1.

The removal is 80% removal efficiency and the numerical values are substituted into Equation 4.42

$$S = S^0 - \frac{J_{ss}aV}{Q} = S^0 - \frac{J_{ss}A}{Q}$$

Where A is in m^2 and J_{ss} is in $\frac{mg}{cm^2 \cdot d}$

Then $X_f L_f = Y J_{ss}/b'$, solving J_{ss} which is 0.03 mg/cm^2

Thus

$$K^* = \frac{D}{L}[\frac{K_s}{\hat{q}X_f L_f}]^{0.5} = \frac{1cm^2}{d \cdot \mu m} \times (\frac{10mg}{L \times 12\frac{mg}{mg\ VSS\ d} \times 10\frac{mg\ VSS}{cm^3} \times 0.75\frac{cm^3}{d}})^{0.5} = 1.1$$

Then

$$S^*_{min} = \frac{b'}{Y\hat{q} - b'} = \frac{0.15\ d^{-1}}{0.5 \times 12 - 0.15} = 0.026$$

Using the Figure 4.11

$J^* = 0.71$ when $S^*_{min} = 0.026$ and $K^* = 1.1$

Thus

$$J_R = J^*(K\hat{q}X_f D_f)^{0.5} = 0.071 \times (\frac{10mg}{L} \times \frac{12\ mg}{mg\ VSS \cdot d} \times \frac{10\ mg\ VSS}{cm^3} \times \frac{0.75\ cm^2}{d})^{0.5}$$

$$\text{Then } S_{min} = K\frac{b'}{Y\hat{q} - b'} = 0.26\ mg/L \text{ and } \frac{S}{S_{min}} = \frac{40}{0.26} = 153.8$$

$$J_{ss}/J_R = 20 \text{ where } \frac{S}{S_{min}} = 153.8 \text{ then } J_{ss} = 1.36\ mg/cm^2 \cdot d$$

$$A = \frac{Q(S^0 - S)}{J_{ss}} = \frac{1000\frac{L}{d} \times 240\frac{mg}{L}}{0.03\frac{mg}{cm^2 \cdot d} \times \frac{1m^2}{10000cm^2}} = 800\ m^2$$

2.

The information given from Question 4.24, the removal is 96%

Where

$$S = S^0 \times remvoal\ efficiency = (1 - 0.96) \times 50 = 2 mg/L$$

When bulk liquid concentration of benzoate is $2\ mg/L$

$$J_{ss} = 0.15 \frac{mg}{cm^2 \cdot d}\ and\ a = 3\ cm^{-1}$$

the numerical values are substituted into Equation 4.42

$$S = S^0 - \frac{J_{ss}aV}{Q}$$

Solving the Volume equation to

$$V = \frac{Q(S^0 - S)}{J_{ss}a} = \frac{100\frac{m^3}{d} \times \frac{1000L}{m^3} \times 48\frac{mg}{L}}{0.15\frac{mg}{cm^2 \cdot d} \times 3 cm^{-1}} = 10.67\ m^3$$

3.

Using the equation Eq 5.39

$$S = K\frac{1 + b\theta_x}{\theta_x(Y\hat{q} - b) - 1} = 4.72\ mg\ COD/L$$

Then plug the value of S into equation Eq 5.47

$$X_v = \frac{\theta_x}{\theta}[X_i^0 + \frac{Y(S^0 - S)(1 + (1 - f_d)b\theta_x)}{1 + b\theta_x}]$$

Thus,

$$\theta = \theta_x[\frac{X_i^0}{X_v} + \frac{Y(S^0 - S)(1 + (1 - f_d)b\theta_x)}{X_v(1 + b\theta_x)})]$$

$$= 6\ d \times [0 + \frac{0.3\frac{g\ VSS}{g\ COD} \times (1000 - 4.72)\frac{mg}{L} \times (1 + (1 - 0.8) \times 0.15d^{-1} \times 6\ d)}{4000\frac{mg}{L} \times (1 + 0.15d^{-1} \times 6\ d)}]$$

$$= 0.28\ days$$