7\ mg\ NO_3\text{-}N/l$$

$$D_{p1} = \text{nitrate load}$$
$$= a\left\{\frac{N_c}{a+s+1} + \frac{O_a}{2.86}\right\} + s\left\{\frac{N_c}{a+s+1} + \frac{O_s}{2.86}\right\}$$

only unknown is $a$ so solve for $a = a_{opt}$

$$a_{opt} = \frac{-B + \sqrt{B^2 + 4AC}}{2A} \quad \text{not error}$$

$$A = \frac{O_a}{2.86}\ ;\ B = N_c - D_{p1} + \frac{(1+s)O_a + sO_s}{2.86}$$

$$C = (1+s)\left\{D_{p1} - \frac{sO_s}{2.86}\right\} - sN_c$$