Design of Anaerobic Treatment/Digestion Processes

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1. pH and Alkalinity in an Anaerobic Process

- Determine the alakalinity required in kg $CaCO_3$/d to maintain a pH value of 7.0 in an anaerobic suspended growth process at 35 ^oC, with 30 % CO_2 content in the gas above the water. The influent wastewater flowrate is 2000 m^3/d, the alkalinity is 400 mg/l as $CaCO_3$, and no alkalinity producing substances are present. At 35 ^oC, Henry's constant for CO_2, computed using Eq. 2-48 and data given in Table 2-8, is 2092 atm and the value of K_{a1} is $4.85x10^{-7}$ mol/L (see F-2 Appendix F)

Metcalf & Eddy, Inc. (2003). *Wastewater Engineering-Treatment and Reuse*, 4th ed., McGraw-Hill, New York, NY. Page 989, Example 10-1

2. Suspended Growth Anaerobic Contact Reactor Process

- For an anaerobic contact process treating the following wastewater to achieve 90% COD removal determine;
  - reactor sizing,
  - gas production rate,
  - energy available,
  - solids production rate and
  - alkalinity and nutrients requirement.

Item	Unit	Value
Flowrate	m^3/d	300
COD	g/m^3	6000
Soluble COD	g/m^3	4000
COD/TSS ratio	g/g	1.8
Degradable fraction of TSS	%	80
Nitrogen	g/m3	10
Phosphorus	g/m3	20
Alkalinity	$gCaCO_3/m^3$	500
Temperature	^oC	25

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Page 1001, Example 10-2

2. Suspended Growth Anaerobic Contact Reactor Process

Design parameters and assumptions:

- Effluent TSS concentration = 150 g/m^3
- Factor of safety for design SRT = 1.5
- VSS/TSS = 0,85 (from Chapter 7)
- f_d = 0,15 g $VSS_{cell\ debris}$/g $VSS_{biomass\ decay}$
- Use kinetic coefficients from Table 10-10.
- Nutrient requirements based on VSS:N = 12% and VSS:P = 2.4 %
- At SRT > 40 d, degradable TSS is transformed
- MLSS = 6000 g/m^3
- Settling rate = 24 m/d
- Gas composition = 65% CH_4 and 35% CO_2

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Page 1001, Example 10-2

3. UASB Treatment Process Design

- For a UASB treatment process treating an industrial wastewater, determine;
  - Size and dimensions of the reactor,
  - Detention time,
  - Reactor SRT,
  - Average VSS concentration in biomass zone of the reactor,
  - Methane gas production,
  - Energy available from methane production and
  - Alkalinity requirements for a wastewater with characteristics given below to achieve >90% soluble COD removal .
- Wastewater is mainly soluble, containing carbohydrate compunds, and a granular sludge is expected. Assume 50% of the influent pCOD and VSS degraded, 90% of the influent sulfate is reduced biologically and the eflluent VSS concentration is 150 g/m^3

Metcalf & Eddy, Inc. (2003). *Wastewater Engineering-Treatment and Reuse*, 4th ed., McGraw-Hill, New York, NY. Page 1012, Example 10-3

3. UASB Treatment Process Design

- Assume the design parameters given below and the typical values given in Table 10-10 and 10-12 are applicable.

Design parameters and assumptions:

- From Table 10-10,

  $Y = 0,08$ g VSS/g COD

  $k_d = 0,03$ g VSS/g VSS.d

  $\mu_m = 0,25$ g VSS/g VSS.d
- $f_d = 0,15$ g $VSS_{cell\ debris}$/g $VSS_{biomass\ decay}$
- CH_4 production at 35°C = 0,4 L/gCOD
- Reactor V effectiveness factor = 85%
- Height for gas collection = 2.5 m

Item	Unit	Value
Flowrate	m^3/d	1000
COD	g/m^3	2300
sCOD	g/m^3	2000
TSS	g/m^3	200
VSS	g/m3	150
Alkalinity	g/m^3 as $CaCO_3$	500
Sulfate	g/m^3	200
Temperature	°C	30

Metcalf & Eddy, Inc. (2003). *Wastewater Engineering-Treatment and Reuse*, 4th ed., McGraw-Hill, New York, NY. Page 1012, Example 10-3

4. Estimating Single-Stage, High-Rate Digester Volume and Performance

- Estimate the size of digester required to treat the sludge from a primary treatment plant designed to treat 38.000 m^3/d of wastewater. Check the volumetric loading, and estimate the percent stabilization and the amount of gas produced per capita. For the wastewater to be treated, it has been found that the quantity of dry voltile solids and biodegradable COD removed is 0,15 kg/m^3 and 0,14 kg/m^3, respectively. Assume that sludge contains about 95% moisture and has a specific gravity of 1.02. Other pertinent design assumptions are as follows:
  - The hydraulic regime of the reactor is complete-mix
  - SRT = 10 days at 35 ^oC (Table 14-26)
  - Efficiency of waste utilization (solids conversion) E = 0,70
  - The sludge contains adequate N and P for biological growth
  - $Y = 0{,}08$ kg VSS/kg $bCOD_{utilized}$ and $k_d = 0{,}03\ d^{-1}$
  - Contstants are for a temperature of 35 ^oC
  - Digester gas is 65% methane

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5. Determination of Volatile Solids Reduction

- From the following analysis of untreated and digested solids, determine the total volatile solids reduction achieved during digestion. It is assumed that (1) the weight of fixed solids in the digested biosolids equals the weight of fixed solids in the untreated sludge and (2) the volatile solids are the only constituents of the untreated sludge lost during digestion.

	Volatile solids, %	Fixed solids, %
Untreated sludge	70	30
Digested sludge	50	50

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6. Estimation of Digester heating Requirements

- A digester with a capacity of 45.000 kg/d of sludge is to be treated by circulation of sludge through an external hot water exchanger. Assuming that the following consitions apply, find the heat required to maintain the required digester temperature. If all heat were shut off for 24 h, what would be the average drop in temperature of the tank contents?
  - Concrete digester dimensions:

    Diameter = 18 m; Side depth = 6 m; Middepth = 9 m
  - Heat transfer coefficients:

    Dry earth embanked for entire depth, U = 0,68 $W/m^2.^oC$

    Floor of digester in groundwater, U = 0,85 $W/m^2.^oC$

    Roof exposed to air, U = 0,91 $W/m^2.^oC$
  - Temperatures:
  - Air = -5 ^oC; Earth next to wall = 0 ^oC; Incoming sludge = 10 ^oC; Earth below floor = 5 ^oC; Sludge content in digester = 32 ^oC;
  - Specific heat of sludge = 4200 $J/kg.^oC$

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Page 1527, Example 14-7