## Oxygen Sag Curve

Oxygen saturation (mg/l) in water at 1 atm

| | Salinity (mg/L) | | | |
|---|---|---|---|---|
| Temperature (°C) | 0 | 5000 | 10000 | 15000 |
| 0 | 14.62 | 13.73 | 12.89 | 12.10 |
| 5 | 12.77 | 12.02 | 11.32 | 10.66 |
| 10 | 11.29 | 10.66 | 10.06 | 9.49 |
| 15 | 10.08 | 9.54 | 9.03 | 8.54 |
| 20 | 9.09 | 8.62 | 8.17 | 7.75 |
| 25 | 8.26 | 7.85 | 7.46 | 7.08 |
| 30 | 7.56 | 7.19 | 6.85 | 6.51 |

$$k_d = k_{d,20} \cdot \theta^{T-20} \quad \text{with } \theta = 1.047$$

$k_{d,20}$ = 0.35-0.70 raw sewage, 0.10-0.25 well-treated sewage and pollute river [day$^{-1}$]

$$k_{r,20} = \frac{3.9u^{1/2}}{H^{3/2}}$$ [day$^{-1}$] with $H$ in [m] and $u$ in [m/s]

$$k_r = k_{r,20} \cdot \theta_r^{T-20} \quad \text{with } \theta_r = 1.024$$

Oxygen deficit [mg/l]:

$$\begin{cases} \dfrac{dD}{dt} = k_d L_0 e^{-k_d t} - k_r D \\ D(t=0) = D_0 \end{cases}$$

$$D(t) = DO_s - DO(t) = \frac{k_d L_0}{k_r - k_d}\left(e^{-k_d t} - e^{-k_r t}\right) + D_0 e^{-k_r t}$$

$$t_c = \frac{1}{k_r - k_d} \ln\left(\frac{k_r}{k_d}\left(1 - \frac{D_0\left(k_r - k_d\right)}{k_d L_0}\right)\right)$$

## Sedimentation

$$v_s = \frac{\left(\rho_s - \rho\right) g d^2}{18\mu} \quad \text{for } \mathrm{Re}_p < 0.3 \text{ (Stokes regime)}$$

$$v_s = \sqrt{\frac{4}{3}\frac{\left(\rho_s - \rho\right)}{\rho}\frac{gd}{c_D}} \quad \text{for } \mathrm{Re}_p > 0.3 \text{ (inertial regime)}$$

## Cell growth kinetics

$$\frac{dX}{dt} = \mu_{\max} \frac{S}{K_S + S} X - k_d X$$

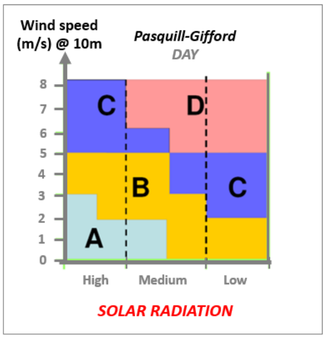
$$\frac{dS}{dt} = -k_{\max} \frac{S}{K_S + S} X \qquad \text{with } k_{\max} = \mu_{\max} / Y$$

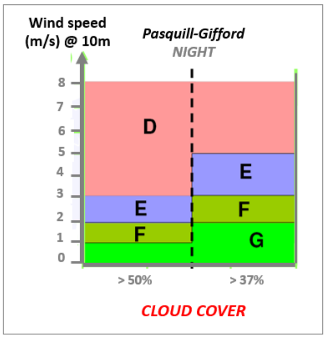
Typical values

| | |
|---|---|
| $k_{max}$ | = 2-5 day$^{-1}$ |
| $K_S$ | = 2-100 mgBODeq/L |
| Y | = 0.4-0.8 mgVSS/mgBODeq |
| $k_d$ | = 0.04-0.075 day$^{-1}$ |

## Atmospheric gas dispersion

| Class | Stability | $\Gamma$ (°C/100 m) |
|---|---|---|
| A | Very unstable | $\Gamma<-1.9$ |
| B | Moderately unstable | $-1.9<\Gamma<-1.7$ |
| C | Slightly unstable | $-1.7<\Gamma<-1.5$ |
| D | Neutral | $-1.5<\Gamma<-0.5$ |
| E | Slightly stable | $-0.5<\Gamma<+1.5$ |
| F | Very stable | $\Gamma>1.5$ |




**Wind Profile Exponent *p*, for Rough Terrain**

| Stability Class | Description | Exponent *p* |
|---|---|---|
| A | Very unstable | 0.15 |
| B | Moderately unstable | 0.15 |
| C | Slightly unstable | 0.20 |
| D | Neutral | 0.25 |
| E | Slightly stable | 0.40 |
| F | Stable | 0.60 |

$$u_2 = u_1\left(\frac{z_2}{z_1}\right)^p$$

$$c(x,y)=\frac{Q}{\pi U\sigma_y\sigma_z}\exp\left(-\frac{y^2}{2\sigma_y{}^2}\right)\exp\left(-\frac{H^2}{2\sigma_z{}^2}\right)$$

$$\sigma_y = a\,x^{0.894} \qquad \sigma_z = cx^d + f$$

**Values of the Constants *a*, *c*, *d*, and *f* for Use in (47) and (48)**

| | | $x \le 1$ km | | | $x \ge 1$ km | | |
|---|---|---|---|---|---|---|---|
| Stability | *a* | *c* | *d* | *f* | *c* | *d* | *f* |
| A | 213 | 440.8 | 1.941 | 9.27 | 459.7 | 2.094 | −9.6 |
| B | 156 | 106.6 | 1.149 | 3.3 | 108.2 | 1.098 | 2.0 |
| C | 104 | 61.0 | 0.911 | 0 | 61.0 | 0.911 | 0 |
| D | 68 | 33.2 | 0.725 | −1.7 | 44.5 | 0.516 | −13.0 |
| E | 50.5 | 22.8 | 0.678 | −1.3 | 55.4 | 0.305 | −34.0 |
| F | 34 | 14.35 | 0.740 | −0.35 | 62.6 | 0.180 | −48.6 |

*Note:* The computed values of $\sigma$ will be in meters when $x$ is given in kilometers.

$$H = h + \Delta h$$

Stable (E, F)

$$\Delta h = 2.6\left(\frac{F}{US}\right)^{1/3}$$

Unstable & Neutral (A-D)

$$\Delta h = \frac{1.6F^{1/3}x_i^{2/3}}{U}$$

$$F = gr^2 v_s\left(1-\frac{T_a}{T_s}\right)$$

$$S = \frac{g}{T_a}\left(\frac{dT_a}{dz}+0.01\ \text{°C/m}\right)$$

$$x_i = \begin{cases} 50F^{5/8} & \text{if } F < 55\ \text{m}^4/\text{s}^3 \\ 120F^{0.4} & \text{if } F \ge 55\ \text{m}^4/\text{s}^3 \end{cases}$$

$\Delta h$ = plume rise [m]
$g$ = gravity acceleration [m/s²]
$r$ = inner radius of the stack [m]
$U$ = wind speed at stack height h [m/s]
$v_s$ = velocity of gas exiting from the stack [m/s]
$T_s$ = stack gas temperature [K]
$T_a$ = ambient temperature at stack height h [K]
$F$ = buoyancy flux parameter [m⁴/s³]
$S$ = stability parameter [s⁻²]
$x_i$ = distance downwind to point of final plume rise [m]
$\frac{dT_a}{dz}$ = actual lapse rate, positive if $T_a$ increases with z [K/m]

Line source at ground level with perpendicular wind: $c(x)=\frac{2}{\sqrt{2\pi}}\frac{q}{\sigma_z U}$