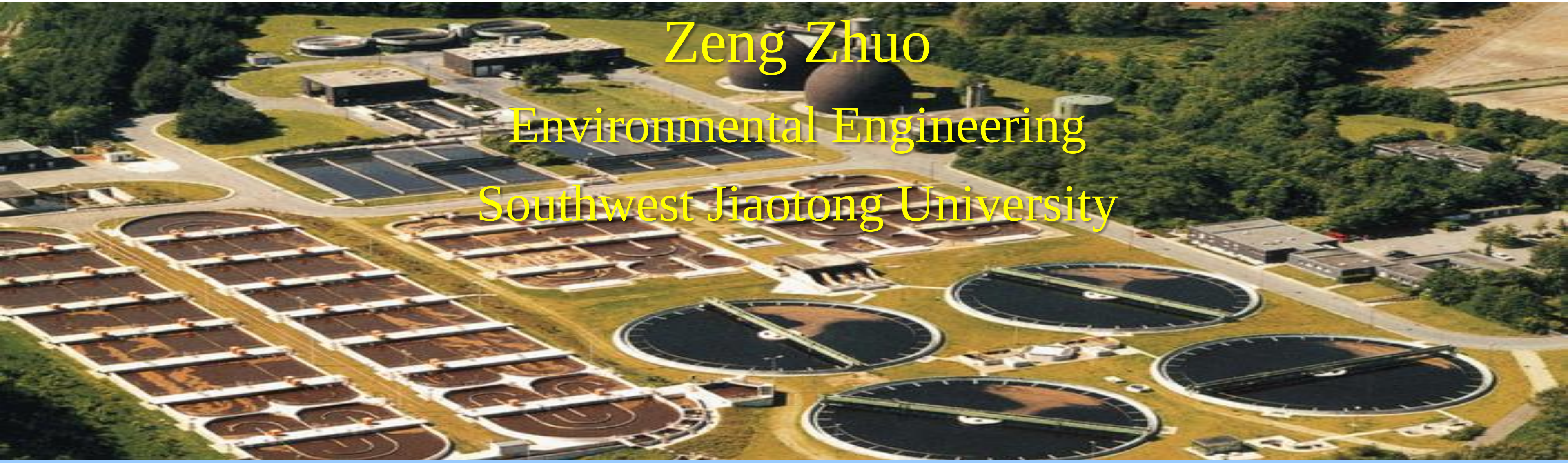
Chapter seven

Design of wastewater treatment systems



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Homework

Define the following terms:

1. **Design loadings**
2. **Detention time**
3. **Overflow rate**
4. **Activated sludge process**
5. θ
6. **WAS**
7. **Sequencing batch reactors**
8. **Oxygen transfer coefficient**
9. **Biological nutrient removal**
10. **Nitrification**
11. **Denitrification**
12. **VFA**
13. ***VSS***
14. **PAOs**
15. **A^2/O process**

Problem 9, Page 439

9 A conventional activated sludge process treats 3,785 m^3/d of wastewater, containing 250 g/m^3 BOD_5, and produces an effluent containing 20 g/m^3 BOD_5. The nominal detention time in the aeration basin excluding the return activated sludge flow is six hours and the MLSS concentration is 3,000 g/m^3. Determine the following:

a. The aeration basin volume (m^3).
b. F/M ratio (d^{-1}).
c. Specific substrate utilization rate (d^{-1}).
d. Substrate removal efficiency (%).

Homework

Problem 12, Page 440

A complete-mix activated sludge process (CMAS) is to be designed to treat 22000 m^3/d of domestic wastewater having a BOD_5 of 180 mg/L. The NPDES permit requires that the effluent BOD_5 and TSS concentrations should be 20 mg/L or less on an annual average basis (effluent soluble BOD_5 should be less than 5 mg/L). The following biokinetic coefficients obtained at 20°C will be used in designing the process: $Y = 0.6$ mg VSS/mg BOD_5, k=4 d^{-1}, K_s=70 mg/L BOD_5, and $k_d = 0.05$ d^{-1}. Assume that the MLVSS concentration in the aeration basin is maintained at 2500 mg/L and the VSS : TSS ratio is 0.75. Determine the following:

a) Mean cell residence time necessary to meet the NPDES permit in 20°C.
b) Volume of the aeration basin in m^3.
c) Oxygen requirements assuming no nitrification in 20 °C.
d) The quantity of excess biomass produced in terms of TSS.

Problem 20 (a), Page 441

20 Design a coarse-bubble diffused aeration system to meet an oxygen demand of 10,000 pounds per day. The plant is located at an elevation of 1,000 feet. There are two aeration basins with a total volume equal to 1.43 MG. Assume the alpha and beta coefficients for the diffusers are 0.45 and 0.98, respectively and use a temperature correction factor (θ) of 1.024. The dissolved oxygen (DO) saturation concentration of water is 7.54 mg/L at sea level and 30°C. A DO concentration of 2.0 mg/L is maintained in the aeration basins. The oxygen transfer efficiency is assumed to be 10%, since coarse-bubble diffusers are being used. The side water depth of the aeration basin is 15 ft with diffusers placed one foot from the bottom of the tank. The atmospheric pressure at an elevation of 1,000 feet is 733 mm Hg. Assume that the specific weight of water is 62.4 lb/ft^3. Determine:

a. Volumetric flow rate of the air (scfm) to meet oxygen requirement of 10,000 lb per day.

Homework

Problem 9, Page 439

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a. The aeration basin volume (m^3).
b. *F/M* ratio (d^{-1}).
c. Specific substrate utilization rate (d^{-1}).
d. Substrate removal efficiency (%).

a) The aeration basin volume (m^3)

$$\boldsymbol{V} = Q\tau = 3785\,\frac{\mathrm{m}^3}{\mathrm{d}} \times \frac{1}{24}\frac{\mathrm{d}}{\mathrm{h}} \times 6\ \mathrm{h} = 946\ \mathrm{m}^3$$

b) F/M (d^{-1})

$$\frac{\boldsymbol{F}}{\boldsymbol{M}} = \frac{QS_i}{XV} = \frac{3785\,\mathrm{m}^3/d \times 250\ g/\mathrm{m}^3}{3000g/\mathrm{m}^3 \times 946\ \mathrm{m}^3}$$
$$= 0.33\ gBOD_5/(gMLSS \cdot d)$$

c) Specific Substrate Utilization Rate (d^{-1})

$$\boldsymbol{U} = \frac{Q(S_i - S_e)}{XV}$$
$$= \frac{3785\,\mathrm{m}^3/d \times (250 - 20)\ g/\mathrm{m}^3}{3000g/\mathrm{m}^3 \times 946\ \mathrm{m}^3}$$
$$= 0.31\ gBOD_5/(gMLSS \cdot d)$$

d) Substrate removal efficiency (%)

$$\boldsymbol{E} = \frac{(S_i - S_e)}{S_i} \times 100\%$$
$$= \frac{(250 - 20)g/\mathrm{m}^3}{250g/\mathrm{m}^3} \times 100$$
$$= 92\%$$

Homework

Problem 12, Page 440

A complete-mix activated sludge process (CMAS) is to be designed to treat 22000 m^3/d of domestic wastewater having a BOD_5 of 180 mg/L. The NPDES permit requires that the effluent BOD_5 and TSS concentrations should be 20 mg/L or less on an annual average basis (effluent soluble BOD_5 should be less than 5 mg/L). The following biokinetic coefficients obtained at 20°C will be used in designing the process: Y = 0.6 mg VSS/mg BOD_5, k=4 d^{-1}, K_s=70 mg/L BOD_5, and k_d = 0.05 d^{-1}. Assume that the MLVSS concentration in the aeration basin is maintained at 2500 mg/L and the VSS : TSS ratio is 0.75. Determine the following:

a) Mean cell residence time necessary to meet the NPDES permit in 20°C.
b) Volume of the aeration basin in m^3.
c) Oxygen requirements assuming no nitrification in 20 °C.
d) The quantity of excess biomass produced in terms of TSS.

a) Mean cell residence time necessary to meet the NPDES permit in 20°C.

$$\frac{1}{\theta_c} = Y\frac{1}{X}\left(\frac{dS}{dt}\right)_U - k_d = Y\frac{1}{X}\frac{kXS_e}{K_s + S_e} - k_d$$

$$\frac{1}{\theta_c} = 0.6\ \frac{\text{mgVSS}}{\text{mg BOD}_5}\frac{4\ \text{d}^{-1} \times 5\ \text{mg/L}}{70\ \text{mg/L} + 5\ \text{mg/L}} - 0.05\ \text{d}^{-1} = 0.11\ \text{d}^{-1}$$

$$\theta_c = 9.1\ \text{d}$$

Secondary wastewater treatment

b) Volume of the aeration basin in m³.

$$V = \frac{YQ(S_i - S_e)}{X(\frac{1}{\theta_c} + k_d)} = \frac{0.6\ \frac{\text{mgVSS}}{\text{mg BOD}_5} \times 22000\ \text{m}^3/\text{d} \times (180\ \text{mg/L} - 5\ \text{mg/L})}{2500\ \text{mgVSS/L} \times (0.11\text{d}^{-1} + 0.05\ \text{d}^{-1})}$$

$$V = 5775\ \text{m}^3$$

c) Oxygen requirements assuming no nitrification in 20 °C.

$$O_2 = Q(S_i - S_e)(1 - 1.42Y) + 1.42k_dXV + NOD$$

$$S_i - S_e = 180\ \ \text{mg/L} - 5\ \ \text{mg/L} = 175\ \ \text{mg/L} = 0.175\ \text{kg/m}^3$$

$$X = 2500\ \ \text{mgVSS/L} = 2.5\ \text{kgVSS/m}^3$$

$$O_2 = 22000\frac{\text{m}^3}{\text{d}} \times 0.175\ \text{kg/m}^3 \times \left(1 - 1.42 \times 0.6\ \frac{\text{mgVSS}}{\text{mg BOD}_5}\right) + 1.42 \times 0.05\ \text{d}^{-1} \times 2.5\ \text{kgVSS/m}^3 \times 5775\ \text{m}^3 + 0$$

$$O_2 = 1595\ \text{kg/d}$$

Secondary wastewater treatment

d) The quantity of excess biomass produced in terms of TSS.

$$\Delta \boldsymbol{X} = \frac{YQ(S_i - S_e)}{1 + \theta_c k_d} = \frac{22000\,\frac{\mathrm{m}^3}{\mathrm{d}} \times 0.175\ \mathrm{kg/m^3} \times 0.6\ \frac{\mathrm{mgVSS}}{\mathrm{mg\ BOD_5}}}{1 + 9.1\ \mathrm{d} \times 0.05\ \mathrm{d^{-1}}}$$

$$\Delta \boldsymbol{X} = 1588\ \ \mathrm{kgVSS/d} = 2117\ \ \mathrm{kgTSS/d}$$

The end