Text problems 14-17

14. $$r_h = K_h \left[\frac{(X_S/X_B)}{K_x + \left(\frac{X_S}{X_B}\right)} \right] X_B$$

difference is that r_h does NOT depend on $\left(\frac{X_S}{K_x + X_S}\right)$ directly although X_S is the substrate

dependence on ratio says that when X_B large <u>relative</u> to X_S, r_h will be 1st order (X_S-limited)

when X_S large <u>relative</u> to X_B, r_h is zero order

ratio reflects surface interaction between particulate substrate & biomass (exo-enzymes)

15. processes

ammonification: biomass-N → NH_3-N + debris N

traditional $\quad i_{NXB}$ biomass COD → NH_3 N + i_{NXD} debris COD

$$r_{SNH} = (i_{NXB} - i_{NXD} f_D) b X_B$$

lysis-regrowth

soluble organic N from X_S

$$r_{SNH} = -r_{SNS}$$

soluble org N

$$r_{SNS} = -K_a S_{NS} X_{BH}$$

Synthesis $\quad r_{SNH} = -i_{NXB} \mu X_B$

15 nitrification $\left(-\frac{1}{Y_A}\right) NH_4\text{-}N - \frac{(4.57 - Y_A)}{Y_A} O_2 = $ biomass COD

$(NH_4^+ \rightarrow NO_3)$

e^- donor only

$$\frac{r_{NH}}{\left(-\frac{1}{Y_A}\right)} = \mu X_{BA} \; (= r_{XA})$$

$$\frac{r_{XA}}{X_A} = \mu_A = \hat{\mu}_A \left(\frac{S_{NH}}{K_{NH} + S_{NH}}\right)\left(\frac{S_o}{K_o + S_o}\right)$$

denitrification $-\frac{1}{Y_H} S_S - \frac{(1 - Y_H)}{2.86\,(Y_H)} S_{NO} = $ biomass COD

$2.86 \; \frac{g\,O_2}{g\,NO_3\text{-}N}$

$$\frac{r_{S_{NO}}}{-\left[\frac{(1-Y_H)}{2.86\,Y_H}\right]} = \frac{\overset{\text{anoxic}}{r_{XBa}}}{1} = \frac{r_s}{\left(-\frac{1}{Y_H}\right)}$$

$$r_{XBa} = \eta_a \, r_{XB} = \eta_a \mu_H X_{BH}$$

$$= \eta_a \hat{\mu}_H \left(\frac{S_S}{K_S + S_S}\right)\left(\frac{S_{NO}}{K_{NO} + S_{NO}}\right)\underbrace{\left(\frac{K_{DO}}{K_{DO} + S_O}\right)}_{O_2 \text{ inhibition}}$$

$$r_{S_{NO}} = -\left[\frac{(1-Y_H)}{2.86\,Y_H}\right] r_{XBa}$$

16. PAO : PO_4 removal

anaerobic (no growth): fermentation

Substrate COD (acetate COD)

$$-S_S + S_A = 0$$

$$r_{S_S} = -r_{S_A}$$

PHB formed ($-S_A$-COD $+ X_{PHB}$-COD $= 0$)

$$r_{X_{PHB}} = -r_{S_A}$$

(X_{PP}) Poly-P destroyed, PO_4 released (S_P)

$$r_{S_P} = -r_{X_{PP}}$$

energy from PP used to make PHB

$$-X_{PP} + Y_P X_{PHB}^{-COD} = 0 \qquad Y_P = \frac{\text{g P used}}{\text{g PHB COD formed}}$$

$$-r_{X_{PP}} = Y_P r_{X_{PHB}}$$

$$-r_{S_A} = r_{X_{PHB}} = \frac{-r_{X_{PP}}}{Y_P} = \frac{r_{S_P}}{Y_P}$$

$$-r_{S_A} = \hat{q}_A \left(\frac{S_A}{K_A + S_A}\right)\left(\frac{(X_{PP}/X_{BP})}{K_{PP} + \left(\frac{X_{PP}}{X_{BP}}\right)}\right) X_{BP}$$

rate depends on % PP in PAO's

PAO's

max rate of acetate consumption is ref. since PAO's NOT growing

16. aerobic PP synthesis & growth of PAO's

growth

$$-\left(\frac{1}{Y_{PAO}}\right)X_{PHB}\text{-COD} - \frac{(1-Y_{PAO})}{-Y_{PAO}}O_2 + X_{PAO}\text{-COD} = 0$$

$$\frac{r_{XPHB}}{\left(-\frac{1}{Y_{PAO}}\right)} = \frac{r_{SO}}{(-1)\left(\frac{1-Y_{PAO}}{Y_{PAO}}\right)} = \frac{r_{X_{BP}}}{1}$$

(growth at expense of X_{PHB})

$$Y_{PAO} = \frac{X_{PAO}\text{-COD formed}}{X_{PHB}\text{-COD consumed}}$$

ref is

$$r_{X_{PAO}} = \hat{\mu}\frac{(X_{PHB}/X_{BP})}{\left(K_{PHB} + \frac{X_{PHB}}{X_{BP}}\right)}\left(\frac{S_P}{K_P + S_P}\right)\left(\frac{S_O}{K_O + S_O}\right)X_{BP}$$

storage of P.P stoichiometry: (X_{pp} is reference)

$$-r_{S_P} + r_{X_{PP}} = 0$$

also - P-stoichiometry:

$$-Y_{PHB}X_{PHB}\text{-COD} - S_P - (-Y_{PHB})S_O + X_{PP} = 0$$

$$Y_{PHB} = \frac{g\text{-}PO_4\text{-P stored}}{g\text{ PHB consumed}}$$

16.

$$r_{X_{PP}} = -r_{S_P} = \frac{-r_{X_{PHB}}}{Y_{PHB}} = \frac{r_{S_0}}{(-1)(-Y_{PHB})}$$

$$r_{X_{PP}} = \hat{q}_{PP}\left[\frac{X_{PHB}/X_{BP}}{K_{PHB}+\frac{X_{PHB}}{X_{BP}}}\right]\left(\frac{S_P}{K_P+S_P}\right)\left(\frac{S_0}{K_0+S_0}\right)\times\cdots$$

max rate of PP synthesis

$$\times\left(\frac{K_{PPMAX}-(X_{PP}/X_{BP})}{K_{IPP}+\left(K_{PMAX}-\frac{X_{PP}}{X_{BP}}\right)}\right)X_{BP}$$

note driving force term
only so much of cell mass can be PP ($K_{PMAX} \simeq 0.3-0.35$ g PP/g PAO)

when X_{PP} approaches K_{PMAX}, PP synthesis slows down.

17. a. $Y_{HO} = 0.7 \frac{g\ X\text{-}COD}{g\ S\text{-}COD}$ "observed" used considering BOTH lysis & decay

$$\text{oxygen requirement} = (1-0.7)\frac{g\ O_2}{g\ S\text{-}COD} = 0.3 \frac{g\ O_2}{g\ S_s}$$

assume that $i_{N_{XB}} = 0.087 \frac{g\ N}{g\ X\text{-}COD}$

$$\text{nitrogen requirement} = 0.087(0.7) = 0.061 \frac{g\ NH_4\text{-}N}{g\ S_s}$$

assume phosphorus requirement = 0.2 × n-requirement

$$P\ \text{requirement} = 0.012 \frac{g\ P}{g\ S_s}$$

K	10 mg/gS_s	Cu	= 0.01 mg/gS_s
Ca	10 mg/gS_s	Mo	= 0.003 mg/gS_s
Mg	5 mg/gS_s	Co	= < 0.0003 mg/gS_s
S	4 mg/gS_s		
Na	2 mg/gS_s		
Cl	2 mg/gS_s		
Fe	1. mg/gS_s		
Zn	0.1 mg/gS_s		
Mn	0.05 mg/gS_s		

Same procedure for b & c (requirements will be lower by 18.6% and 49%, resp.)