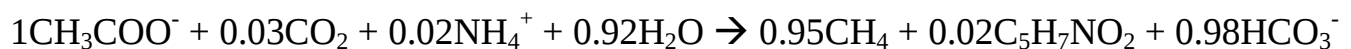


CVEN 5534 Wastewater Treatment

Assignment 3

Due: Tuesday, Sept. 28

1. A municipal wastewater treatment plant receives $70 \text{ m}^3/\text{min}$ of medium strength wastewater (see attached characterization). Approximately 95% of the COD is removed before discharge. Of the fraction removed, 65% of the influent COD is oxidized by bacteria to CO_2 and 35% is incorporated into bacterial biomass.
 - a. What is the mass flow rate of oxygen (kg/day) that must be supplied?
 - b. What is the biomass generation rate (kg/year) if the chemical for bacterial cells is $\text{C}_5\text{H}_7\text{NO}_2$?
2. Show by means of comparing the oxidation of a simple carbohydrate, CH_2O , that the oxygen equivalence of nitrate when nitrate is the electron acceptor in respiration = $2.86 \text{ g-O}_2/\text{g-NO}_3\text{-N}$.
3. The maximum growth yield for a culture of bacteria growing on soluble COD = $0.4 \text{ g-cells (as COD)}/\text{g-substrate COD}$. However, it was observed in a batch growth test using soluble COD as the growth substrate that the observed yield was only $0.32 \text{ g-cells (as COD)}/\text{g-substrate COD}$.
 - a. If 30% of the cells were lysed during the growth experiment, calculate the fraction of the COD from the cells that was available as substrate.
 - b. What fraction of the solids are inert (debris)?
4. A municipal treatment plant receives an average wastewater flow of $50,000 \text{ m}^3/\text{d}$. The influent COD is $300 \text{ g}/\text{m}^3$, and the observed growth yield for the population of bacteria in the plant is $0.45 \text{ g-cells}/\text{g-COD}$.
 - a. Calculate the observed yield on a COD basis.
 - b. Write the COD-based stoichiometry for oxidation of the influent organic matter (COD).
 - c. Calculate the mass of oxygen required per day to stabilize the waste.
 - d. What is the rate at which viable cells are grown (in terms of mass COD/day).
5. Methane production by a strain of *Archaea* growing on acetate follows this molar stoichiometry when cell yield is considered:



- a) Write the mass-basis stoichiometry for methane production and show that mass conservation is satisfied.
- b) Write the COD-basis stoichiometry for methane production and show that COD is conserved.

- c) If acetate is consumed in an anaerobic digester at a rate of 500 kg-CH₃COO⁻/d, at a temperature of 35 °C and a pressure of 1 atm, what is the rate of methane (CH₄) production in m³/day, assuming the stoichiometry given above?
- d) What is the rate of volatile suspended solids generation (kg-VSS/day) assuming 1 g C₅H₇NO₂ = 1 g VSS (volatile suspended solids)?

6. For the following concurrent reactions and rate expressions,

- a. develop a tableau formulation for the reactions and components by populating the cells in the table below. Leave cells blank when there is no appropriate coefficient
- b. (next page)

Reaction 1: heterotrophic bacteria growth and aerobic mineralization of soluble COD

$$-\frac{1}{Y_H} S_S - \frac{(1-Y_H)}{Y_H} S_O + 1^* X_{BH} = 0$$

Reaction 1a: synthesis uptake of ammonia nitrogen by heterotrophic bacteria

$$-i_{NXB} S_{NH} + i_{NXB} X_{NB} = 0$$

Reaction 2: autotrophic bacteria growth on ammonia and energy production, neglect synthesis uptake of ammonia for autotrophs

$$-\frac{1}{Y_{YA}} S_{NH} - \frac{(4.57 - Y_A)}{Y_A} S_O + 1^* X_{BA} = 0$$

Reaction 3: death, lysis and decay of heterotrophic bacteria and formation of debris and soluble substrate COD

$$(-1)X_B + (1-f_D)S_S + f_D X_D = 0$$

Where components and stoichiometric coefficients are

X_{BH} = heterotrophic bacteria cells (g-COD/m³)

X_{BA} = autotrophic bacteria cells (g-COD/m³)

X_D = nonbiodegradable cell debris (g-COD/m³)

X_{NB} = nitrogen stored in cells (g-N/m³)

S_S = substrate soluble COD (g-COD/m³)

S_{NH} = soluble ammonia nitrogen (g-N/ m³)

S_O = oxygen (g-O₂/ m³)

i_{NXB} = g-N/g-cell-COD and i_{NXD} = g-N/g-debris-COD

Y_H = g-heterotroph cell-COD/g-COD consumed

Y_A = g-autotroph cell-COD/g-NH₄-N consumed

f_D = g debris-COD produced/g biomass-COD decayed

COD AND NITROGEN STOICHIOMETRIC AND KINETIC MATRIX FOR GROWTH AND DECAY

	Components							Rates
Process	Soluble COD S_s (mg/L COD)	Soluble NH_4 -N S_{NH} (mg/L N)	Dissolved O_2 , S_O (mg/L O_2)	Heterotrophic biomass, X_{BH} (mg/L COD)	Autotrophic (Nitrifying) Biomass, X_{BA} (mg/L COD)	Debris, X_D (mg/L COD)	Ammonia N in cells X_{NB} (mg/L N)	r_j
Aerobic Heterotrophic Growth								1 and 1a $\mu_H X_{BH}$
Aerobic Growth of Autotrophs (Nitrification)								2 $\mu_A X_{BA}$
Decay and Lysis of Heterotrophs								3 $b_H X_{BH}$

And reaction rates are

$\mu_H X_{BH}$ = growth rate for heterotrophs (d^{-1})

$\mu_A X_{BA}$ = growth rate for autotrophs (d^{-1})

$b_H X_{BH}$ = decay rate for heterotrophs (d^{-1})

- c. Give the total rate expressions for ammonia nitrogen, heterotrophic bacteria, autotrophic bacteria, debris, soluble COD, and oxygen considering the reactions 1, 1a, 2, and 3