Biofilm kinetics IV

Today's lecture

- Estimating parameter values
  - Diffusion coefficients, D and D_f
  - Effective diffusion layer thickness, L
  - Biofilm loss coefficient, b'
- Analyzing performance of an attached growth bioreactor

Parameters for biofilm analysis

- Eight variables: $\hat{q}, K, Y, b', D_f, D, L, S$
- S is given
- $\hat{q}, K, Y, and\ b$ are obtained from batch experiments

→ Still need to determine $b_{det}, D_f, D, and\ L$

Parameters for biofilm analysis

You do not have to memorize any equations here. Just understand the concepts and logics and get ready for future uses!!!

Parameters for biofilm analysis

1. Aqueous diffusion coefficient, ***D***
   - Depends on size of a molecule
   - Molecule size ↑ → *D* ↓
   - Look up chemical engineering handbooks
   - Some online resources can be useful (ex: SPARC online calculator)
2. Diffusion coefficient in the biofilm, D_f
   - Linear correlation with *D*
   - Smaller than *D*: restriction in diffusion (biofilm consists of bacterial cells and slime)
   - For small solutes that do not adsorb to the biofilm matrix, D_f/D = 0.5-0.8 (using 0.8 may be appropriate for general cases)
   - Adsorption may result in significantly smaller D_f

Parameters for biofilm analysis

3. Thickness of effective diffusion layer, ***L***
   - Depends on *D* and flow velocity of the bulk liquid, *u*
   - Look up the literature for correlation equations appropriate for your own system
   - ex) For biofilm on spherical porous media, following equation may be used:

$$L = \frac{D(Re_m)^{0.75} Sc^{0.67}}{0.57u}$$

$Sc = \mu/\rho D$, Schmidt number

$Re_m = 2\rho d_p u/(1-\varepsilon)\mu$, modified Reynolds number

μ = absolute viscosity [g/cm/d]

ρ = water density [g/cm^3]

$u = Q/A_c$ = superficial flow velocity [cm/d]

d_p = diameter of solid medium [cm]

ε = porosity of medium bed

Q = volumetric flow rate [cm^3/d]

A_c = cross-sectional area of the flow stream [cm^2]

Parameters for biofilm analysis

4. Overall biofilm-loss coefficient, ***b'***

- Recall that $b' = b + b_{det}$
- b_{det} and b are comparable (both terms should be considered)
- b_{det} depends on the shear stress acting on the biofilm surface
- ex) Rittmann (1982) suggested following equations:

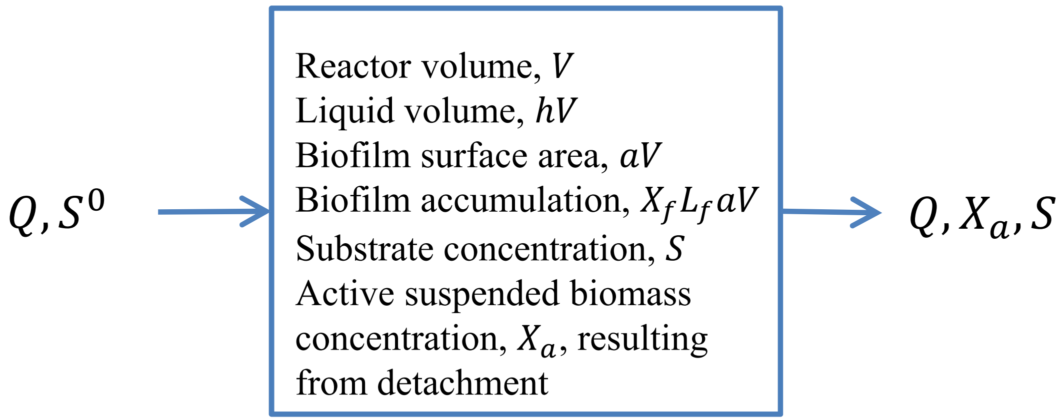
$$b_{det} = 8.42 \times 10^{-2} \cdot \sigma^{0.58} \qquad (L_f < 0.003\ cm)$$

$$b_{det} = 8.42 \times 10^{-2} \cdot \left(\frac{\sigma}{1 + 433.2\left(L_f - 0.003\right)} \right) \sigma^{0.58}$$

$$(L_f > 0.003\ cm)$$

Analyzing an attached growth bioreactor

For simplicity, let's deal with the simplest attached growth bioreactor, a completely mixed biofilm reactor:



h = fraction of water in the reactor

$a = A_{T,biofilm}/V$ = biofilm specific surface area [L^{-1}]

$A_{T,biofilm}$ = total biofilm surface area in the reactor [L^2]

Analyzing an attached growth bioreactor

Steady-state mass balance for substrate

$$0 = QS^0 - QS - J \cdot aV$$

Steady-state mass balance for biofilm's active biomass

$$0 = YJ \cdot aV - b'X_f L_f \cdot aV$$

Calculate J and $X_f L_f$, and get S (Final target I)

Get biomass production = $b_{det} X_f L_f \cdot aV$ (Final target II)

Analyzing an attached growth bioreactor

Suspended active biomass in an attached growth bioreactor

- For an attached growth bioreactor, suspended active biomass may not significantly contribute to the degradation of the substrate
- Still, we are interested in suspended active biomass (originates from detachment from the biofilm) because this affects the effluent quality (particulate BOD/COD)

Steady-state mass balance for suspended active biomass

$$0 = -X_a Q + b_{det} X_f L_f \cdot aV$$

$$\Rightarrow \quad X_a = b_{det} X_f L_f \cdot aV / Q$$

Analyzing an attached growth bioreactor

Q: Calculate the effluent dissolved substrate concentration, biomass production, and total effluent COD in a completely mixed biofilm reactor with an initial substrate concentration of 100 mg/L and reactor configuration parameters as follows:

$$V = 1000\, m^3, a = 100\, m^{-1},\ Q = 100\, m^3/d$$

Apply the parameters given in the last question for the biofilm, plus b_{det} = 0.05/d. Assume that substrate and suspended active biomass are the two main contributor of the effluent COD.