AERATION

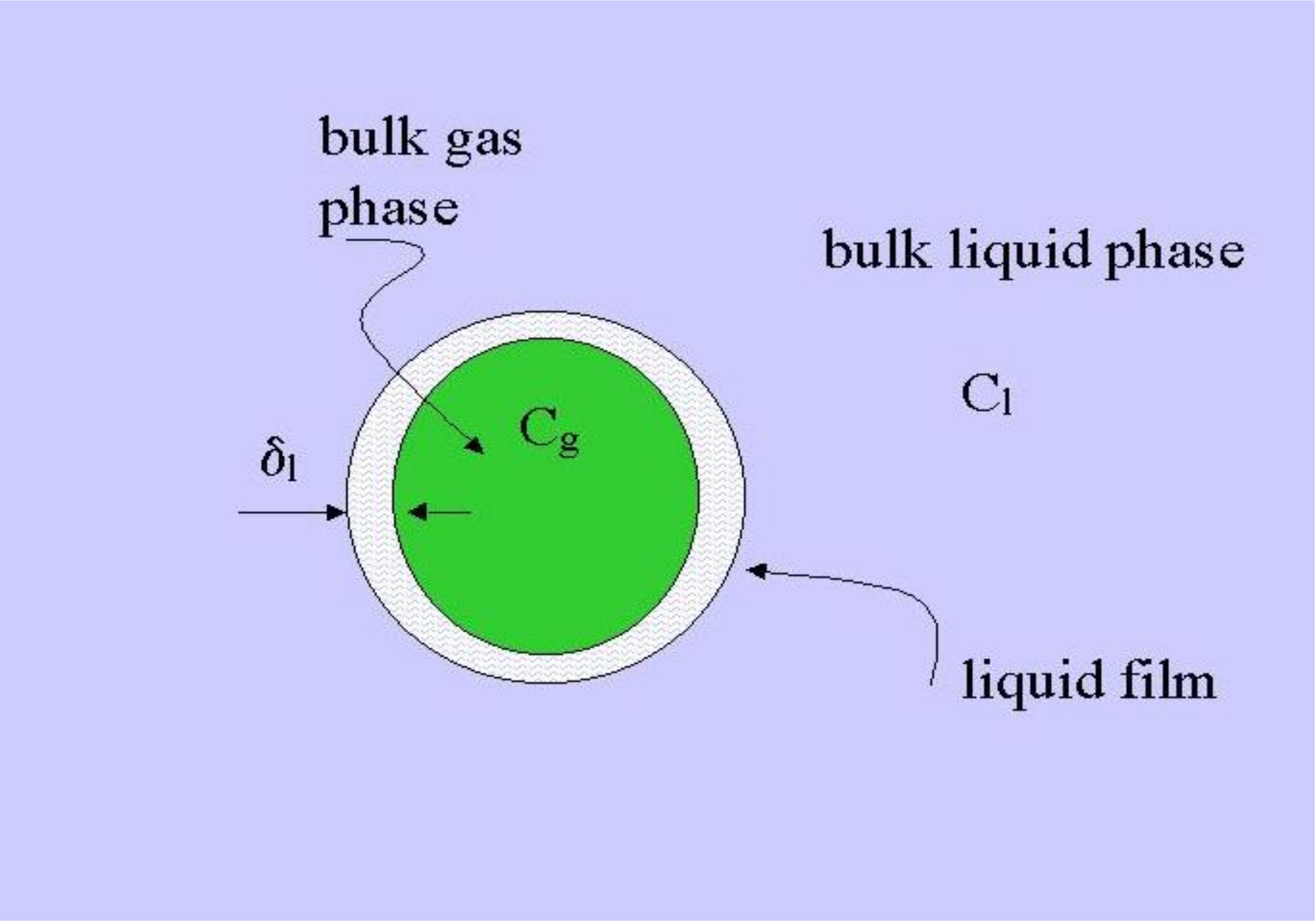
Ref: ceeserver.cee.cornell.edu

Aeration

Aeration or transfer of air or oxygen to water. Bubble injection is a common method.

For the case of O_2 transfer to water consider each bubble to consist of completely mixed bulk gas phase (inside the bubble) plus a stagnant liquid film. (the stagnant air film may exist but for O_2 transfer control is usually in the liquid film. Remember O_2 is sparingluy soluble).

For a single bubble:



$$J = \frac{D_l}{\delta_l}\left(C_l^* - C_l\right)$$

$$C_l^* = \frac{C_g}{H_c}$$

For the case of many bubbles with total surface area = A (in a unit volume of liquid in which they are suspended), total flux per unit volume of liquid is given by:

$$J_{total} = J \times A$$

$$\frac{\text{mol}}{\text{sec}} = \frac{\text{mol}}{\text{cm}^2 \cdot \text{sec}} \times \text{cm}^2$$

$$J_{total} = A \cdot K_l \left(C_l^* - C_l \right)$$

If the liquid film is controlling:

$$k_l = \frac{D_l}{\delta} \approx K_l$$

If the liquid bulk phase concentration is not at steady-state, then:

$$\frac{dC_l}{dt} = \frac{A}{V} \cdot J = \frac{A}{V} \cdot K_l \left\{ C_l^* - C_l \right\}$$

$$\frac{mol}{L^3 \times sec} = \frac{L^2}{L^3} \times \frac{mol}{L^2 \cdot sec}$$

V is the volume of the liquid phase.

Further, we can then define:

$$K_l a = \frac{A}{V} K_l$$ Volumetric mass transfer coefficient

$K_l a$ is a lumped parameter which takes into account bubble size, temperature (through its effect on diffusion), turbulence (through its effect on film thickness or surface renewal rate). It's a handy engineering coefficient. Note $K_l a$ has units 1/time.

Temperature corrections for $K_l a$ are generally made using the expression:

$$K_l a_T = K_l a_{20^o C} \theta^{(T - 20^o C)}$$

$$\theta = 1.024$$

Turbulence levels affects the bubble size and the liquid film thickness. As turbulence increases film thickness decreases and bubble size decreases. Both result in increases in K_la. As bubble size decreases K_la increases up to a certain point where the bubble rise velocity increases with bubble size. As the rise velocity increases the film thickness decreases and K_la again increases. With all these factors taken into account, it turns out that the optimum bubble size is about $r = 1.5$ mm.

Another important factor affecting $K_l a$ is the concentration of surfactants in the liquid phase. This is of particular concern when we deal with wastewaters. Surfactant effects are often taken into account by defining :

$$\alpha = \frac{K_l a(\text{wastewater})}{K_l a(\text{clean water})}$$

$$0.2 < \alpha < 1$$

In addition, since the solubility of gases in wastewater is affected by the TDS, the following term is also defined to adjust for solubility.

$$\beta = \frac{C_l^*(\text{wastewater})}{C_l^*(\text{clean water})}$$

$$0.85 < \beta < 1$$

Determination of $K_l a$:

$K_l a$ is usually determined by experimental techniques such as the non-steady state procedure described here.

The time rate of change of gas concentration in the liquid phase is given by:

$$\frac{dC_l}{dt} = K_l a\left(C_l^* - C_l\right)$$

Integration yields:

$$K_l a(t) = \ln \frac{\left(C_l^* - C_0\right)}{\left(C_l^* - C_l\right)}$$

C_0 is the initial liquid bulk concentration at $t = 0$.

$$D = \left(C_l^* - C_l\right)$$

and:

$$D_0 = \left(C_l^* - C_0\right)$$

then:

$$\ln \frac{D}{D_0} = -K_l a(t)$$

A plot of ln D/D_0 versus time should yield a straight line with slope equal to $-K_l a$.

Aeration Systems

Diffused Air:

Focus for the moment on oxygen transfer since it is a common and important process in wastewater treatment. A common way to aerate water is via diffused air. In these systems air is pumped through some sort of diffuser to generate small bubbles. These diffusers are porous ceramics, cloth or plastic.

Usually gas (air or oxygen) is injected into the bottom of the aeration tank and is allowed to rise to the surface in an open tank. Oxygen transfer from the bubble varies as the bubble changes size, velocity, oxygen content and hydrostatic pressure (depth changes). These factors have to be considered in calculating overall transfer rate of oxygen to water.