

Chapter 11, Problem 6P

Bookmark

Show all steps: ON

Problem

A plug-flow denitrification stage is to be designed for a three-stage nitrification-denitrification treatment process. Pertinent data for the design are as follows: design flow = 19,000 m³/d, temperature = 25°C, cellular recycle will be used, NO₃⁻-N from the second stage = 25 mg/l, maximum allowable NO₃⁻-N in the final effluent = 0.5 mg/l, maximum allowable suspended solids in the final effluent = 5 mg/l, and volatile suspended solids are 80% of suspended solids. Use median values for the kinetic coefficients needed. Determine:
a. Minimum solids retention time for denitrification.
b. Design solids retention time.
c. Design nitrate removal rate, kg NO₃⁻-N/kg m³s/d.
d. Hydraulic detention time at the design flow.
e. Sludge wasting required, kg m³s/d.
f. Methanol required, kg methanol/d.

Step-by-step solution

Step 1 of 10

a)
Write the expression to determine the denitrification minimum solid retention time $\theta_{\text{min}}^{\text{den}}$.
$$\frac{1}{\theta_{\text{min}}^{\text{den}}} = Y\bar{q} - k_d \dots\dots (1)$$

Here, Y is the gross yield, $\bar{q}$ is the peak nitrate removal rate, k_d is the decar coefficient
Substitute 0.9 mg VSS/mg NO₃⁻-N for Y , 0.34 mg NO₃⁻-N oxidized/mg MLVSS-day for $\bar{q}$ (at 25°C), and 0.04 day⁻¹ k_d in the equation (1).

[Comment](#)

Step 2 of 10

$$\frac{1}{\theta_{\text{min}}^{\text{den}}} = Y\bar{q} - k_d$$
$$= \left(0.9 \frac{\text{mg VSS}}{\text{mg NO}_3^- \text{-N}}\right) \left(0.34 \frac{\text{mg NO}_3^- \text{-N}}{\text{mg VSS-day}}\right) - 0.04 \text{ day}^{-1}$$
$$= 0.306 - 0.04$$
$$= 0.266$$
$$\frac{1}{\theta_{\text{min}}^{\text{den}}} = 0.266$$
$$\theta_{\text{min}}^{\text{den}} = 3.76 \text{ days}$$

Therefore, the minimum time for the solids retention is 3.76 days.

[Comment](#)

Step 3 of 10

b)
Write the expression to determine the design solids retention time θ_d .
$$\frac{1}{\theta_d} = \frac{Y\bar{q}(D_s - D_1)}{(D_s - D_1) + K_d \ln \frac{D_s}{D_1}} - k_d \dots\dots (2)$$

Here, Y is the gross yield, $\bar{q}$ is the peak nitrate removal rate, k_d is the decar coefficient, K_d is the half saturation constant, D_s is the influent NO₃⁻-N, D_1 is the effluent NO₃⁻-N
Substitute 0.9 mg VSS/mg NO₃⁻-N for Y , 0.34 mg NO₃⁻-N oxidized/mg MLVSS-day for $\bar{q}$ (at 25°C), 0.04 day⁻¹ for k_d , 25 $\frac{\text{mg NO}_3^- \text{-N}}{\ell}$ for D_s , 0.5 $\frac{\text{mg NO}_3^- \text{-N}}{\ell}$ for D_1 , and 0.16 $\frac{\text{mg NO}_3^- \text{-N}}{\ell}$ for K_d in the equation (2).
$$\frac{1}{\theta_d} = \frac{Y\bar{q}(D_s - D_1)}{(D_s - D_1) + K_d \ln \frac{D_s}{D_1}} - k_d$$
$$= \left(0.9 \frac{\text{mg VSS}}{\text{mg NO}_3^- \text{-N}}\right) \left(0.34 \frac{\text{mg NO}_3^- \text{-N}}{\text{mg VSS-day}}\right) (25 - 0.5) \left(\frac{\text{mg NO}_3^- \text{-N}}{\ell}\right) - 0.04 \text{ day}^{-1}$$
$$(25 - 0.5) \left(\frac{\text{mg NO}_3^- \text{-N}}{\ell}\right) + \left(0.16 \frac{\text{mg NO}_3^- \text{-N}}{\ell}\right) \ln \left(\frac{25 \frac{\text{mg NO}_3^- \text{-N}}{\ell}}{0.5 \frac{\text{mg NO}_3^- \text{-N}}{\ell}}\right)$$
$$= 0.2584$$
$$\frac{1}{\theta_d} = 0.2584$$
$$\theta_d = 3.869 \text{ days}$$

Therefore, the design solids retention time is, 3.87 days.

[Comment](#)

Step 4 of 10

c)
Write the expression to determine the design nitrate removal rate:
$$\frac{1}{\theta_d} = Yq - k_d \dots\dots (3)$$
$$q = \frac{1 + k_d \theta_d}{Y\theta_d}$$

Substitute 0.9 lb MLVSS/lb NO₃⁻-N for Y , 3.87 days for θ_d , and 0.04 day⁻¹ k_d in the equation (3).
$$q = \frac{1 + k_d \theta_d}{Y\theta_d}$$
$$= \frac{1 + (0.04 \text{ day}^{-1})(3.87 \text{ days})}{(0.9 \text{ mg MLVSS/mg NO}_3^- \text{-N})(3.87 \text{ days})}$$
$$= 0.332 \text{ lb NO}_3^- \text{-N/lb MLVSS-day}$$

Therefore, the design nitrate removal rate is, 0.332 lb NO₃⁻-N/lb MLVSS/day.

d)
Write the expression to determine the hydraulic detention time, θ .
$$\theta = \frac{D_s - D_1}{qX_1} \dots\dots (4)$$

Here, X_1 is the VSS in the denitrification reactor.
Assume the amount of MLSS in the denitrification reactor is, 3000 mg/l.
Obtain the value of the MLSS is MLVSS.
$$X_1 = \left(\frac{80}{100}\right)(3000 \text{ mg/l})$$
$$= 2400 \text{ mg/l}$$

[Comment](#)

Step 5 of 10

Substitute 0.332 mg NO₃⁻-N/mg MLVSS-day for q , 2400 mg MLVSS/ ℓ for X_1 ,
25 $\frac{\text{mg NO}_3^- \text{-N}}{\ell}$ for D_s , and 0.5 $\frac{\text{mg NO}_3^- \text{-N}}{\ell}$ for D_1 in the equation (4).
$$\theta = \frac{D_s - D_1}{qX_1}$$
$$= \frac{(25 - 0.5) \frac{\text{mg NO}_3^- \text{-N}}{\ell}}{\left(\frac{0.332 \text{ mg NO}_3^- \text{-N}}{\text{mg MLVSS-day}}\right) \left(2400 \frac{\text{mg MLVSS}}{\ell}\right)}$$
$$= 0.031 \text{ day}$$
$$= 0.74 \text{ hr}$$

Therefore, the hydraulic detention time is, 0.74 hr.

[Comment](#)

Step 6 of 10

e)
Write the expression to determine the amount of required sludge wasting X_w .
Determine the mass of MLVSS in the reactor:
$$\text{MLVSS in reactor} = X_1 \theta Q \dots\dots (5)$$

Substitute 0.031 day for θ and 19000 $\frac{\text{m}^3}{\text{day}}$ for Q in the equation (5).
$$\text{MLVSS in reactor} = X_1 \theta Q$$
$$= \left(2400 \frac{\text{mg MLVSS}}{\text{lb mixed liquor}}\right) (0.031 \text{ day}) \left(19000 \frac{\text{m}^3}{\text{day}}\right) \left(\frac{1 \text{ kg}}{10^6 \text{ mg}}\right)$$
$$= 1414 \text{ kg MLVSS}$$

[Comment](#)

Step 7 of 10

Write the expression to determine the amount of MLVSS leaving the reactor per day.
$$\text{MLVSS leaving/day} = \frac{\text{MLVSS in reactor}}{\theta_d}$$

Substitute 1414 kg MLVSS for MLVSS in reactor and 3.87 days for θ_d .
$$\text{MLVSS leaving/day} = \frac{\text{MLVSS in reactor}}{\theta_d}$$
$$= \frac{1414 \text{ MLVSS}}{3.87 \text{ days}}$$
$$= 365.4 \text{ kg MLVSS/day}$$

[Comment](#)

Step 8 of 10

Determine the amount of MLVSS allowed in the final effluent.
$$\text{MLVSS leaving in final effluent/day} = \left(19000 \frac{\text{m}^3}{\text{day}}\right) \left(5 \frac{\text{mg MLSS}}{\ell \text{ mixed liquor}}\right) \left(0.8 \frac{\text{kg MLVSS}}{\text{kg MLSS}}\right) \left(\frac{1000 \ell}{\text{m}^3}\right) \left(\frac{1 \text{ kg}}{10^6 \text{ mg}}\right)$$

$$\text{MLVSS leaving in final effluent/day} = 76 \text{ kg MLVSS/day}$$

Determine the difference between the MLVSS leaving the system and the MLVSS allowed in the final effluent. The difference in these values yields the amount of MLVSS that must be removed and wasted.
$$X_w = (365.4 - 76) \text{ kg MLVSS/day}$$
$$= 289 \text{ kg MLVSS/day}$$

Therefore, the sludge wasting required is, 289 kg MLVSS/day.

[Comment](#)

Step 9 of 10

f)
Write the expression to calculate the amount of methanol required per day.
The requirement of methanol is 3.0 lb of methanol per lb of NO₃⁻-N removed.
$$M_{\text{meth}} = \left(m \times \frac{\text{lb methanol}}{\text{lb NO}_3^-}\right) Q(D_s - D_1)$$

Here, m represents the mass ratio of methanol to nitrate.

[Comment](#)

Step 10 of 10

Substitute 25 $\frac{\text{mg NO}_3^- \text{-N}}{\ell}$ for D_s , and 0.5 $\frac{\text{mg NO}_3^- \text{-N}}{\ell}$ for D_1 , 19000 $\frac{\text{m}^3}{\text{day}}$ for Q , and 3 for m .
$$M_{\text{meth}} = \left(m \times \frac{\text{lb methanol}}{\text{lb NO}_3^-}\right) Q(D_s - D_1)$$
$$= \left(3 \times \frac{\text{kg methanol}}{\text{kg NO}_3^-}\right) \left(19000 \frac{\text{m}^3}{\text{day}}\right) (25 - 0.5) \left(\frac{\text{mg NO}_3^- \text{-N}}{\ell \text{ waste}}\right) \left(\frac{1000 \ell}{\text{m}^3}\right) \left(\frac{1 \text{ kg}}{10^6 \text{ mg}}\right)$$
$$= 1400 \text{ kg methanol/day}$$

Therefore, the methanol required is, 1400 kg methanol/day.

[Comment](#)

Was this solution helpful? 0 0

Recommended solutions for you to review

1 of 2

2/6/2018, 10:18

