Errata

Chapter 7 Design of Wastewater Treatment Systems

On page 379 at the bottom of the right hand column, the value of R with appropriate units should be: $R = \frac{53.3 \text{ ft} \cdot \text{lb}}{\text{lb} \cdot {}^{o}\text{R}} \left(\frac{8.314 \text{ kJ}}{\text{k mol} \cdot \text{K}} \right)$

On page 380, Example 7.13, second column, revised calculations to show the calculated value of **Pr** as follows:

$$\text{Pr} = (15\,\text{ft} - 1\,\text{ft}) \left(\frac{62.4\,\text{lb}}{\text{ft}^3} \right) \left(\frac{1\,\text{ft}^2}{144\,\text{in}^2} \right) + 14.7\,\text{psia} \left(\frac{760\,\text{mm Hg}}{760\,\text{mm Hg}} \right)$$

$$\text{Pr} = \boxed{21\,\text{psia}}$$

On page 381 in the bottom right column, replace the specific weight of air $\left(\frac{0.0175 \text{ lb air}}{\text{ft}^3 \text{air}} \right)$ with

$$\left(\frac{0.075 \text{ lb air}}{\text{ft}^3 \text{ air}} \right)$$

On page 381 at top left, scfm should be calculated as follows:

$$\text{scfm} = 4.2 \times 10^4 \frac{\text{lb}\,O_2}{\text{d}} \left(\frac{\text{ft}^3}{0.075\,\text{lb}} \right) \left(\frac{\text{lb air}}{0.23\,\text{lb}\,O_2} \right) \left(\frac{\text{d}}{24\,\text{h}} \right) \left(\frac{\text{h}}{60\,\text{min}} \right) \left(\frac{1}{0.10} \right)$$

$$= \boxed{1.69 \times 10^4}$$

On page 381 at top left, mixing air should be calculated as follows:

$$\text{Mixing air} = \frac{1.69 \times 10^4\,\text{scfm}}{1.43 \times 10^6\,\text{gal}} \left(\frac{7.48 \text{ gal}}{\text{ft}^3} \right) \left(\frac{10^3 \text{ ft}^3}{10^3 \text{ ft}^3} \right)$$

$$= \boxed{\frac{88\,\text{scfm}}{10^3 \text{ ft}^3}}$$

On page 381 after calculating mixing air, replace 7,300 scfm with **16,900 scfm**.

At bottom of page 381 in left column, recalculate air and mass required at a different temperature and pressure:

$$1.69\times10^4\ \text{scfm}\times\left(\frac{760\,\text{mm}}{760\,\text{mm}}\right)\left(\frac{560\,^\circ\text{R}}{528\,^\circ\text{R}}\right)=1.79\times10^4\ \text{cfm}$$

$$\text{w}=\left(1.79\times10^4\ \text{cfm}\right)\left(0.070\,\frac{\text{lb}}{\text{ft}^3}\right)\left(\frac{\text{min}}{60\,\text{s}}\right)=20.9\,\frac{\text{lb}}{\text{s}}$$

On page 381 at top in right column, recalculate power required as follows:

$$P_w=\frac{wRT_1}{C_1ne}\left[\left(\frac{p_2}{p_1}\right)^{0.283}-1\right] \qquad (7.177)$$

$$P_w=\frac{20.9\ \text{lb/s}\left(53.3\,\frac{\text{ft}\cdot\text{lb}}{\text{lb air}}\right)\left(560^\circ R\right)}{\left(550\,\frac{\text{ft}\cdot\text{lb}}{\text{s}\cdot\text{hp}}\right)(0.283)(0.75)}\left[\left(\frac{21\,\text{psia}}{14.7\,\text{psia}}\right)^{0.283}-1\right]$$

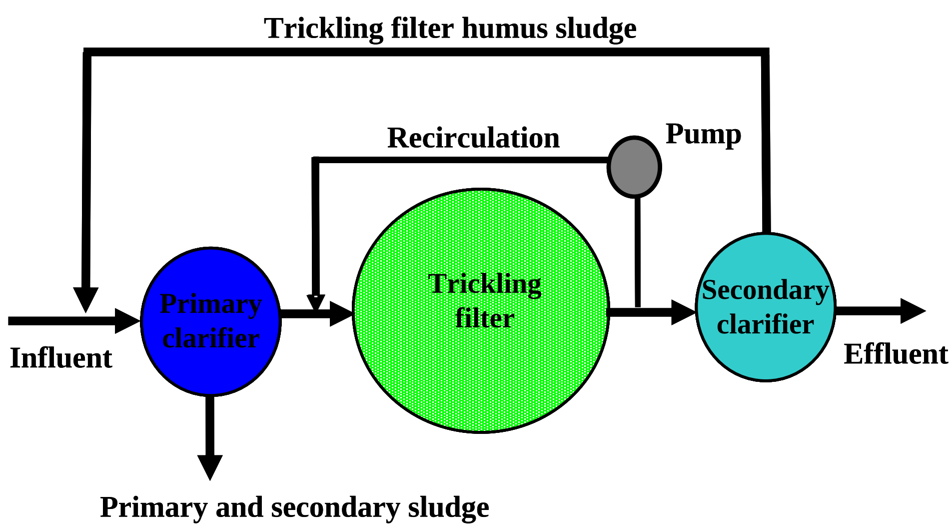
$$=\boxed{568\,\text{hp}}$$

$$\text{bhp}=568$$

$$\text{mhp}=\text{motor horsepower}$$

$$\text{mhp}=\frac{\text{bhp}}{e_m} \qquad \text{mhp}=\frac{568\,\text{hp}}{0.95}=598\cong\boxed{600\,\text{hp}}$$

On page 382, Figure 7.37, replace Trickling filter humus sludger, with “Trickling filter humus sludge”.



On page 382, definition of $\frac{W_1}{V}$ for Equation (7.181) should have the following units:

$$\frac{\text{lb}}{\left(\text{d}\cdot 10^3\,\text{ft}^3\right)}\left(\frac{\text{kg}}{\text{d}\cdot\text{m}^3}\right)$$

On page 383, definition of $\frac{W_2}{V}$ for Equation (7.183) should have the following units:

$$\frac{\text{lb}}{\left(\text{d}\cdot 10^3\,\text{ft}^3\right)}\left(\frac{\text{kg}}{\text{d}\cdot\text{m}^3}\right)$$

On page 383, Example 7.14, assume that the wastewater temperature is 20°C.

On pages 384 to 385, replace Example 7.15 with the following revisions.

EXAMPLE 7.15 Design of trickling filters with plastic media

Two biotowers operating in parallel are to be designed to treat a flow of 4.0 million gallons per day (MGD). The BOD_5 in the effluent from the primary clarifier is 135 mg/L and the effluent BOD_5 from the secondary clarifier is 20 mg/L. The minimum wastewater temperature is expected to be 16°C. The value of k is assumed to be 0.078 $(\text{gpm})^{0.5}/\text{ft}^2$ at 20°C. Biotower depth = 20 ft.

Determine:
a) The radius of each biotower, ft.
b) The volume of media, ft^3.
c) The recycle flow around the biotowers if the minimum wetting rate is 0.75 gpm/ft^2 and the recycle ratio, R.

Solution Part A

Normalize k for site specific depth and influent BOD_5 concentration using Equation(7.188).

$$k_2 = k_1\left(\frac{D_1}{D_2}\right)^{0.5}\left(\frac{S_1}{S_2}\right)^{0.5} = 0.078(\text{gpm})^{0.5}/\text{ft}^2\left(\frac{20\text{ ft}}{20\text{ ft}}\right)^{0.5}\left(\frac{135\,\text{mg/L}}{135\,\text{mg/L}}\right)^{0.5}$$

$$k_2 = 0.078(\text{gpm})^{0.5}/\text{ft}^2$$

Correct k_2 for a temperature of 16°C using Equation (7.186).

$$k_{T°C} = k_{\,20°C}(1.035)^{(T°C-20°C)} = 0.078(\text{gpm})^{0.5}/\text{ft}^2(1.035)^{(16°C-20°C)}$$

$$k_{20°C} = 0.068(\text{gpm})^{0.5}/\text{ft}^2$$

The hydraulic loading rate, *q*, is determined by substituting the appropriate values into Equation (7.187).

$$\frac{S_e}{S_o} = e^{-kD/q^n}$$

$$\frac{20\,\text{mg/L}}{135\,\text{mg/L}} = e^{-0.068(\text{gpm})^{0.5}/\text{ft}^2\,(20\,\text{ft})/q^{0.5}}$$

$$q^{0.5} = \frac{-0.068(\text{gpm})^{0.5}/\text{ft}^2\,(20\,\text{ft})}{\ln\left(\frac{20\,\text{mg/L}}{135\,\text{mg/L}}\right)}$$

$$q = \left(\frac{-0.068(\text{gpm})^{0.5}/\text{ft}^2\,(20\,\text{ft})}{\ln\left(\frac{20\,\text{mg/L}}{135\,\text{mg/L}}\right)}\right)^{(1/0.5)} = 0.51\frac{\text{gpm}}{\text{ft}^2}$$

The surface area of the biotowers can now be determined by dividing the volumetric flow rate by the hydraulic loading rate as follows:

$$A_{\text{cross section}} = \frac{Q}{q} = \frac{4.0\times10^6\,\text{gal/d}}{0.51\,\text{gpm/ft}^2}\left(\frac{1\,\text{d}}{24\,\text{h}}\right)\left(\frac{1\,\text{h}}{60\,\text{min}}\right) = 5.45\times10^3\,\text{ft}^2$$

$$\frac{A_{\text{cross section}}}{\text{biotower}} = \frac{5.45\times10^3\,\text{ft}^2}{2} = 2.73\times10^3\,\text{ft}^2$$

$$A_{\text{cross section}} = 2.73\times10^3\,\text{ft}^2 = \pi r^2$$

$$r = \sqrt{\frac{2.53\times10^3\,\text{ft}^2}{\pi}} = 29.5\,\text{ft} \cong \boxed{30\,\text{ft}}$$

The volume of the biotower media is determined by multiplying the cross sectional area by the depth or height.

$$\forall = \pi r^2 \times D = \pi(30\,\text{ft})^2 \times 20\,\text{ft} = 5.65\times10^4\,\text{ft}^3$$

$$\forall_{\text{Total}} = \left(5.65\times10^4\,\text{ft}^3\right)\times 2\,\text{biotowers} = \boxed{1.13\times10^5\,\text{ft}^3}$$

The minimum wetting rate has been specified as 0.75 gpm/ft^2 so the sum of the hydraulic loading rate (q) and recycle loading rate (q_r) must be at least equal to or greater than the minimum wetting rate.

$$q + q_r = 0.75\ \text{gpm/ft}^2$$
$$q_r = 0.75\ \text{gpm/ft}^2 - 0.51\ \text{gpm/ft}^2 = \boxed{0.24\ \text{gpm/ft}^2}$$

The recycle ratio is calculated as follows:

$$R = \frac{q_r}{q} = \frac{0.21\text{gpm/ft}^2}{0.51\text{gpm/ft}^2} = \boxed{0.47}$$

On page 387, replace Example 7.16 with the following revision.

EXAMPLE 7.16 Design of rotating biological contactors for BOD removal

Design a multi-stage RBC WWTP for the following wastewater for BOD removal. Influent flow = 6,340 m^3/d, influent BOD_5 = 250 g/m^3, primary clarifier removes 34% of BOD_5, total effluent BOD_5 and effluent TSS = 20 g/m^3, effluent soluble BOD_5 ($sBOD_5$) = 10 g/m^3, and T = 20°C.

Determine:
- a) The number of stages and number of trains.
- b) The soluble BOD_5 in the effluent from each stage.
- c) The organic loading on the first stage.
- d) The overall organic loading to the RBC WWTP.
- e) The overall hydraulic loading rate to the RBC WWTP.

Solution Part A

Determine the number of RBCs shafts for the first stage assuming that the primary effluent soluble BOD_5 is 50% of the primary effluent total BOD_5 and that the total soluble BOD_5 loading rate is 15 g $sBOD_5$/(m^2·d).

First, calculate the total BOD_5 in the primary effluent.

$$\text{Total BOD}_5 \text{ in primary effluent} = (1\ -\ 0.34)\times 250\frac{\text{g}}{\text{m}^3} = 165\frac{\text{g}}{\text{m}^3}$$

Calculate the soluble BOD_5 in the primary effluent.

$$\text{Soluble BOD}_5 \text{ in primary effluent} = 165\frac{\text{g}}{\text{m}^3}\times 0.5 = 82.5\frac{\text{g}}{\text{m}^3}$$

Calculate the soluble BOD_5 loading to the first stage.

$$\text{Soluble BOD}_5 \text{ Loading} = \left(6.34\times 10^3\frac{\text{m}^3}{\text{d}}\right)\times\left(82.5\frac{\text{g}}{\text{m}^3}\right) = 5.23\times 10^5\frac{\text{g}}{\text{d}}$$

Determine the number of shafts in the first stage.

$$\text{Media Surface Area} = \frac{5.23\times10^5\ \text{g sBOD}_5/\text{d}}{\dfrac{15.0\ \text{g sBOD}_5}{\left(\text{m}^2\cdot\text{d}\right)}} = 3.49\times10^4\ \text{m}^2$$

$$\text{Number of Shafts} = \frac{3.49\times10^4\ \text{m}^2}{9,300\ \text{m}^2/\text{shaft}} = 3.8 \cong 4.0\ \text{shafts per stage}$$

Assume there are four treatment trains and three stages with 4.0 shafts per stage.

Solution Part B
Next, calculate the flow per train.

$$\text{Flow per train} = \frac{6.34\times10^3\ \text{m}^3/\text{d}}{4\ \text{trains}} = \frac{1.585\times10^3\ \text{m}^3/\text{d}}{\text{train}}$$

Determine the ratio of surface area to the flow rate as follows:

$$\frac{A_s}{Q} = \frac{9,300\ \text{m}^2}{1.585\times10^3\ \text{m}^3/\text{d}} = \frac{5.9\ \text{d}}{\text{m}}$$

Calculate the soluble BOD_5 from each stage using Equation(7.189).

$$S_1 = \frac{-1+\sqrt{1+(4)(0.00974)(A_s/Q)S_0}}{(2)(0.00974)(A_s/Q)}$$

$$S_1 = \frac{-1+\sqrt{1+(4)(0.00974)(5.9\ \text{d/m})(82.5\ \text{g/m}^3)}}{(2)(0.00974)(5.9\ \text{d/m})} = \boxed{30.2\ \frac{\text{g}}{\text{m}^3}}$$

$$S_2 = \frac{-1+\sqrt{1+(4)(0.00974)(A_s/Q)S_1}}{(2)(0.00974)(A_s/Q)}$$

$$S_2 = \frac{-1+\sqrt{1+(4)(0.00974)(5.9\ \text{d/m})(30.2\ \text{g/m}^3)}}{(2)(0.00974)(5.9\ \text{d/m})} = \boxed{15.8\ \frac{\text{g}}{\text{m}^3}}$$

$$S_3 = \frac{-1+\sqrt{1+(4)(0.00974)(A_s/Q)S_2}}{(2)(0.00974)(A_s/Q)}$$

$$S_3 = \frac{-1+\sqrt{1+(4)(0.00974)(5.9\,\mathrm{d/m})(15.8\,\mathrm{g/m^3})}}{(2)(0.00974)(5.9\,\mathrm{d/m})} = \boxed{10.0\,\frac{\mathrm{g}}{\mathrm{m^3}}} = 10.0\,\frac{\mathrm{g}}{\mathrm{m^3}}\ \text{Good!}$$

Solution Part C

The soluble organic loading on the first-stage is calculated below.

$$\text{First-stage soluble BOD}_5\text{ loading} = \frac{(6.34\times10^3\,\mathrm{m^3/d})(82.5\,\mathrm{g/m^3})}{(4\,\text{shafts})(9{,}300\,\mathrm{m^2/shaft})} = \boxed{14.1\,\frac{\mathrm{g\ sBOD_5}}{(\mathrm{m^2\cdot d})}}$$

$$\text{Within range}\left(12.2-19.5\,\frac{\mathrm{g\,sBOD_5}}{(\mathrm{m^2\cdot d})}\right)$$

Solution Part D

The total organic loading on the RBC WWTP is calculated as follows.

$$\text{Total BOD}_5\text{ loading} = \frac{(6.34\times10^3\,\mathrm{m^3/d})(165\,\mathrm{g/m^3})}{(3\,\text{stages})(4\,\text{shafts/stage})(9{,}300\,\mathrm{m^2/shaft})} = \boxed{9.4\,\frac{\mathrm{g\,BOD_5}}{(\mathrm{m^2\cdot d})}}$$

$$\text{Within range}\left(8-20\,\frac{\mathrm{g\,BOD_5}}{(\mathrm{m^2\cdot d})}\right)$$

Solution Part E

The hydraulic loading on the RBC WWTP is calculated as follows.

$$\text{Hydraulic loading} = \frac{(6.34\times10^3\,\mathrm{m^3/d})}{(3\,\text{stages})(4\,\text{shafts/stage})(9{,}300\,\mathrm{m^2/shaft})} = \boxed{0.057\,\frac{\mathrm{m^3}}{(\mathrm{m^2\cdot d})}}$$

$$\text{Slightly below range}\left(0.08\text{ - }0.16\,\frac{\mathrm{m^3}}{(\mathrm{m^2\cdot d})}\right)\text{but should work.}$$

On page 440, problem 14, add **"The substrate is measured in terms of mg/L of BOD_5."**

On page 441, problem 20, **Assume that the density of air at sea level and 100°F is 0.070 lb/ft^3.**

On page 442, problem 25, assume that the wastewater temperature is 20°C and the flow rate should be **2.5 million gallons per day (MGD)** instead of 5.0 MGD.

On page 442, problem 28, the units should be in Lps/m^2 as shown below.

c. The recycle flow **(Lps/m^2)** around the biotowers if the minimum wetting rate is 0.5 **Lps/m^2** and the recycle ratio, *R*.

On page 444, problem 32, use a safety factor of **1.5** rather than 1.25.

On page 444, problem 33 should read as follows:

33. A 4-stage Bardenpho process is to be designed to meet a 5/5/3/ mg/L effluent standard for BOD_5, TSS, and TN, respectively. The influent wastewater characteristics, mixed liquor parameters, and biokinetic coefficients to be used in design are presented in the tables below. Assume that the influent ammonium concentration is equal to the TKN concentration, RAS flow = 1*Q* and MLR flow = 4*Q*, DO in the RAS and MLR recycle is 1.0 mg/L and 1.0 mg/L entering the second anoxic zone.

Wastewater characterization

Influent		**Mixed liquor**	
Q	56,775 m^3/d	DO	2.0 mg/L
pH	7.2	MLSS =	3,500 mg/L
Minimum temperature	18°C	MLVSS	0.70 MLSS
TKN	30 mg/L	K_{DO}	0.5 mg/L
Alkalinity	250 mg/L as $CaCO_3$	MLVSS	2,625 mg/L
BOD_5	200 mg/L		
TSS	167 mg/L		
Inerts (X_L)	50 mg/L		

Heterotrophic biokinetic coefficients at 20°C

Coefficient		**Coefficient**	
Y	0.6 g VSS/g BOD_5	k_d	0.055 d^{-1}
k	4.4 d^{-1}	K_s	60 mg/L BOD_5

***Nitrosomonas* biokinetic coefficients at 20°C**

Coefficient		**Coefficient**	
Y_{NS}	0.15 g VSS/g NH_4^+-N	$(k_d)_{NS}$	0.046 d^{-1}
k_{NS}	2.6 d^{-1}	$(K_s)_{NS}$	0.67 mg/L NH_4^+-N

Heterotrophic biokinetic coefficients at 18°C

Coefficient		**Coefficient**	

Y	0.6 g VSS/g BOD_5	k_d	**0.051 d^{-1}**
k	**3.8 d^{-1}**	K_s	60 mg/L BOD_5

***Nitrosomonas* biokinetic coefficients at 18°C**

Coefficient		**Coefficient**	
Y_{NS}	0.15 g VSS/g NH_4^+-N	$(k_d)_{NS}$	**0.043 d^{-1}**
k_{NS}	**2.3 d^{-1}**	$(K_s)_{NS}$	0.60 mg/L NH_4^+-N

A temperature correction coefficient *(θ)* of 1.04 should be used for correcting both the heterotrophic and *Nitrosomonas* k_d values; whereas a θ of 1.07 should be used for correcting both the heterotrophic and *Nitrosomonas* k values. The heterotrophic K_s value is corrected with a θ of 1.00 and the *Nitrosomonas* K_s is corrected with a theta value of 1.053. All temperature correction coefficients were obtained from Metcalf and Eddy (2003). Use a safety factor of 2.5 and peaking factor of 1.2 and assume that **F_n = 0.10.**