Solution to Homework 7, Problem 1

Parts a.-k. - Original design

Part l. - Redesign

Design parameters

Design flow rate	Q	0.0088	m^3/s	0.0088	m^3/s
Reactor volume	V	25	m^3	50	m^3
Influent COD concentration	S_{in}	300	mg COD/L	300	mg COD/L
Solids concentration of recycled sludge	X_R	12000	mg VSS/L	12000	mg VSS/L
Clarified effluent from secondary clarifier	X_e	15	mg VSS/L	15	mg VSS/L
Safety factor	SF	20		80	

Kinetic constants:

Maximum specific growth rate	μ_{max}	9.6	day^{-1}
Half-saturation constant	K_S	75	mg/L as COD
Cell yield	Y	0.4	g VSS/g COD
Endogenous respiration rate	k_e	0.096	day^{-1}

Computed characteristics

a.	Hydraulic residence time	t_R	0.8	hours	1.6	hours
b.	Minimum solids retention time	$\theta_{c,min}$	2.5	hours	2.5	hours
	Washout solids retention time	$\theta_{c,w}$	3.16	hours	3.16	hours
c.	Design solids retention time (sludge age)	θ_c	51	hours	202	hours
	Design solids retention time (sludge age)	θ_c	2.1	days	8.4	days
d.	Reactor biomass concentration	X	6288	mg VSS/L	8447	mg VSS/L
e.	Effluent substrate concentration	S	4.7	mg COD/L	1.7	mg COD/L
	Efficiency	E	98.4	percent	99.4	percent
f.	Substrate utilization rate	U	1.43	g COD/g VSS/day	0.54	g COD/g VSS/day
g.	Food:microorganism ratio	F/M	1.45	g COD/g VSS/day	0.54	g COD/g VSS/day
h.	Recycle ratio	r	1.08		2.36	
	Recycle flow rate	Q_R	0.010	m^3/s	0.021	m^3/s
i.	Sludge wasting rate	Q_W	0.00025	m^3/s	0.00016	m^3/s
		Q_W/Q	2.8%		1.9%	
j.	Sludge production rate	P	3.1	kg VSS/hr	2.1	kg VSS/hr

k. This plant has a high F/M ratio and short SRT. As such, it would be classified as a high-rate aeration plant. Such a plant can work, but is not compatible with the intended low level of maintenance planned for this facility. More bluntly, this plant is a disaster waiting to happen!

l. The plant needs to be redesigned as a low-rate AST plant. A design safety factor of SF = 100 is more appropriate and would raise the SRT to 8.4 days, which is more consistent with a low-maintenance, low-rate treatment plant. However, raising the SRT has the perverse effect of raising the biomass concentration (X) which in turn raises the F/M ratio (see Lecture 19, Equation 41). To lower the F/M ratio, we can increase the tank volume, which increases t_R, which in turn lowers F/M according to Equation 30.