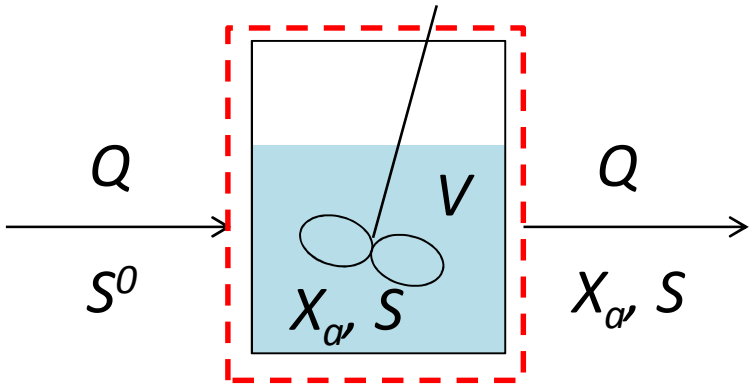
Bioreactor analysis & design I

Today's lecture

- Extended list of variables of interest with respect to reactor analysis & design
- Study on additional variables and analyses
  - Non-biodegradable VSS
  - (more in the next class)

CSTR, Monod: Master equations



Assumptions:

- Steady state
- X_a = 0 in the influent

  (negligible influent active biomass)

$$S = K\frac{1 + b\theta}{Y\hat{q}\theta - (1 + b\theta)}$$

$$X_a = Y\frac{S^0 - S}{1 + b\theta}$$

Bioreactor performance: Addt'l variables & analyses

- So far, we considered
  - Mass balance for S (of influent origin) and X_a only

    S: soluble, biodegradable organics; X_a: active (living) biomass

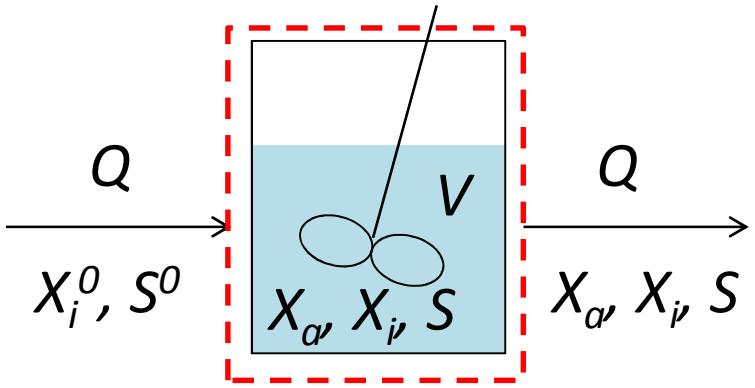
- Although there should be
  - **Particulate, biodegradable organics**
    - influent origin, partially degraded in the reactor (rate slower than S)
    - contributes to effluent BOD, COD & VSS
  - **Particulate, non-biodegradable organics**
    - influent origin + generated in the reactor by cell decay
    - contributes to effluent COD & VSS (not BOD)
  - ***S* of reactor origin**
    - soluble, biodegradable organics produced by microorganisms
    - contributes to effluent BOD & COD

<Note> There should be soluble, non-biodegradable organics as well, but we can simply apply influent conc. = effluent conc.

Addt'l variables & analyses (cont'd)

- For reactor design & operation, we also need to know
  - **Nutrient balance**: are there any limitation/redundancy in the influent nutrient supply?
    - Nutrient limiting – substrate utilization will not occur as predicted; external nutrient supply may be needed
    - Nutrient redundancy – significant level of residual N & P in effluent can be a concern (e.g., algal bloom)
  - **e^- acceptor balance**: (usually for O_2) how much should be supplied to support substrate utilization?

Including non-biodegradable VSS

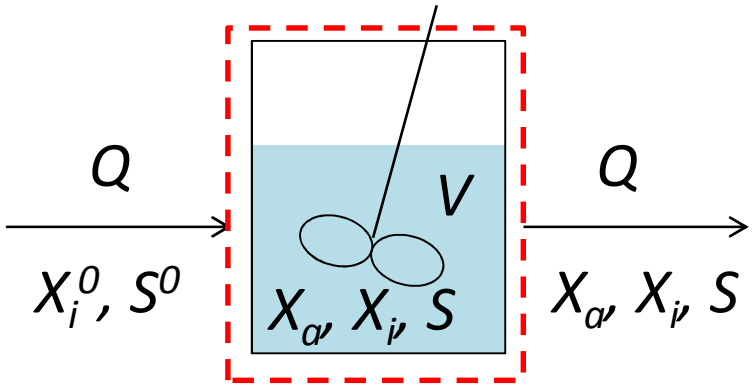


Recall:

$$\left(\frac{1}{X_a}\frac{dX_a}{dt}\right)_{inert} = -\frac{1}{X_a}\frac{dX_i}{dt} = -(1-f_d)b$$

$$\frac{dX_i}{dt} = (1-f_d)bX_a$$

Including nbVSS: mass balance



Steady-state mass balance for X_i:

$$0 = QX_i{}^0 - QX_i + (1 - f_d)bX_aV$$

$$X_i = X_i{}^0 + (1 - f_d)bX_a\theta$$

Including nbVSS: solutions

Solution for nbVSS: $X_i = {X_i}^0 + X_a(1 - f_d)b\theta$

Solution for total VSS:

$$X_v = X_i + X_a = {X_i}^0 + Y(S^0 - S)\frac{1 + (1 - f_d)b\theta}{1 + b\theta}$$