11 DILUTION PURIFICATION

Dilution purification (also known as *self purification*) refers to discharge of partially treated sewage into a body of water such as a stream or river. If the body is large and is adequately oxygenated, the sewage's BOD may be satisfied without putrefaction. Other conditions which must be monitored besides BOD are oxygen content and suspended solids.

Equation 8.20 can be used to calculate the final concentration of BOD, oxygen, and sediment when the two flows are mixed. Dilution requirements may be expressed in terms of ratios (e.g., 23 stream volumes per discharge volume) or absolute flow quantities (e.g., 4 to 7 cfs per 1000 population).

$$C_1Q_1 + C_2Q_2 = C_f(Q_1 + Q_2) \qquad 8.20$$

Example 8.3

Wastewater (DO = 0.9 mg/l, 6 MGD) is discharged into a 50°F stream flowing at 40 cfs. Assuming the stream is saturated with oxygen, what is the oxygen content of the stream immediately after mixing?

From appendix B, the saturated oxygen content at 50°F (10°C) is 11.3 mg/l.

$$(6\text{ MGD})\left(1.547\ \frac{\text{cfs}}{\text{MGD}}\right) = 9.28\text{ cfs}$$

$$C = \frac{(0.9)(9.28) + (11.3)(40)}{9.28 + 40} = 9.34\text{ mg/l}$$

The *oxygen deficit* is the difference between actual and saturated oxygen concentrations. Since reoxygenation and deoxygenation of a polluted river occur simultaneously, an oxygen deficit will occur only if the reoxygenation rate is less than the deoxygenation rate. If the oxygen content goes to zero, anaerobic decomposition and putrefaction will occur.

The oxygen deficit at any time t is given by the *Streeter-Phelps equation*:

$$\begin{aligned} D_t &= DO_{\text{sat}} - DO_t \\ &= \frac{K_D \text{BOD}_u}{K_R - K_D}\left(10^{-K_D t} - 10^{-K_R t}\right) \\ &\quad + D_o\left(10^{-K_R t}\right) \qquad 8.21 \end{aligned}$$

D_t is the dissolved oxygen deficit, t is in days, and BOD_u is the ultimate carbonaceous BOD of the stream immediately after mixing. K_D and K_R are the deoxygenation and reoxygenation rate constants respectively, and D_o is the dissolved oxygen deficit immediately after mixing.[9]

K_R can be approximated by equation 8.22 if field test data is not available.[10]

$$K_{R,20°\text{C}} \approx \frac{3.3v}{d^{1.33}} \qquad 8.22$$

K_R for different temperatures is given by equation 8.23. Typical values of K_R are given in table 8.12.

$$K_{R,T} = (1.016)^{T-20} K_{R,20°\text{C}} \qquad 8.23$$

Table 8.12
Typical Reoxygenation Constants (base 10, 1/days)

white water	0.5 and above
swiftly flowing	0.3 to 0.5
large streams	0.15 to 0.3
large lakes	0.10 to 0.15
sluggish streams	0.10 to 0.15
small ponds	0.05 to 0.10

Equations 8.6 and 8.21 can be plotted simultaneously as shown in figure 8.5. The plot of equation 8.21 is known as the *oxygen sag curve*. The difference between the two curves is the effect of reoxygenation.

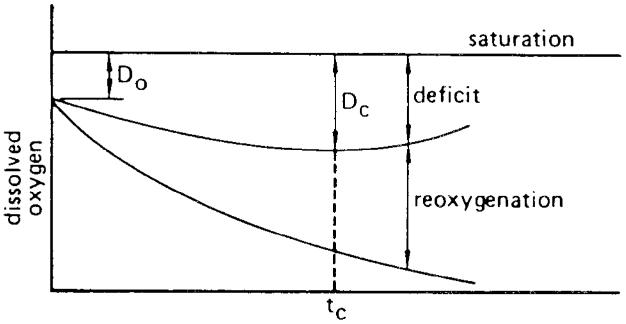

Figure 8.5 The Oxygen Sag Curve

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[9] K_R and K_D may be written as K_1 and K_2 by other authors

[10] Equation 8.22 is the O'Connor and Dobbins formula for natural streams.