# BOD Analysis

# 19.4 Biochemical Oxygen Demand (BOD)

- It was impractical to rigorously quantify how each compound in sewage decomposes.
- Empirical approach is used – *merely measured how much oxygen was consumed, this resulting quantity is BOD*.
- BOD(t) – oxygen consumed changes with time, e.g., $BOD_5$ as 5-day BOD, and $BOD_u$ as ultimate BOD or ultimate oxygen that can be consumed during decomposition.
- Introduce (*L*) as oxidizable organic matter remaining in the bottle expressed as oxygen equivalents

# Change of *L*, *y*, and *o* with time

$$V\frac{dL}{dt} = -k_1 VL$$

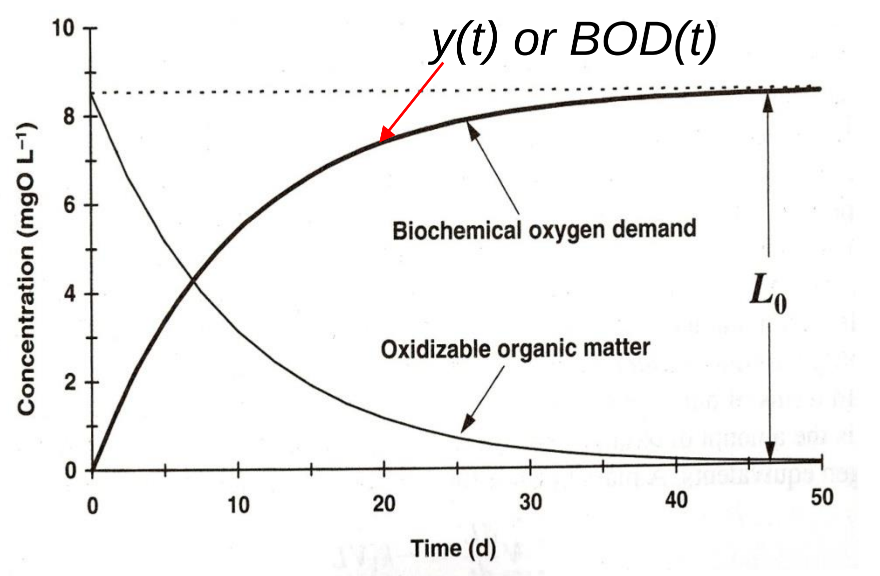
$$L = L_o e^{-k_1 t}$$

$$y = L_o - L$$

$$y = L_o(1 - e^{-k_1 t})$$

$$V\frac{do}{dt} = -k_1 V L_o e^{-k_1 t}$$

$$o = o_o - L_o(1 - e^{-k_1 t})$$

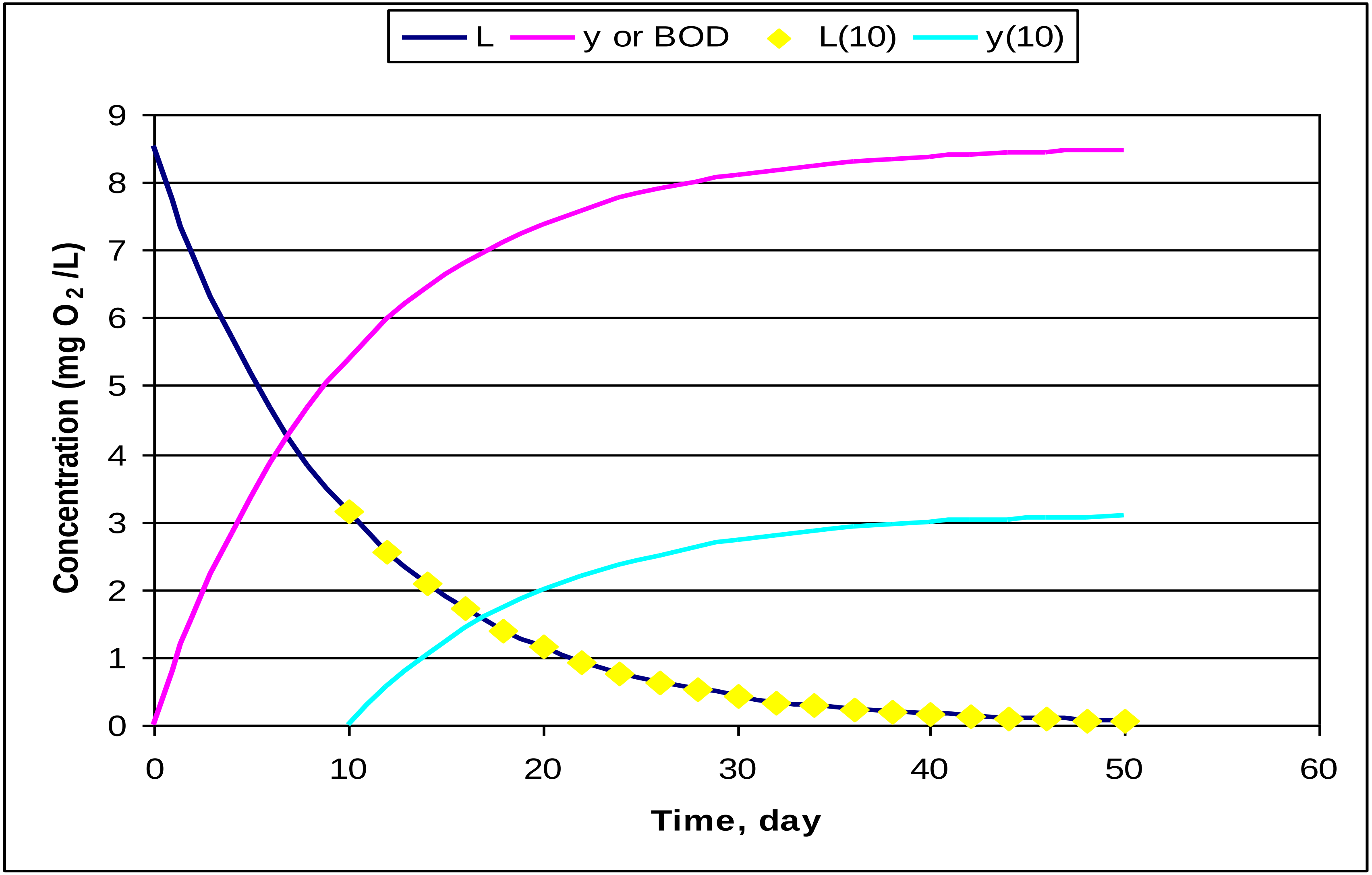



- y is the (cumulative) oxygen consumed during the decomposition process
- y = BOD
- o is oxygen concentration in the environment (containing sewage)

# $L_o$ and $BOD_u$

- Form 19.4, we have $L_o$ = $BOD_u$, i.e., initial oxidizable organic matter = ultimate BOD
- We can use $BOD_u$ or BOD to quantify how much organic matter in the sewage as oxygen consumption equivalent
- L(t) as oxidizable organic matter remaining in the sewage (expressed by oxygen equivalents) at any time is presented as BOD(t) or y(t)
- $L_o = BOD_u = BOD$
- CBOD – carbonaceous BOD due to decomposition of carbonaceous matter
- NBOD – nitrogenous BOD- oxidation of ammonia to nitrite then to nitrate (nitrification)

# L or BOD or $BOD_u$



# 19.5 BOD model for a stream

$$\frac{\partial L}{\partial t} = -U\frac{\partial L}{\partial x} - k_r L$$

$$k_r = k_d + k_s$$

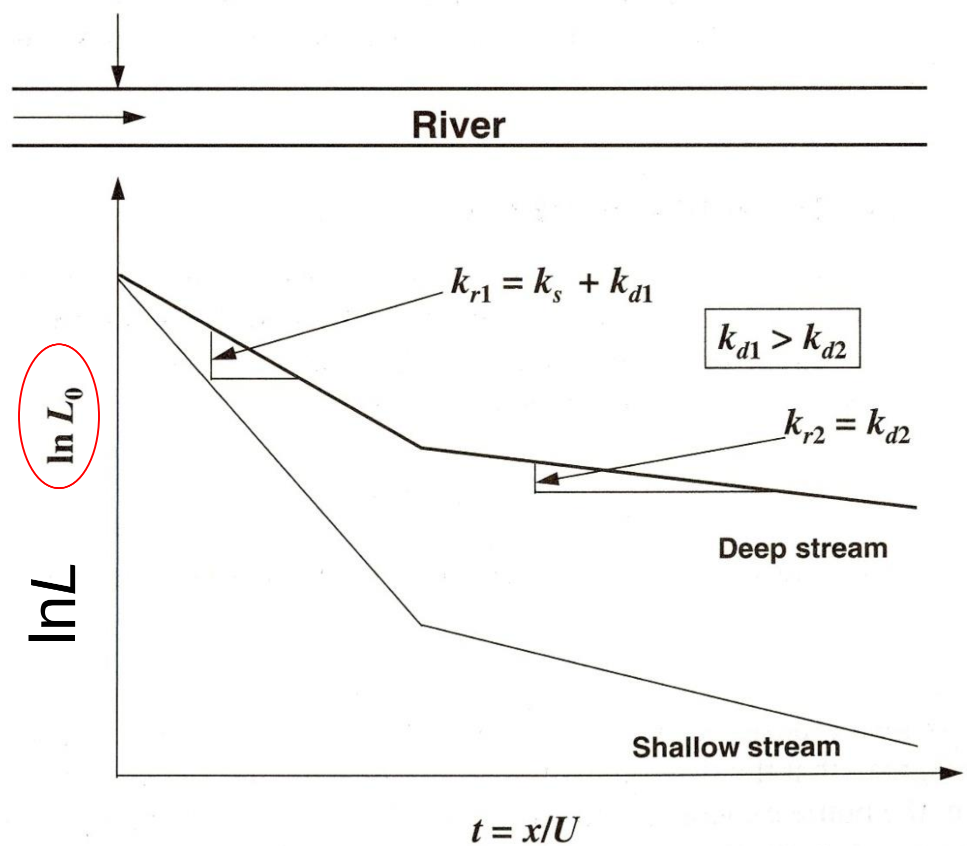
$$k_s = \frac{v_s}{H}$$

$$0 = -U\frac{\partial L}{\partial x} - k_r L$$

$$L_o = \frac{Q_w L_w + Q_r L_r}{Q_w + Q_r}$$

$$L = L_o e^{-\frac{k_r}{U}x}$$

- **$K_r$ is total removal rate as sum of decomposition (first order $k_d$) and settling ($k_s$) with settling velocity of $v_s$.**



# 19.6 BOD loading, concentration and rates

**TABLE 19.1**
**Typical values of the BOD bottle decomposition rate for various levels of treatment. $BOD_u$ is the ultimate BOD. Values here are for CBOD**

| Treatment | $k_1$(20°C) | $BOD_5/BOD_u$ |
|---|---|---|
| Untreated | 0.35 (0.20–0.50) | 0.83 |
| Primary | 0.20 (0.10–0.30) | 0.63 |
| Activated sludge | 0.075 (0.05–0.10) | 0.31 |

- $BOD_5$ (5-Day BOD)
- Ultimate BOD – $BOD_u$
- $L_o = BOD_u$
  $= BOD_5/[1-\exp(-k_1 5)]$
  $= y_5/[1-\exp(-k_1 5)]$

(see equation 19.26 on page 357)

**TABLE 19.2**
**Typical loading rates for untreated domestic sewage**

| | Per-capita flow rate ($m^3$ capita$^{-1}$ d$^{-1}$) | Per-capita CBOD ($m^3$ capita$^{-1}$ d$^{-1}$) | CBOD concentration (mg L$^{-1}$) |
|---|---|---|---|
| United States | 0.57 (150)† | 125 (0.275)‡ | 220 |
| Developing countries | 0.19 (50)† | 60 (0.132)‡ | 320 |

† Gallons capita$^{-1}$ day$^{-1}$; ‡ pounds capita$^{-1}$ day$^{-1}$.

# 19.6.3 BOD removal rate

Total BOD removal rate

- Settling effects

$$k_r = k_d + \frac{v_s}{H}$$

- Bed effects

$$k_d = 0.3\left(\frac{H}{8}\right)^{-0.434} \qquad 0 \le H \le 8\,ft$$

$$k_d = 0.3 \qquad H > 8\,ft$$

- Attached bacteria in shallow water have higher removal rate (more effective in decomposition.

**Temperature adjustment:** $\theta_{k_d} \cong 1.047$

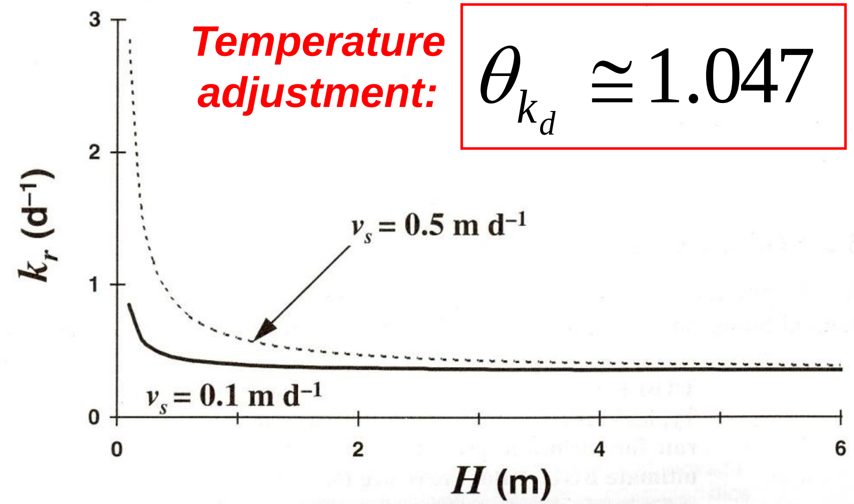



**FIGURE 19.6**
Plot of total removal rate versus stream depth for BOD that is 50% in settleable form. A range of settling velocities is depicted. Note that a decomposition rate of 0.35 d$^{-1}$ is used.