Engi 9601, Envs 6004
Water Problems.

7-3)

7-4)

7-5)

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7-11)

7-13)

7-24)

7-37)

Engi 9601, Envs 6004, Water Pollution Problems.

7-3) Find ThOD of acetic acid, CH_3COOH, 300 mg/L

$$CH_3COOH + 2O_2 \rightleftarrows 2CO_2 + H_2O.$$

Atomic weights: C = 12, H = 1, O = 16

molecular weights CH_3COOH = 60, $2O_2 = 64$

$$\frac{300\ \frac{mg}{L}\ CH_3COOH \times 64\ mg\ 2O_2}{60\ mg\ CH_3COOH} = \underline{\underline{320\ \frac{mg}{L}\ \text{oxygen}, O_2}}$$

7-4) BOD_5 = 220 mg/L, UBOD = 320.0 mg/L
T = 20°C.
Find rate constant k.

$$BOD_t = UBOD\,(1-e^{-kt})$$

$$BOD_5 = UBOD\,(1-e^{-5(t)})$$

$$220\ mg/L = 320\ mg/L\,(1-e^{-5t})$$

$$\frac{220}{320} = 1-e^{-5t}$$

$$1-\frac{220}{320} = e^{-5t}$$

$$\ln\left(1-\frac{220}{320}\right) = -5t = -1.1631$$

$$\underline{\underline{k = 0.233}}$$

7-5) $BOD_7 = 60\ mg/L$, $UBOD = 85\ mg/L$
$T = 20°C$
Find rate constant, k

$$BOD_t = UBOD\,(1 - e^{-kt})$$

$$BOD_7 = UBOD\,(1 - e^{-7k})$$

$$\frac{60}{85} = 1 - e^{-7K}$$

$$1 - \frac{60}{85} = e^{-7K}$$

$$\ln\left(1 - \frac{60}{85}\right) = -7K = -1.2238$$

$$\underline{\underline{k = 0.175}}$$

7-8) $BOD_7 = 60\ mg/L$, $UBOD = 85\ mg/L$, $T = 25°C$
Find rate constant, k at $16°C$.

$$K_{25} = 0.175$$

$$K_T = K_{20} \times \theta^{T-20}$$

$$K_{20} = K_T \div \theta^{T-20} = 0.175 \div 1.056^{25-20} = 0.1333$$

$$K_{16} = K_{20} \times \theta^{T-20} = 0.1333 \times 1.135^{16-20} \underline{\underline{= 0.0803}}$$

7-10) what percent sample size will limit oxygen consumption to 4.0 mg/L if BOD_5 = 350 mg/L?

$$BOD_5 = \frac{DO_1 - DO_2}{P}$$

$$P = \frac{DO_1 - DO_2}{BOD_5} = \frac{4.0 \text{ mg/L}}{350 \text{ mg/L}} = 0.0114$$

Sample size, in percent is $\underline{\underline{1.14\%}}$

7-11) BOD_5 = 327 mg/L, for oxygen consumption equal to 4.8 mg/L, what sample size in % is needed?

$$BOD_5 = \frac{DO_1 - DO_2}{P}$$

$$P = \frac{DO_1 - DO_2}{BOD_5} = \frac{4.8 \text{ mg/L}}{327 \text{ mg/L}} = 0.01468$$

Sample size in percent is $\underline{\underline{1.47\%}}$.

7-13) BOD_5 = 280 mg/L and $k = 0.08 d^{-1}$ and $k = 0.12 d^{-1}$
Find UBOD values

$$BOD_t = UBOD\left(1 - e^{-kt}\right)$$

$$UBOD = \frac{BOD_t}{\left(1 - e^{-kt}\right)} = \frac{280 \text{ mg/L}}{\left(1 - e^{-5(0.08)}\right)} = \underline{\underline{849 \text{ mg/L}}}$$

$$UBOD = \frac{280 \text{ mg/L}}{\left(1 - e^{-5(0.12)}\right)} = \underline{\underline{620 \text{ mg/L}}}.$$

7-24) $Q_W = 0.126\ m^3/s$, $BOD_{5,W} = 34\ mg/L$
$Q_R = 0.126\ m^3/s$, $BOD_{5,R} = 1.2\ mg/L$

$T_R = T_W = 20°C$.
$K_W = 0.222\ d^{-1}$; $K_R = 0.090\ d^{-1}$

Find UBOD after mixing.

$$UBOD_W = \frac{BOD_W}{(1-e^{-kt})} = \frac{34\ mg/L}{(1-e^{-0.222\times 5})} = 50.71\ mg/L$$

$$UBOD_R = \frac{1.2\ mg/L}{(1-e^{-0.090\times 5})} = 3.31\ mg/L.$$

$$Q_m = Q_W + Q_R = 0.126\ m^3/s + 0.126\ m^3/s = 0.252\ m^3/s$$

$$Q_m\, UBOD_m = Q_R\, UBOD_R + Q_W\, UBOD_W.$$

$$UBOD_m = \frac{(0.126\ m^3/s)(3.31\ mg/L) + (0.126\ m^3/s)(50.71\ mg/L)}{0.252\ m^3/s}$$

$$= \frac{0.4171 + 6.389}{0.252}\ mg/L$$

$$= \underline{\underline{27.0\ mg/L}}$$

7-37) $Q_W = 0.1507\ m^3/s$ $\quad$ $Q_R = 1.08\ m^3/s$

$BOD_{5,16,W} = 128\ mg/L$ $\quad$ $UBOD_{5,16,R} = 11.40\ mg/L$

$DO_W = 1.0\ mg/L$ $\quad$ $DO_R = 7.95\ mg/L$

$T = 16°C$ $\quad$ $T = 16°C$

$K_{20} = 0.4375\ d^{-1}$

$Speed_R = 0.390\ m/s$

$Depth_R = 2.80\ m$

$\eta_R = 0.200$

Oxygen min. for river is 5.0 mg/L.
2nd town is 15.55 km downstream.

Find DO at 2nd town.
Find critical DO. and it's location downstream.
Is the min. DO of the river acceptable?

Convert K_{20} to K_{16} so every term is relative to 16°C.

$$K_T = K_{20} \times \theta^{T-20} = 0.4375 \times 1.135^{16-20} = 0.2636\ d^{-1}$$

$$K_{16} = 0.2636\ d^{-1}$$

$$UBOD_W = \frac{BOD_W}{(1-e^{-kt})} = \frac{128\ mg/L}{(1-e^{-0.2636 \times 5})} = 174.78\ mg/L$$

$$Q_m = Q_W + Q_R = 1.2307\ m^3/s$$

$$UBOD_m = \frac{Q_W\, UBOD_W + Q_R\, UBOD_R}{Q_m}$$

$$= \frac{(0.1507)(174.78) + (1.08)(11.40)}{1.2307}\ mg/L$$

$$= \frac{26.339 + 12.312}{1.2307} = 31.41\ mg/L.$$

7-37) continued

$$DO_m = \frac{DO_W\, Q_W + DO_R\, Q_R}{Q_m}$$

$$= \frac{(1.0)(0.1507) + (7.95)(1.08)}{1.2307} \text{ mg/L}$$

$$= \frac{(0.1507) + (8.586)}{1.2307} = 7.10 \text{ mg/L}$$

Find k_d and k_r at 20°C and convert to 16°C

$$k_d = k_{20} + \frac{u}{H}\eta = 0.4375 + \frac{0.390\,(0.200)}{2.80} = 0.4654 \text{ d}^{-1}$$

$$k_r = \frac{3.9\, u^{1/2}}{H^{3/2}} = \frac{3.9\,(0.390^{1/2})}{2.80^{3/2}} = \frac{2.4355}{4.6853} = 0.5198 \text{ d}^{-1}$$

$$k_{d,16} = k_{d,20} \times \theta^{T-20} = 0.4654 \times 1.135^{(16-20)} = 0.2804 \text{ d}^{-1}$$

$$k_{r,16} = k_{r,20} \times \theta^{T-20} = 0.5198 \times 1.024^{(16-20)} = 0.4728 \text{ d}^{-1}$$

$u_R = 0.390$ m/s ; Travel distance $= 15.55$ km.

$$\text{Travel time} = \frac{15.55 \text{ km}}{0.390 \text{ m/s}} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{\text{d}}{86{,}400 \text{ s}} = 0.4615 \text{ d}$$

$$D_m = \frac{k_d\, UBOD_m}{k_r - k_d}\left(e^{-k_d t} - e^{-k_r t}\right) + D_{mo}\, e^{-k_r t}$$

At 16°C, $DO_{sat} = 9.95$ mg/L.

$$D_{mo} = DO_{sat} - DO_m = 9.95 - 7.10 = 2.85 \text{ mg/L}.$$

7-37) cont'd.

$$D_m = \frac{0.2804\,(31.41)}{0.4728 - 0.2804}\left(e^{\overset{-0.1294}{-0.2804\times 0.4615}} - e^{\overset{-0.2182}{-0.4728\times 0.4615}}\right) + 2.85\, e^{\overset{-0.2182}{-0.4728\times 0.4615}}$$

$$D_m = \frac{0.2804\,(31.41)}{0.1924}\left(0.8786 - 0.8040\right) + 2.85\,(0.8040)$$

$$= 3.4149 + 2.2914 = 5.706 \text{ mg/L}.$$

$$\underset{\text{at town}}{DO} = DO_{sat} - D_m = 9.95 - 5.706 = \underset{\text{not O.K.}}{\underline{\underline{4.244 \text{ mg/L}}}} \ngtr 5.0 \text{ mg/L}$$

$$t_c = \frac{1}{K_r - K_d} \ln\left\{\frac{K_r}{K_d}\left[1 - \frac{D_{mo}\,(K_r - K_d)}{K_d\, UBOD_m}\right]\right\}$$

$$= \frac{1}{0.1924} \ln\left\{\frac{0.4728}{0.2804}\left[1 - \frac{2.85\,(0.1924)}{0.2804\,(31.41)}\right]\right\} = 2.381 \text{ d}.$$

$$D_c = \frac{0.2804\,(31.41)}{0.1924}\left(e^{\overset{-0.6674}{-0.2804\,(2.38)}} - e^{\overset{-1.125}{-0.4728\,(2.38)}}\right) + 2.85\, e^{-1.125}$$

$$= 45.776\left(0.5130 - 0.3247\right) + 0.9253 = 9.545 \text{ mg/L}.$$

$$DO_c = DO_{sat} - D_c = 9.95 - 9.545 = \underset{\text{not O.K.}}{\underline{\underline{0.405 \text{ mg/L}}}} \ngtr 5.0$$

It occurs at:

$$\frac{2.381 \text{ d} \times 0.390 \text{ m} \times 86{,}400 \text{ s} \quad \text{km}}{\text{s} \qquad\qquad \text{d} \quad 1000 \text{ m}} = \underset{\text{downstream}}{\underline{80.23 \text{ km}}}$$