The EU funded SWIM-SM: developing capacity for Sustainable and Integrated Wastewater Treatment and Reuse

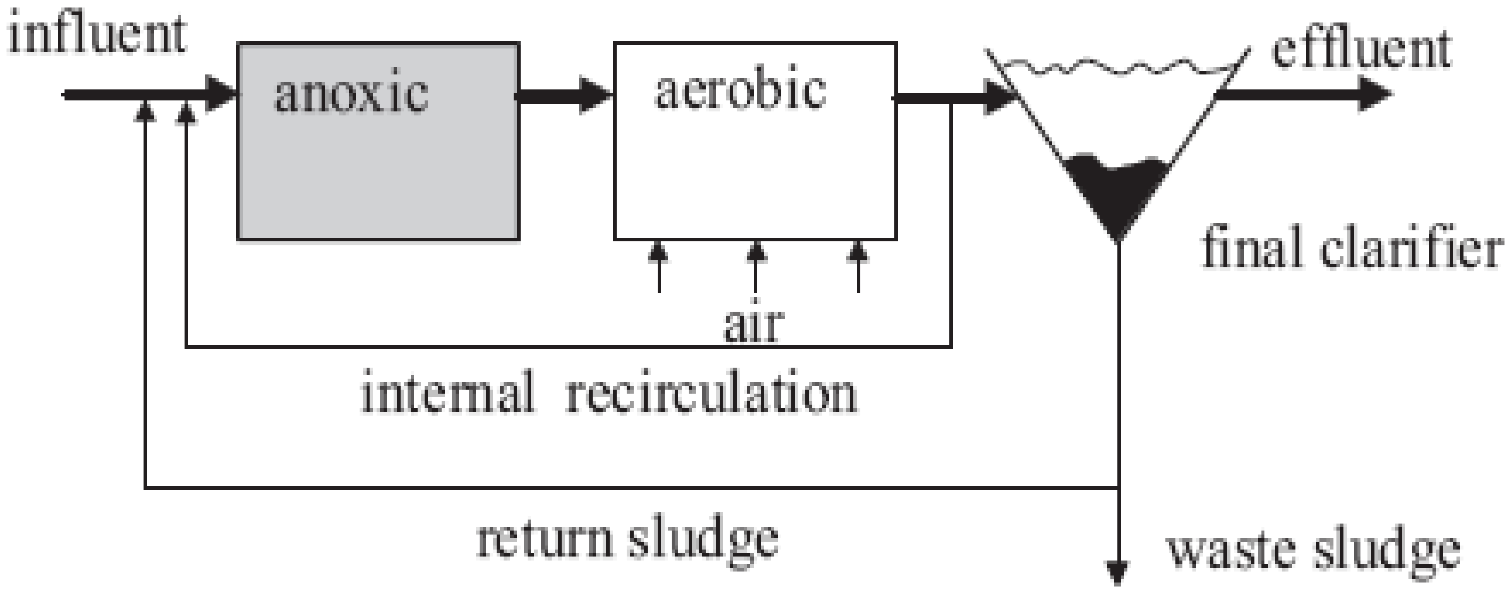
Online Course on Natural Treatment Systems: Organic Matter Removal

Organic Matter Removal

Activated Sludge

Most intensively studied

Microbial process descriptions applicable for other treatment systems (ponds etc.)



Wastewater composition

- Wastewater comprises both <u>organic</u> and <u>inorganic</u> materials (measured in influent).

- These are removed in by:
  - Biological conversion by m.o.

    BIODEGRADABLE

  - Phase transformations (physicochemical and biological (dissolved → solid; dissolved → gas↑)

    BIODEGRADABLE AND/OR CHEMICAL REACTIVE

  - Solid-liquid separation

    SETTLEABLE or SUSPENDED

DISCUSSION:

- How do you expect that the different organic constituents (particulate, colloidal and dissolved) are removed as a function of their (bio-) degradability in a wastewater treatment plant?

Transformations

- So irrespective of treating raw or settled WW:
  - Particulates (settleable and non-settleable/ colloidals) get enmeshed in the sludge mass
  - Biodegradable organics (settleable, non-settleable, dissolved) become biomass (able to settle)
  - Unbiodegradable dissolved organics escape with effluent.

- Some sludge mass is daily harvested from reactor to control the mass in reactor (in case of e.g. activated sludge system).

Biological behaviour

This involves two metabolic processes:

(1) Organism growth – utilization of biodegradable organics for metabolism:

- Anabolism – material for new cell mass
- Catabolism – generation of energy to make new cell mass.

(2) Organism "Death"/ endogenous respiration – loss of organism.

Biological behaviour

- Catabolism can be via fermentation and/or respiration

- Fermentation: organic compound is e-acceptor
- Respiration: O_2 is electron acceptor

Biological behaviour

Organism metabolism (growth and endogenous respiration) involves two aspects:

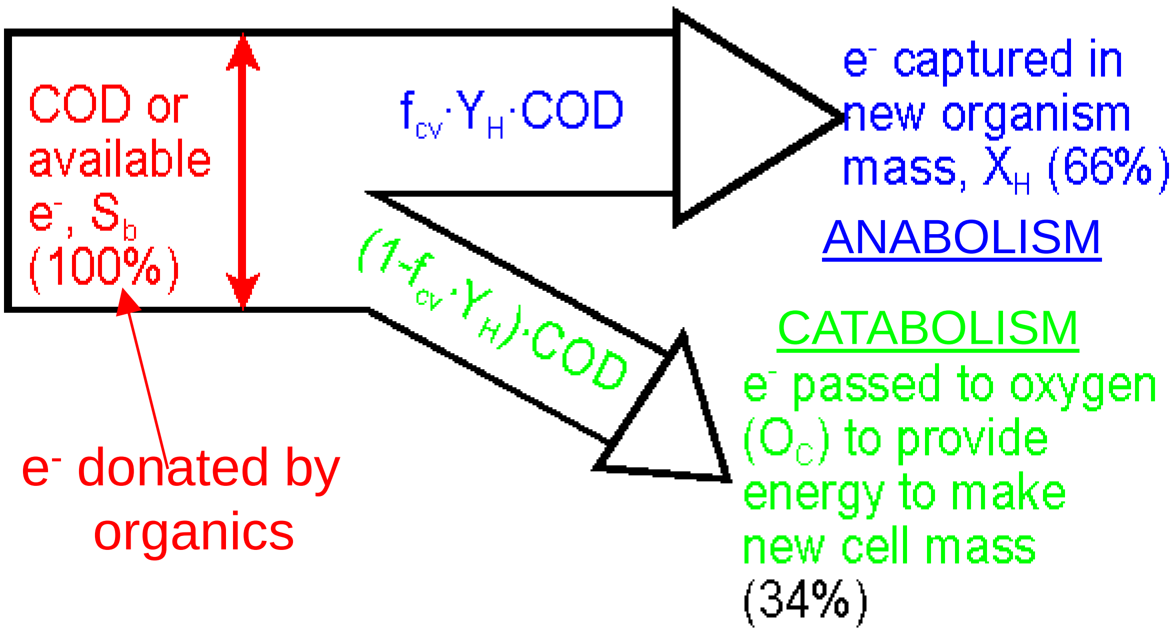
(1) Stoichiometry – quantitative relationship between bioprocess reactants (e.g. organics) and products (e.g. biomass formed, oxygen consumed).

(2) Kinetics – rate at which bioprocesses take place.

Growth and endogenous resp. stoichiometry

Y_{COD} = COD of biomass formed/COD utilized = 0.66

$Y_H = Y_{COD}/f_{cv}$ = 0.66/1.48 = 0.45 mgVSS/mgCOD



COD mass balance! – fundamental to all models

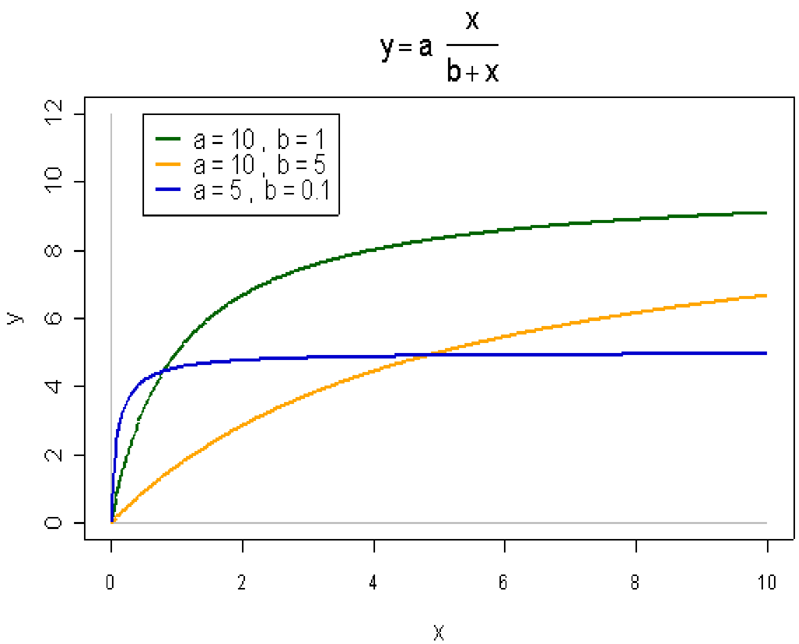
Growth and endogenous resp. stoichiometry

Growth (metabolism) transforms biodegradable COD into OHO biomass:

- Anabolism: Y_{COD} (=0.66; 2/3^{rds}) of the e^- (COD) in influent biodegradable organics become biomass
- Catabolism: 1-Y_{COD} (=0.34;1/3rd) of the e^- (COD) in influent biodeg. organics are passed to oxygen generating heat (loss).

Growth and endogenous resp. kinetics

- Growth follows Monod equation
- End. Resp. is first order



Heterotrophic growth:

$$r_{het.gr.} = \mu_{Het.} \frac{S_S}{K_S + S_S} \frac{S_O}{K_O + S_O} X_{Het.}$$

Endogenous respiration:

$$r = b \, X_B$$

Growth in aerated reactor fed with WW

- All biodegradable organics are used for growth:

  - Soluble biodegradable organics are readily utilized even at HRT 6-24h.

  - Particulate biodegradable organics are slowly degraded but they get enmeshed in sludge for at least one SRT (min. 4-5 days).

Growth in aerated reactor fed with WW

- With the growth process complete, its kinetics can be ignored !
- … and only the stoichiometry of the growth process needs to be considered.

Endogenous process in aerated reactor fed with WW

- Endogenous process transforms biomass biodegradable organics into:
  - unbiodegradable endogenous residue (which accumulates in the reactor as VSS).
  - requires additional oxygen consumption.

- … But, it is very slow and does not reach completion (even at very long SRT)… its stoichiometry and kinetics are needed.

Solids in aerated reactor fed with WW reactor

TSS

- VSS = X_V (ORGANICS)
  - X_{BH}: OHO Biomass
  - X_E: OHO's endogenous residue
  - X_I: Unbiodegradable particulate COD
- ISS = X_{IO} (INORGANICS)

Reactor VSS

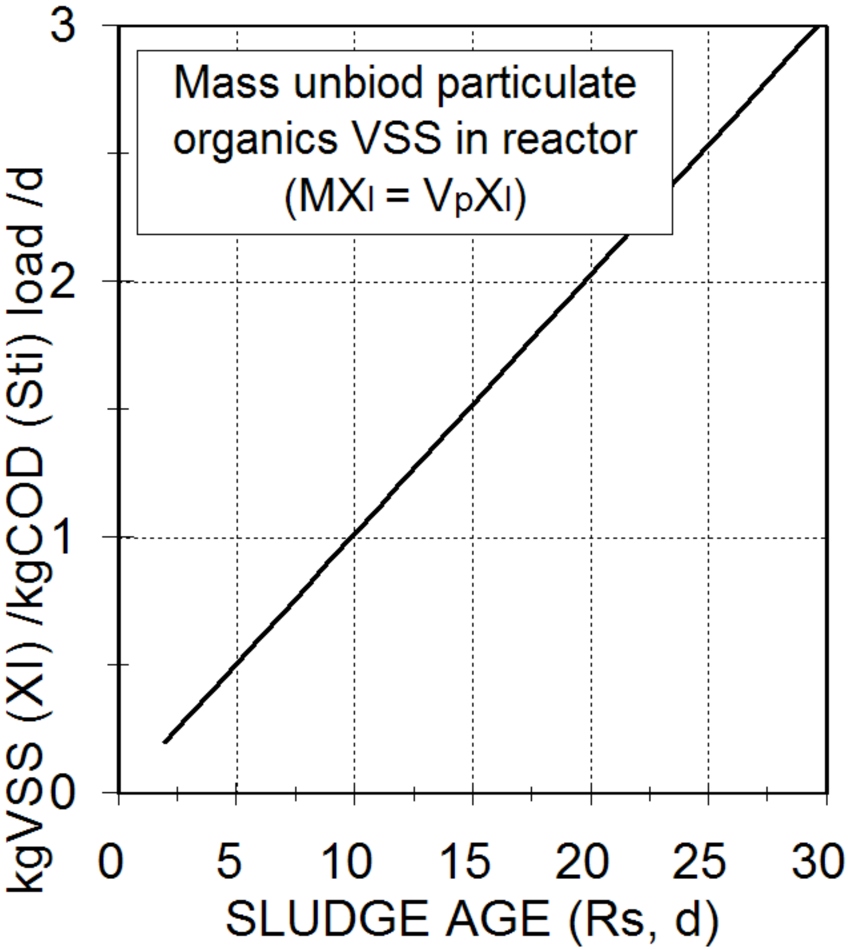
$$X_v = X_{BH} + X_{EH} + X_I \text{ [mgVSS/L]}$$

- The VSS mass in the reactor (MX_v) is the VSS concentration (X_v) x reactor volume (V_p):

$$MX_v = X_{BH} V_p + X_{EH} V_p + X_I V_p$$

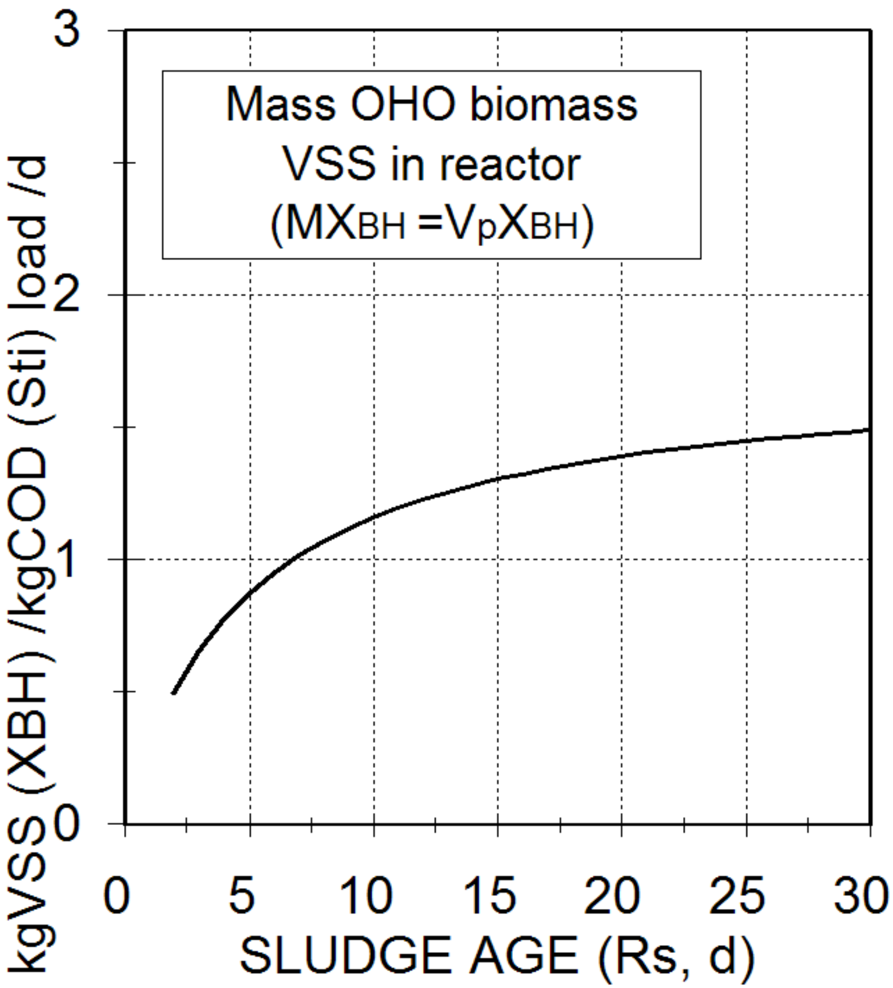
$$MX_v = X_v V_p \text{ [kgVSS]}$$

Unbiodegradable particulate organics



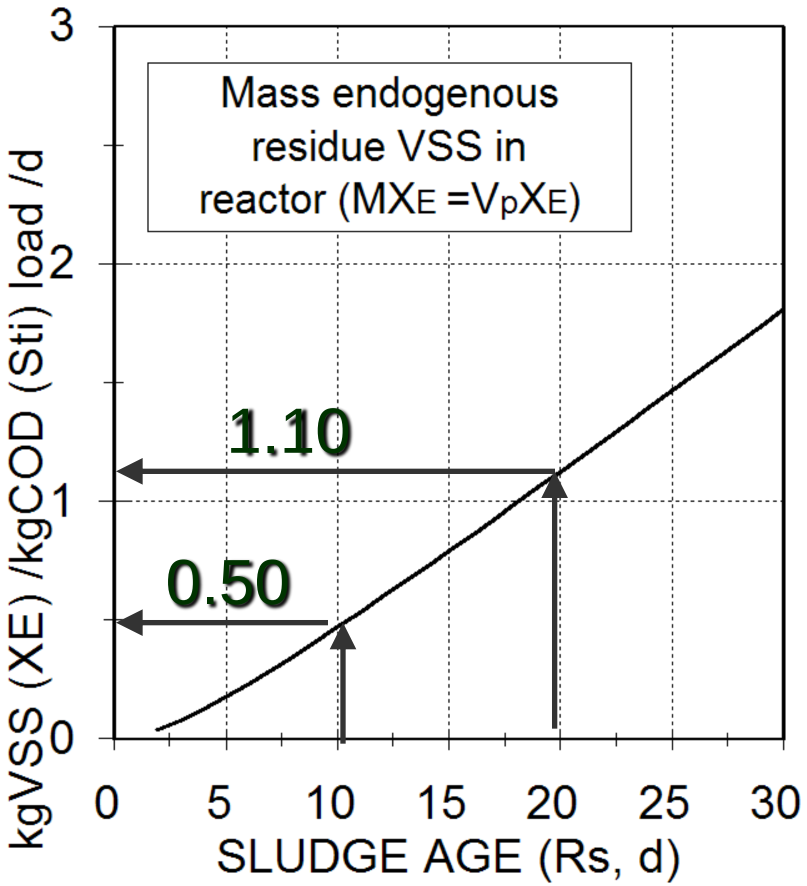
- At steady state, MX_I increases linearly with sludge age (R_s).
- MXI at 20 d ~ double than at 10 d.

Active biomass



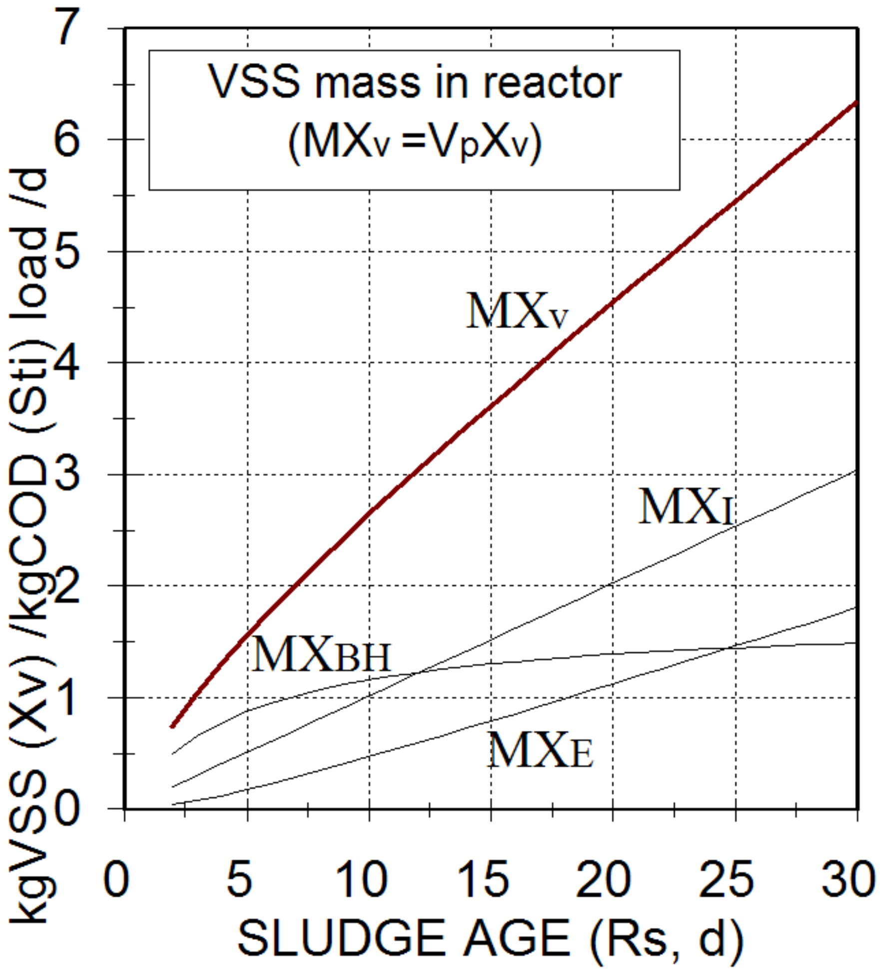
- MX_{BH} in reactor increases with sludge age (R_s) but increase gets smaller as sludge age gets longer due to longer duration of endogenous process.

Endogenous residue



- MX_{EH} increases with sludge age (R_s) but increase gets larger as sludge age gets longer due to longer duration of endogenous process.

Reactor VSS



- For raw WW:
- At 10d sludge age, VSS mass in reactor is ~2.7 kgVSS per kgCOD load in reactor,
- At 20d, ~4.5 kgVSS/kgCOD load per day.

Reactor ISS

- VSS is organic part of suspended solids in reactor.
- TSS is total and includes inorganic suspended solids (ISS).
- Reactor ISS arises from influent ISS accumulation and from ISS in biomass.

Reactor ISS

- If influent ISS is not known, can choose a VSS/TSS ratio (f_i) for the AS:

f_i = 0.75- 0.85 for raw wastewater

f_i = 0.80- 0.88 for settled wastewater.

So reactor TSS can be calculated as:

$$MX_t = MX_v/f_i \quad [kgTSS] \text{ and,}$$

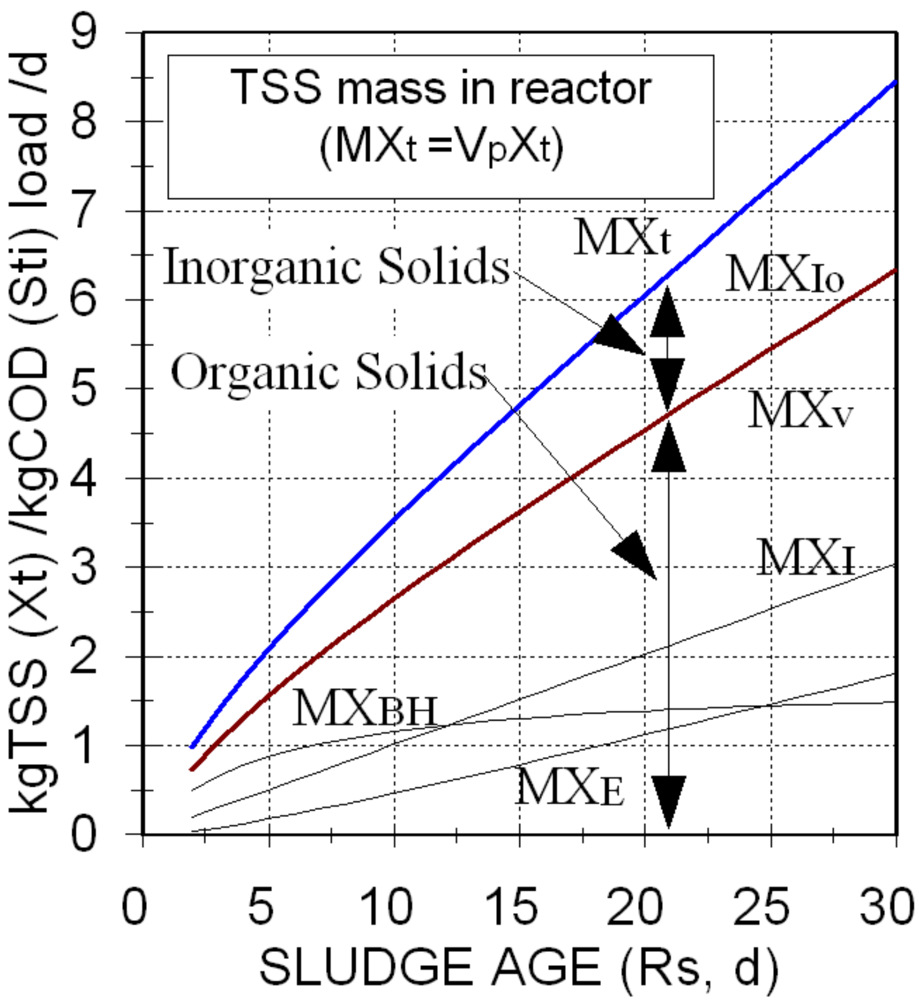
$$MX_{Io} = MX_t - MX_v \quad [kgTSS]$$

Reactor solids

TSS

- VSS = MX_V **(ORGANICS)**
  - MX_{BH}: OHO Biomass
  - MX_E: OHO's endogenous residue
  - MX_I: Unbiodegradable particulate COD
- ISS = MX_{IO} **(INORGANICS)**

Reactor solids



- For raw WW:
- At 10d sludge age, TSS mass in reactor is ~3.5 kgTSS per kgCOD load in reactor,
- At 20d, ~6.0 kgTSS/kgCOD load per day.

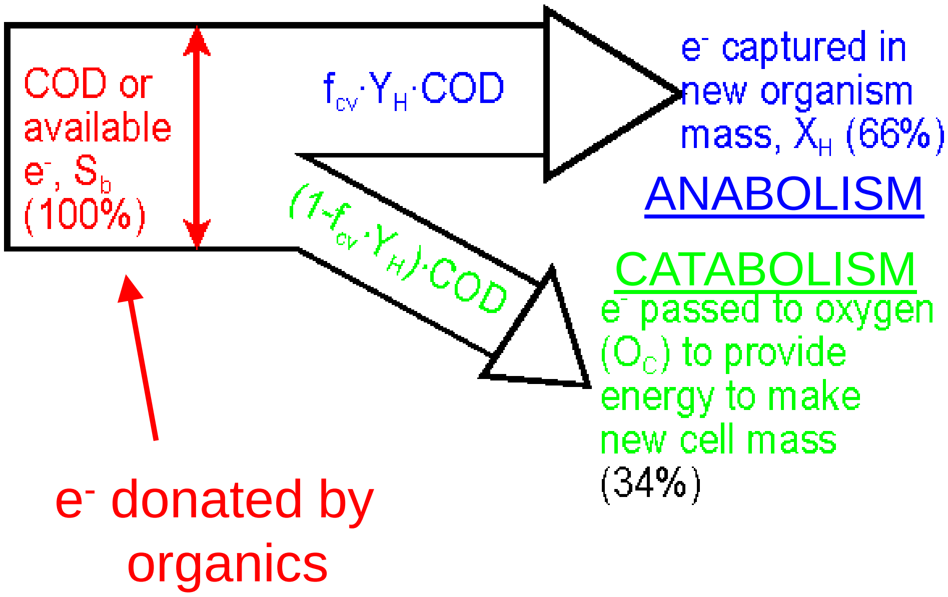
Oxygen demand

Recall that oxygen is required for two bio-processes:

(1) Growth and

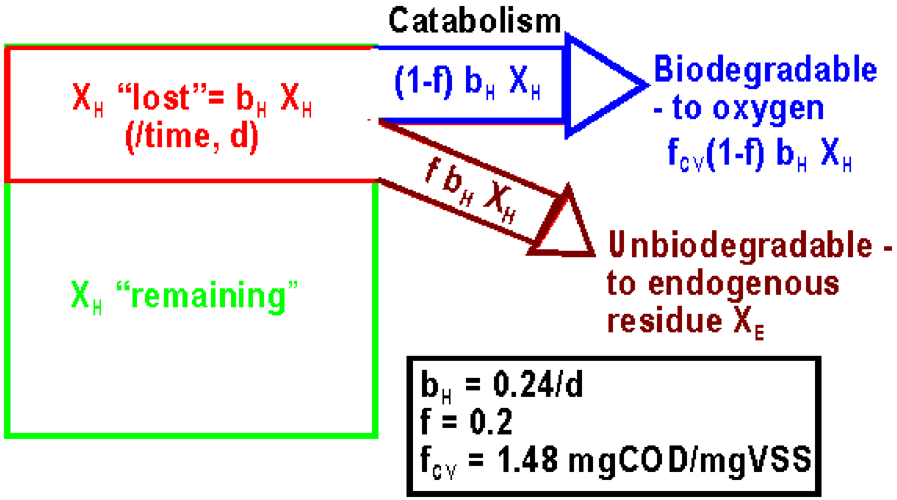
(2) Endogenous Respiration

Oxygen for growth



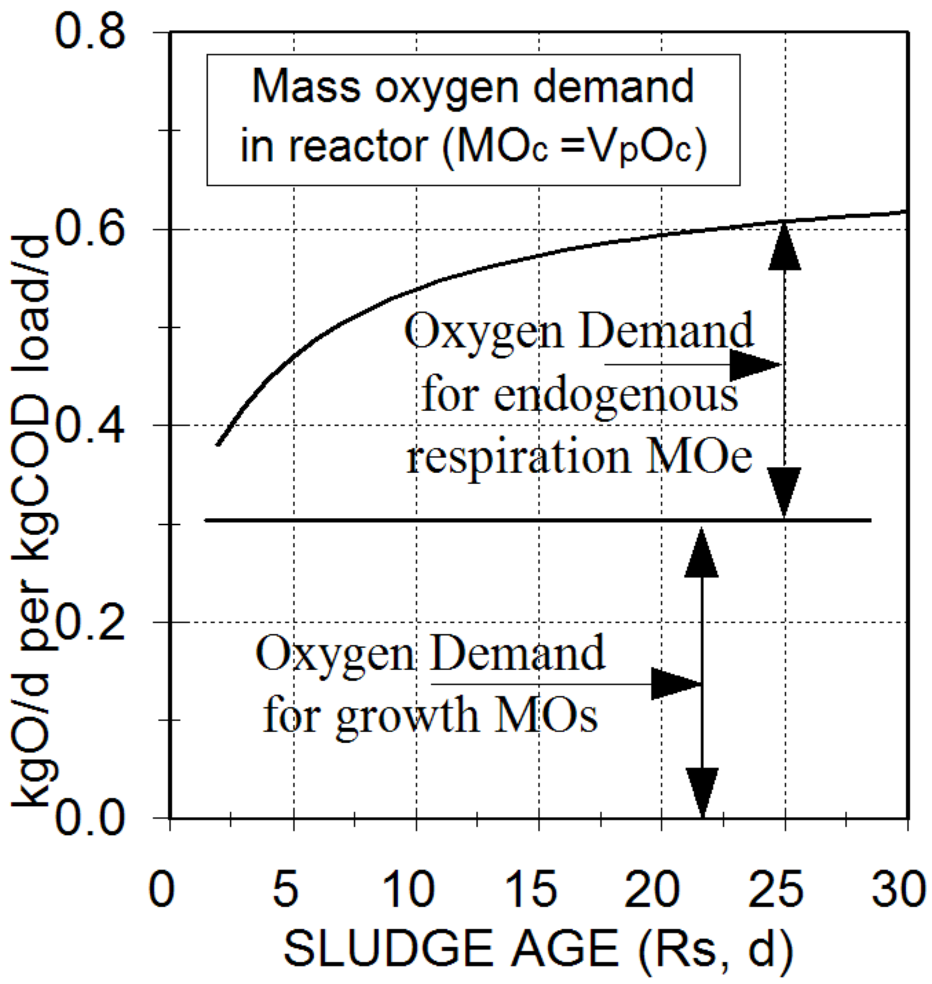
Organics e^- through catabolism passed to oxygen.

Oxygen for endogenous respiration



e^- of biomass (X_{BH}) biodeg. organics passed to oxygen – catabolic energy generation.

Oxygen demand



- Note: Oxygen demand for organics removal increases as sludge age increases because endogenous process continues further the longer the sludge age.

Values for constants

- Stoichiometric:

  Y_{Hv} = OHO yield = 0.45 mgVSS/mgCOD

  f_{cv} = COD/VSS = 1.48 mgCOD/mgVSS

  f = OHO unbiodegradable fraction = 0.20

- Kinetics:

  only the endogenous rate

  $b_{HT} = b_{H20}(1.029)^{(T-20)}$ /d ; b_{H20}=0.24/d

  (valid between 12 and 30^{o}C)