a.

Refer back to homework 2, the yield is

$$Y_0 = 0.07\ g\ cells/\ g\ BrO_3^-$$

The information given from the question

$$\hat{q} = 12\ \frac{mgBrO_3^-}{mgcells \cdot d} \qquad K = 50 \frac{\mu gBrO_3^-}{L}$$

$$S^o = \ 200 mg/L \qquad b = 0.01\ d^{-1}$$

Then

$$S^{min} = K \times \frac{b}{Y\hat{q} - b} = \frac{50\mu g}{L} \times \frac{0.01\ d^{-1}}{0.07\ \frac{mg\ cells}{mg\ BrO_3^-} \times 12\ \frac{mgBrO_3^-}{mgcells \cdot d} - 0.01\ d^{-1}} = 0.60 \mu g/L$$

$$[\theta^{min}]_{lim} = \frac{1}{Y\hat{q} - b} = \frac{1}{0.07\ \frac{mg\ cells}{mg\ BrO_3^-} \times 12\ \frac{mgBrO_3^-}{mgcells \cdot d} - 0.01\ d^{-1}} = 1.20\ d$$

b.

In my opinion, I think the volume value is missing for this part, because S value depends on the

$\theta_x = \frac{V}{Q}$ directly due to the equation $S = K \frac{1 + b\theta_x}{\theta_x(Y\hat{q} - b) - 1}$

Or according to the a part, possibly

the $S_{min} = 0.60\ \mu g/L < 10\ \mu g/L$ if the θ_x is much larger

Then this design can achieve the goal concentration of bromide.

c.

If a chemostat can achieve the target treatment goal

$$S = 10\ \mu g/L$$

According the relative equation

$$\frac{1}{\theta_x} = Y\frac{\hat{q}S}{K+S} - b = 0.07\ \frac{mg\ cells}{mg\ BrO_3^-} \times \frac{12\ \frac{mgBrO_3^-}{mgcells \cdot d} \times 10\ \frac{\mu g}{L}}{50\ \frac{\mu g}{L} + 10\ \frac{\mu g}{L}} - 0.01d^{-1} = 0.13d^{-1}$$

$$\theta_x = 7.7\ d$$

If a chemostats cannot achieve the target treatment goal and its safety factor is 10

$$\theta_x^{min} = \frac{K + S^0}{S^0(Y\hat{q} - b) - bK} = 1.20$$

$$SF\ = \frac{\theta_x}{\theta_x^{min}} = 10\ \text{ then }\ \theta_x = 12\ d$$

According the relative equation

$$S = K\frac{1 + b\theta_x}{\theta_x(Y\hat{q} - b) - 1} = \frac{50\mu g}{L} \times \frac{1 + 0.01d^{-1} \times 12d}{12d \times (0.07\ \frac{mg\ cells}{mg\ BrO_3^-} \times 12\ \frac{mgBrO_3^-}{mgcells \cdot d} - 0.01\ d^{-1}) - 1} = 6.2\mu g/L$$

d.

According to the reaction

$$0.01NO_3^- + 0.05CO_2 + 0.12BrO_3^- + 0.01H^+ + 0.5H_2 \rightarrow 0.01C_5H_7O_2N + 0.47H_2O + 0.12Br^-$$

Then

$$Y_{H_2}^0 = 0.5(2)/0.12(129) = 0.0064\ g\ H_2/g\ BrO_3^-$$

Then if a chemostat can achieve the target treatment goal

$$C_{min}^{H_2} = (S^0 - S) \times Y_{H_2} = 12.92\ mg/L$$

e.

When Nitrite as electron acceptor

$$R_d : H^+ + e^- \rightarrow \frac{1}{2}H_2 \qquad 39.87\ kj/e^-eq$$

$$R_a : \frac{1}{5}NO_3^- + \frac{6}{5}H^+ + e^- \rightarrow \frac{1}{10}N_2 + \frac{3}{5}H_2O \qquad -72.20\ kj/e^-eq$$

$$R_c : \frac{1}{5}CO_2 + \frac{1}{20}NH_4^+ + \frac{1}{20}HCO_3^- + H^+ + e^- \leftrightarrow \frac{1}{20}C_5H_7O_2N + \frac{9}{20}H_2O$$

According to the Table 3.1 $\qquad f_s^0 = 0.2$

$$R = f_e^0 \times (R_a - R_d) + f_s^0 \times (R_c - R_d)$$

$$= 0.80 \times [\frac{1}{5}NO_3^- + \frac{1}{20}NH_4^+ + \frac{1}{20}HCO_3^- + \frac{1}{2}H_2 \rightarrow \frac{1}{20}C_5H_7O_2N + \frac{9}{20}H_2O] +$$

$$0.20 \times [\frac{1}{5}CO_2 + \frac{1}{20}NH_4^+ + \frac{1}{20}HCO_3^- \leftrightarrow \frac{1}{20}C_5H_7O_2N + \frac{9}{20}H_2O]$$

For denitrification process

$$0.16NO_3^- + 0.04CO_2 + 0.05NH_4^+ + 0.05HCO_3^- + 0.4H_2 \rightarrow 0.05C_5H_7O_2N + 0.45H_2O$$

For Bromide reduction process

$$0.01NO_3^- + 0.05CO_2 + 0.12BrO_3^- + 0.01H^+ + 0.5H_2 \rightarrow 0.01C_5H_7O_2N + 0.47H_2O + 0.12Br^-$$

$$C_{extra}^{H_2} = C_{min}^{H_2} \times \frac{0.05(113)}{0.4(2)} \times \frac{2(0.5)}{0.01(113)} = 80.75\ mg/L$$

f.

Refer back to the c part, I choose SF = 10 design, where $\theta_x = 12d$ and $S = 6.2\mu g/L$

$$X_a = Y(S^0 - S)\frac{1}{1 + b\theta_x} = 0.07\ \frac{mg\ cells}{mg\ BrO_3^-} \times (200 - 0.0064)\ mg/L \times \frac{1}{1 + 0.01d^{-1} \times 15.1d} = 12.50\ mg/L$$

$$X_i = X_i^0 + X_a(1 - f_d)b\theta_x = 0 + X_a \times (1 - 0.8) \times 0.01d^{-1} \times 15.1d = 0.30\ mg/L$$

$$X_v = X_i + X_a = 12.80\ mg/L$$

$$r_{ut} = -\frac{S^0 - S}{\theta_x} = -\frac{(200 - 0.0064)\ mg/L}{15.1d} = -\ 16.66\ mg\ BOD_L/L{\cdot}d$$

For SMP calculation,

Where

$k_1 = 0.12g\ COD_p/g\ COD_s$ $\qquad$ $\hat{q}_{UAP} = 1.8g\ COD_p/g\ VSS_a$

$k_2 = 0.09g\ COD_p/g\ COD_s$ $\qquad$ $K_{UAP} = 100mg\ COD_p/g\ VSS_a$

$$UAP = \frac{-(\hat{q}_{UAP}X_a\theta + K_{UAP} + k_1 r_{ut}\theta) + \sqrt{(\hat{q}_{UAP}X_a\theta + K_{UAP} + k_1 r_{ut}\theta)^2 - 4K_{UAPk}k_1 r_{ut}\theta}}{2} = 6.8\ mg/L$$

$$BAP = \frac{-(K_{BAP} + (\hat{q}_{BAP} - k_2)X_a\theta) + \sqrt{(K_{BAP} + (\hat{q}_{BAP} - k_2)X_a\theta)^2 + 4K_{BAP}k_2X_a\theta}}{2} = 11.69\ mg/L$$

$$Total\ COD\ = S + SMP + (1.42\ gCOD/g\ VSS){\cdot}X_v = 36.67mg/L$$

$$Total\ BOD_L\ = Total\ COD\ \times 80\,\% = 29.34\ mg/L$$

$$BOD_5 = BOD_L \times (1 - e^{-0.23d^{-1} \times 5d}) = 20.05\ mg/L$$

g.

The N source may be insufficient with time passing by, causing the lower water treatment efficiency. On the other hand, Br^- is likely to oxide in the real world conditions, thus, oxidation equilibrium should be considered.