SAMBA ITT6

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CASE

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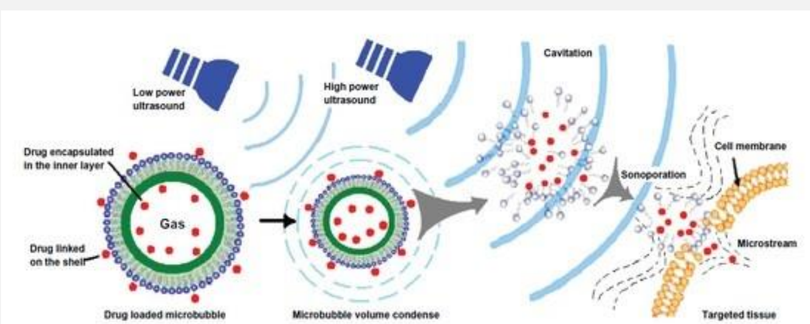
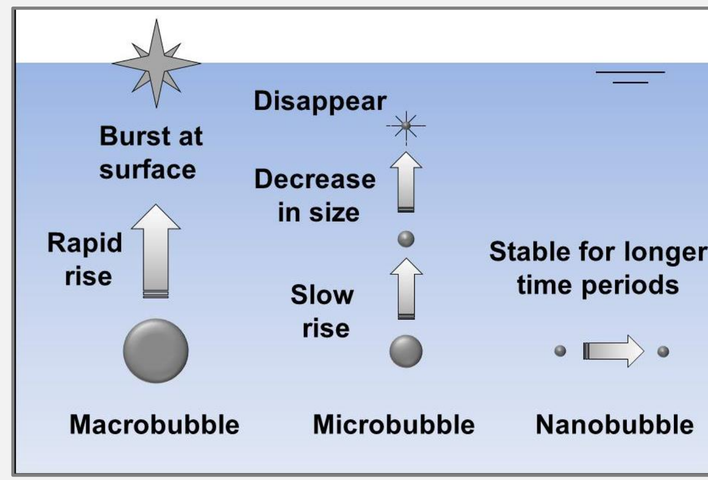
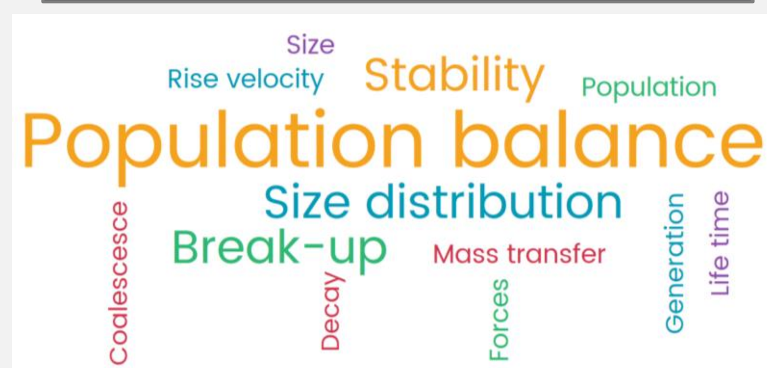
Growth and Break-up of Microbubbles

Gas-Liquid



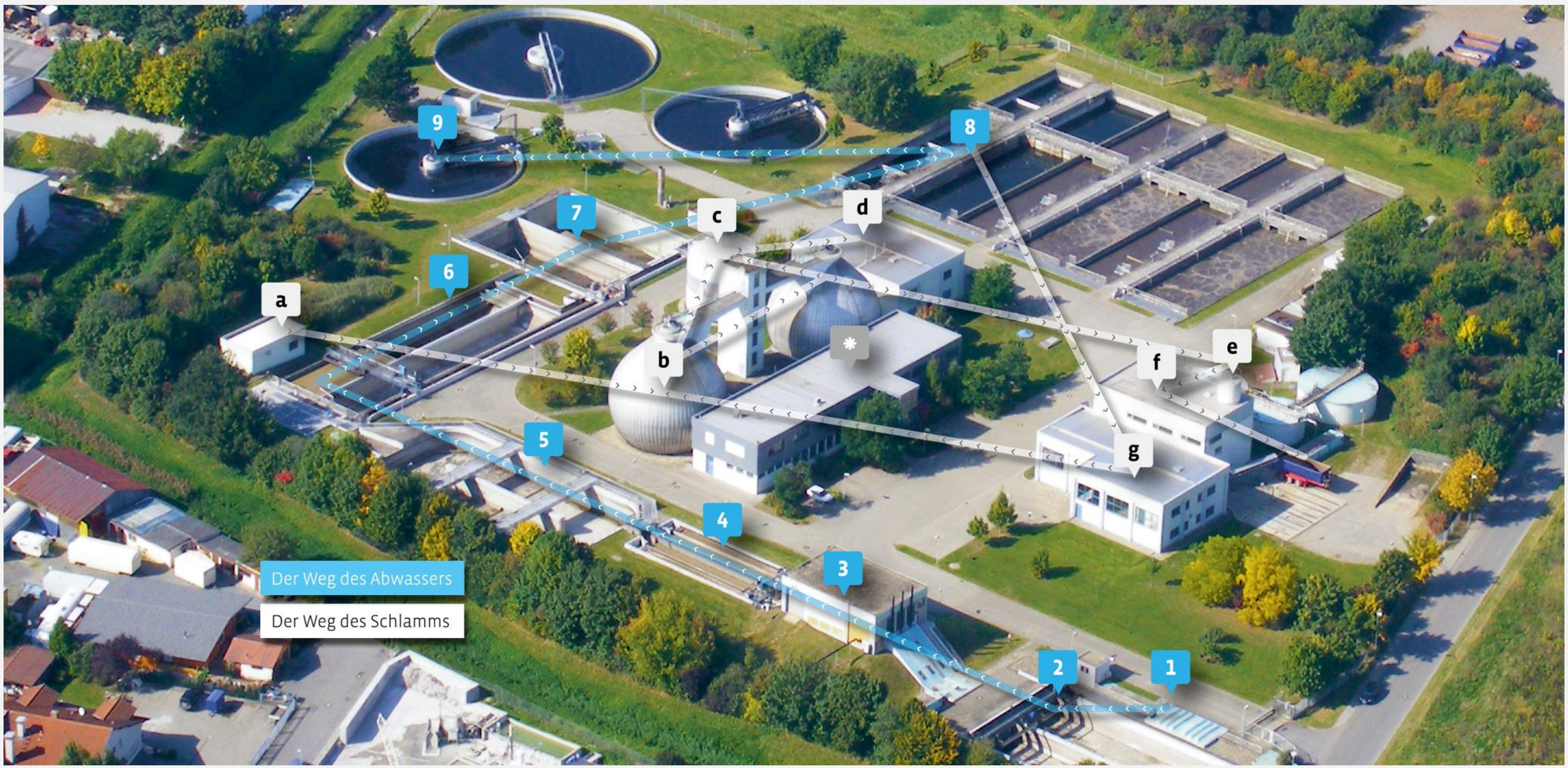
Size of Bubbles



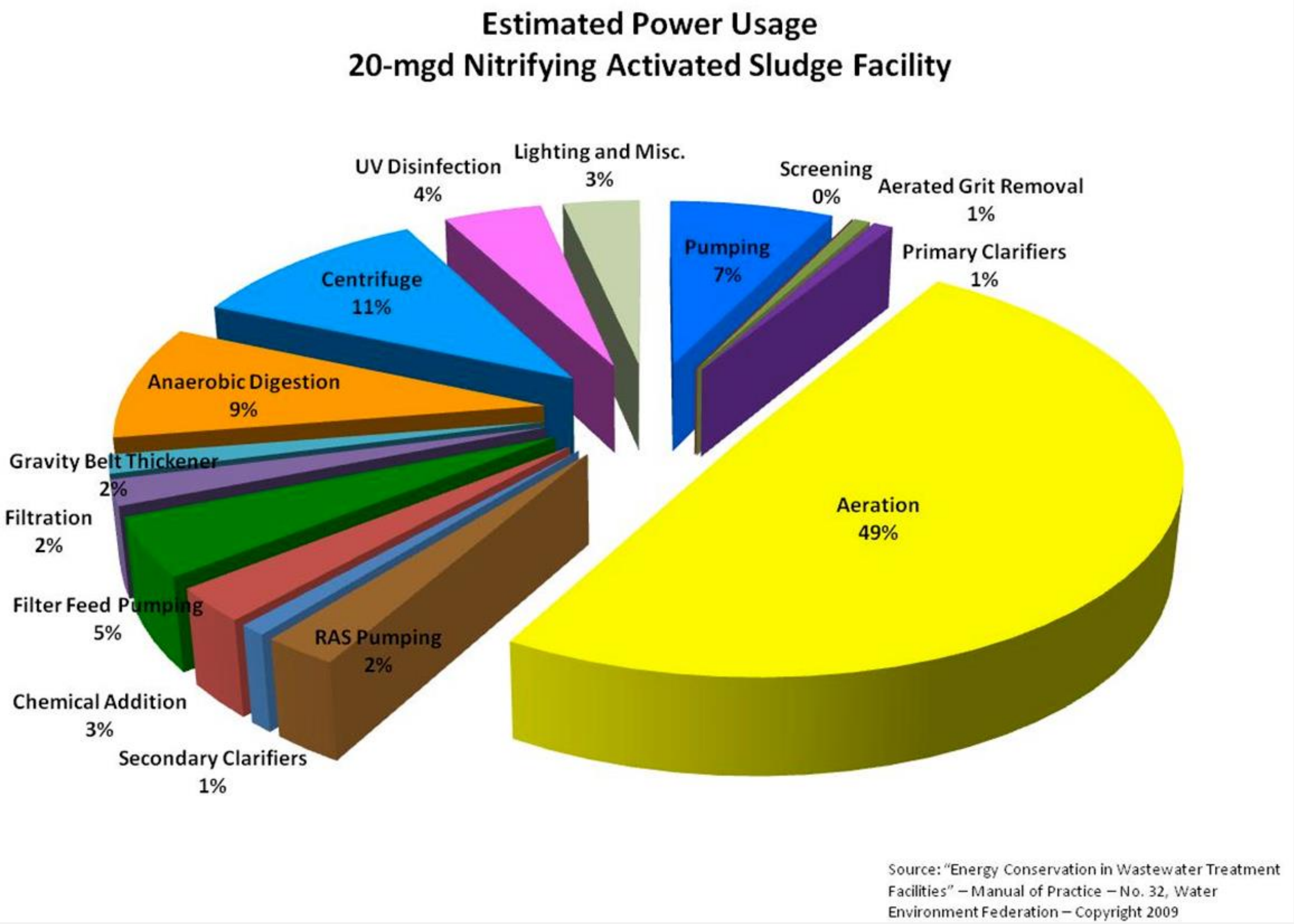


Applications

Modern wastewater treatment plant of a medium sized city
(Example Bensheim / Germany population 100.000)



Cost breakdown for wastewater treatment



Why aeration is needed for wastewater treatment?

Wastewater aeration

Wastewater contains carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products.

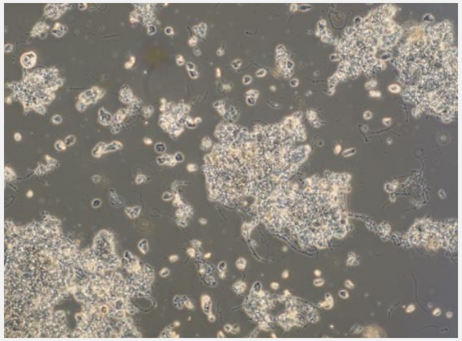
In the activated sludge process and other biological treatment processes beneficial microorganisms degrade this organic matter.

Stoichiometric equations for oxygen demand of wastewater

$$C_nH_aO_bN_c + \left(n + \frac{a}{4} - \frac{b}{2} - \frac{3}{4}c\right) O_2 \rightarrow nCO_2 + \left(\frac{a}{2} - \frac{3}{2}c\right) H_2O + cNH_3$$

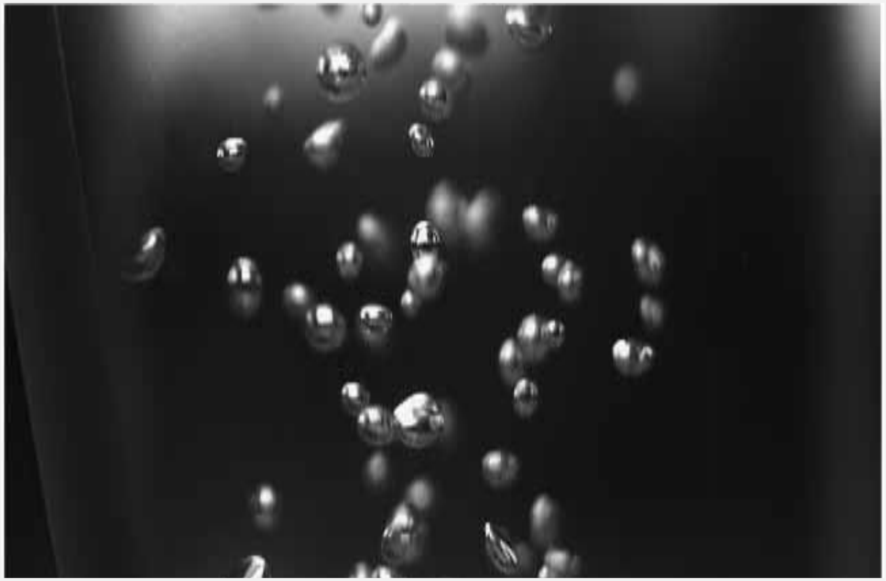
$$NH_3 + 2O_2 \rightarrow NO_3^- + H_3O^+$$

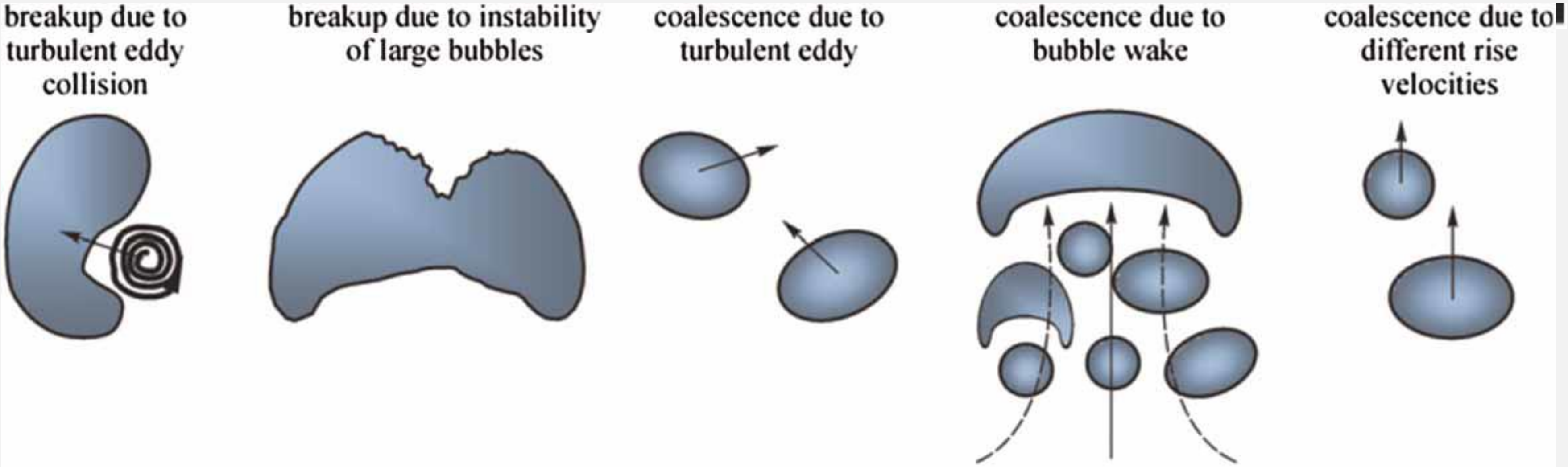
‘Natural’ aeration is not efficient enough.



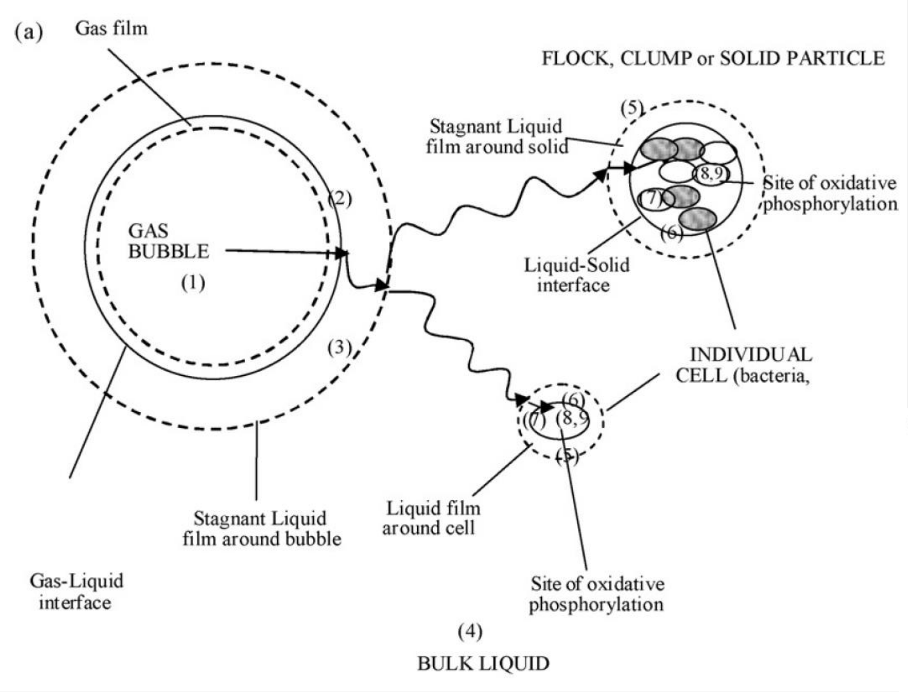
Activated sludge microbial community

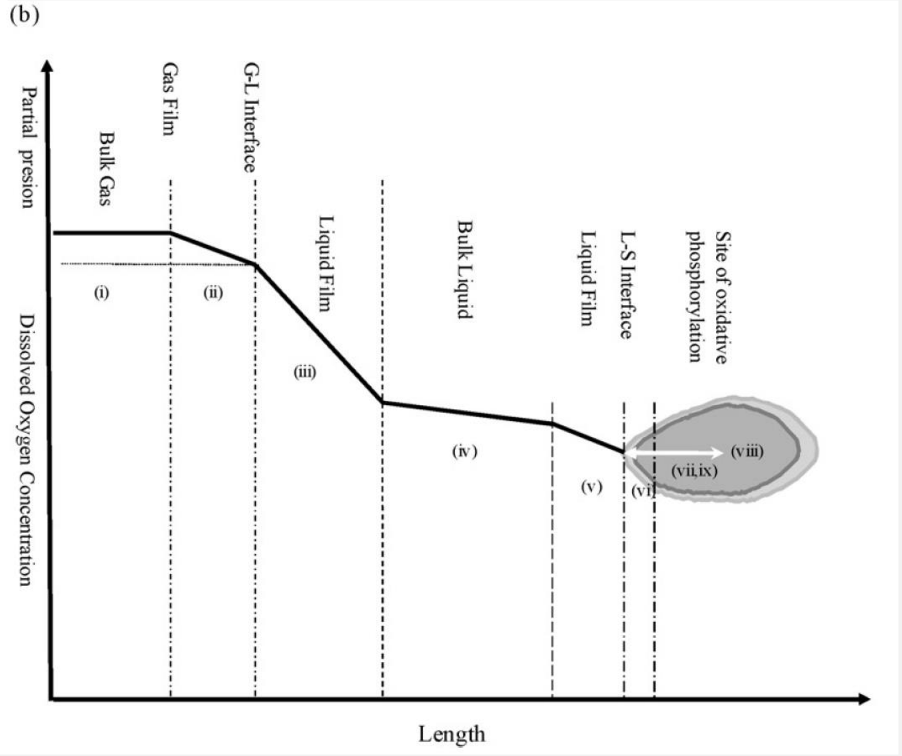
Traditional aeration equipment and fine bubble behaviour





Transport Mechanisms



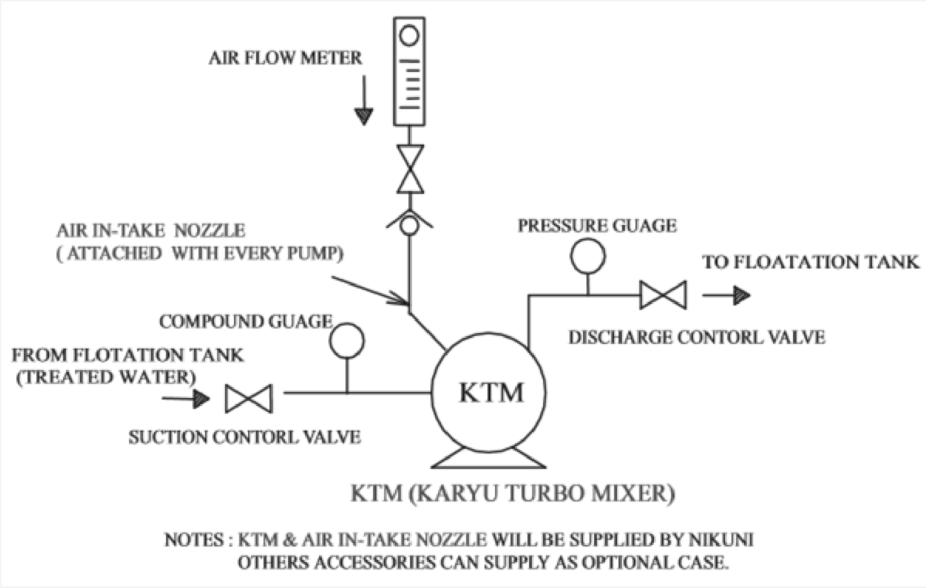


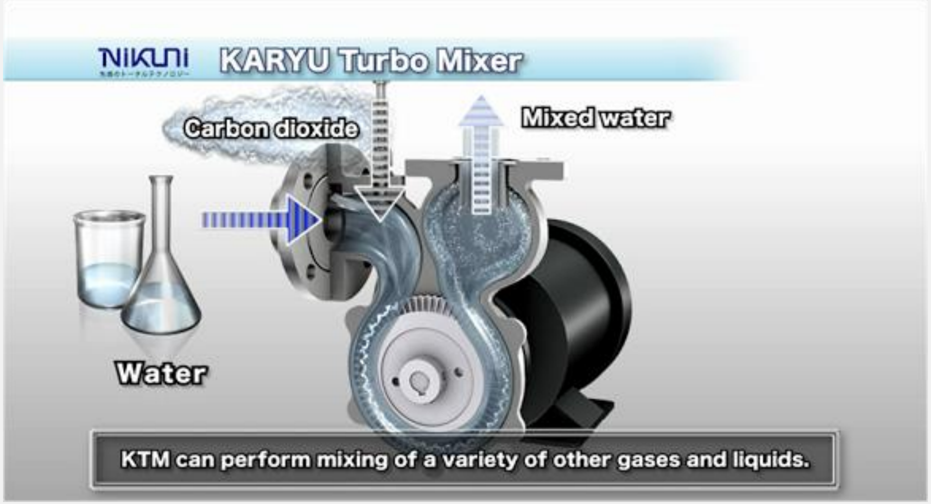
Garcia-Ochoa et al. (2010) *Biochemical Engineering Journal* **49** pp. 289–307

Hypothesis

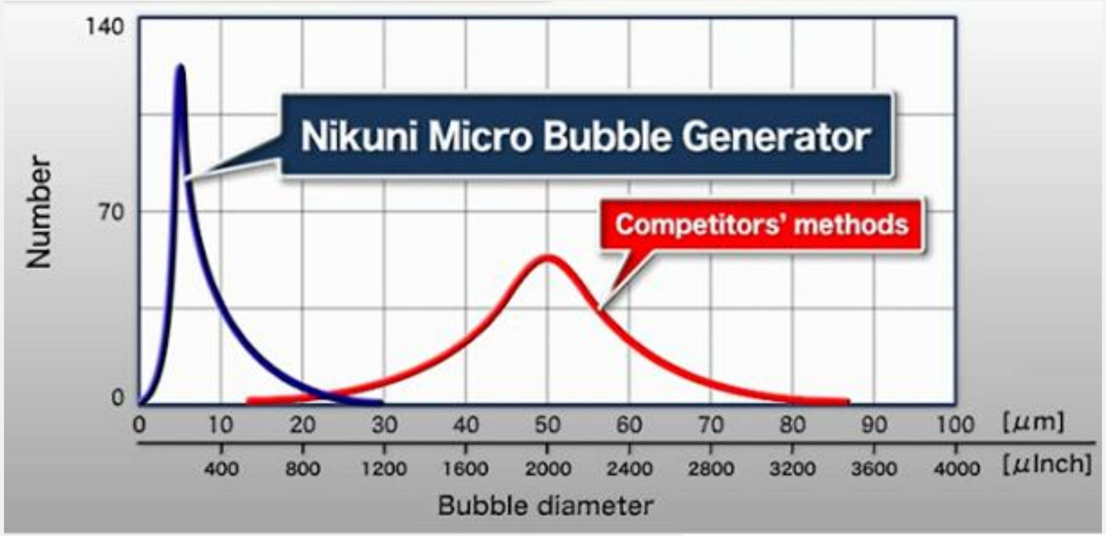
- Small scale bubbles will significantly improve the mass transfer of oxygen from gas to liquid phase
- The technology can be retrofitted to existing wastewater treatment plants
- The potential energy savings from using small scale bubbles in large scale waste water treatment is significant
- Smoother process control can be achieved due to improved mixing conditions

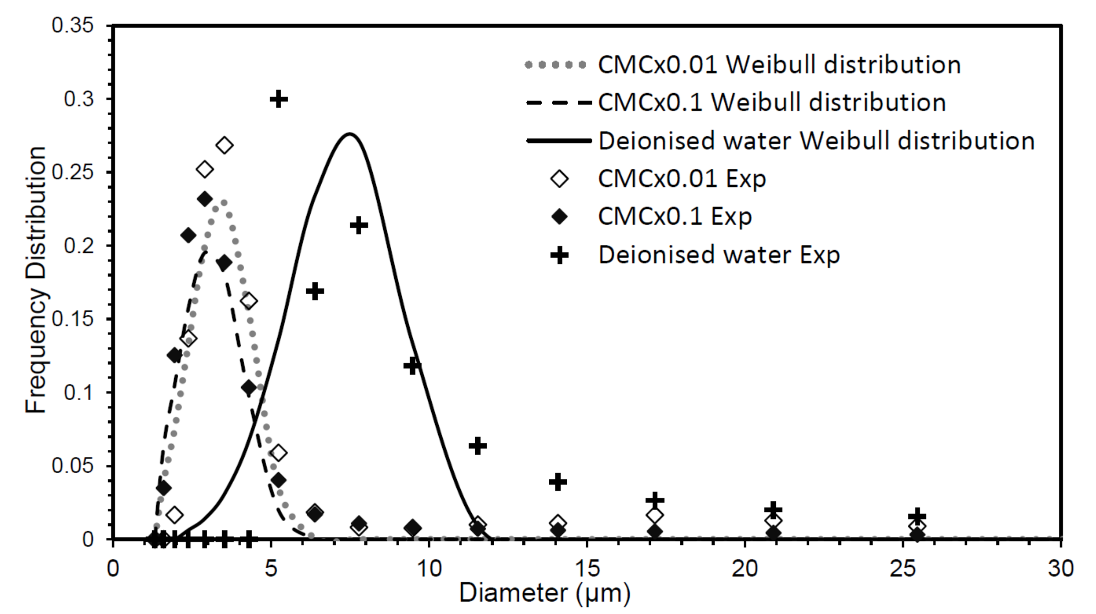
Microbubble Generation



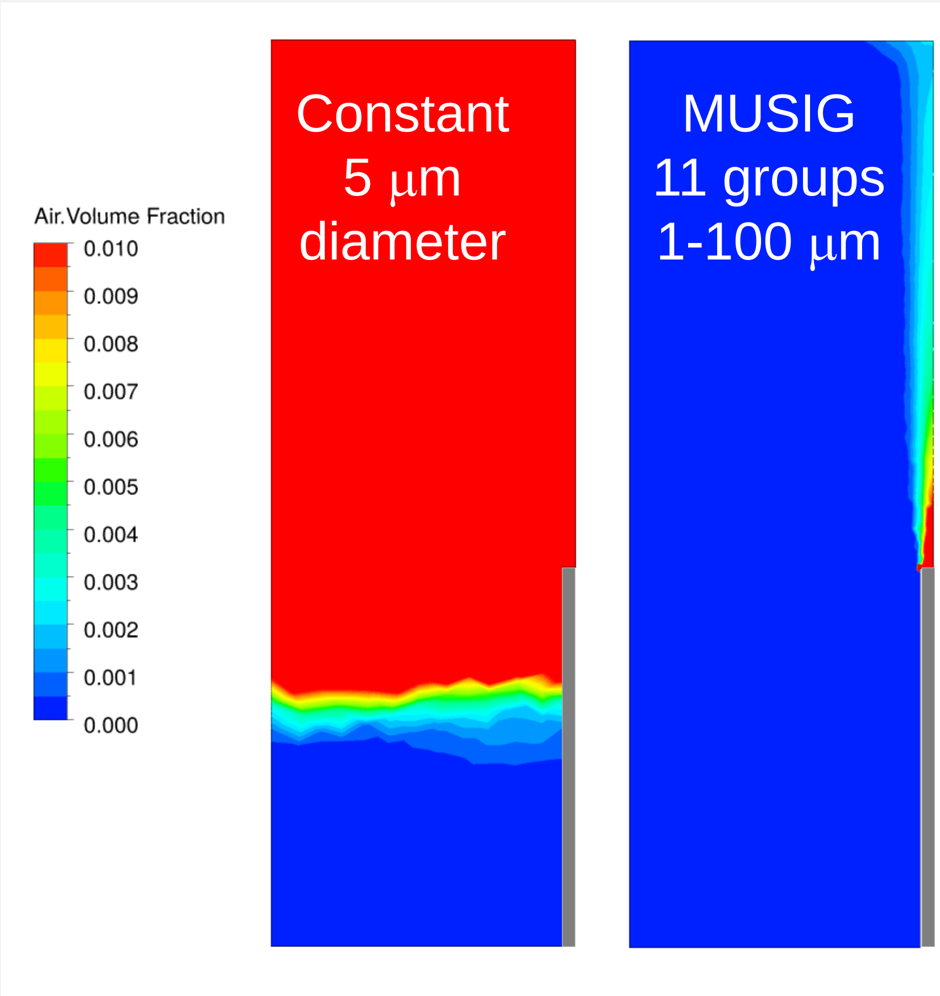


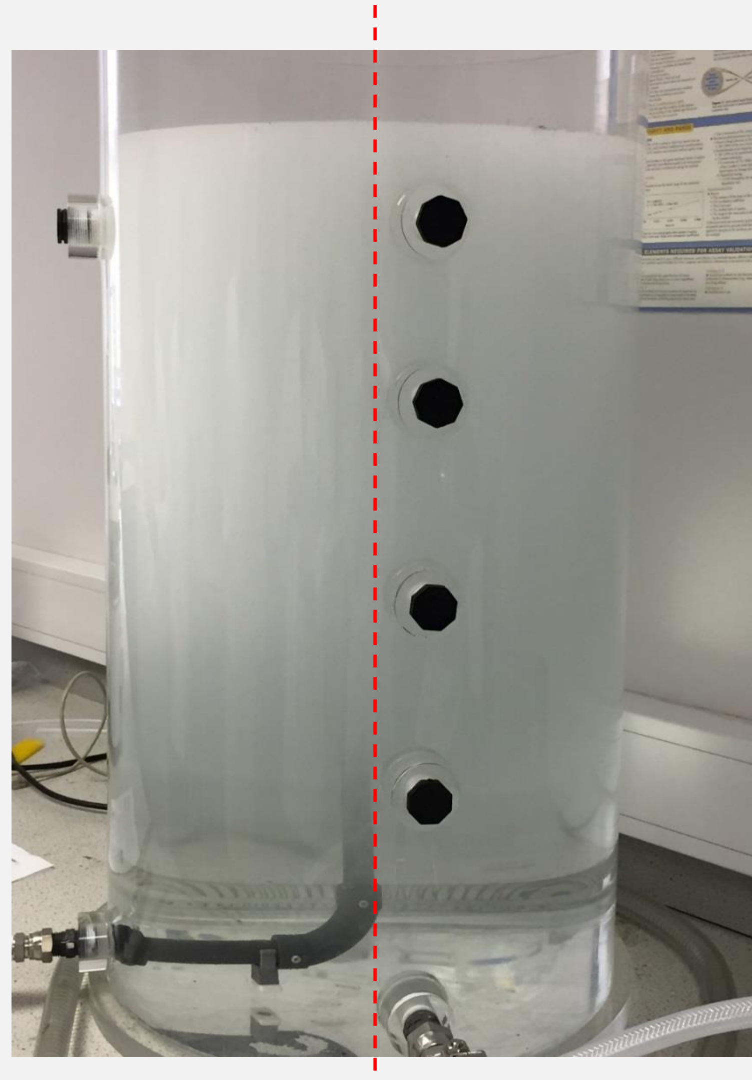
MB Particle Size Distribution



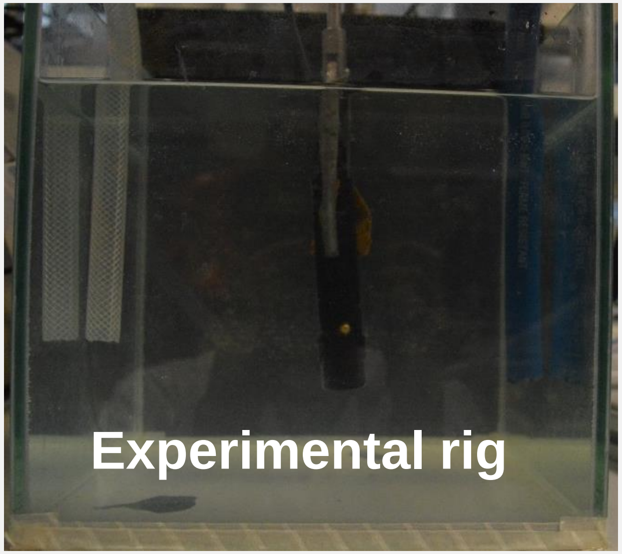


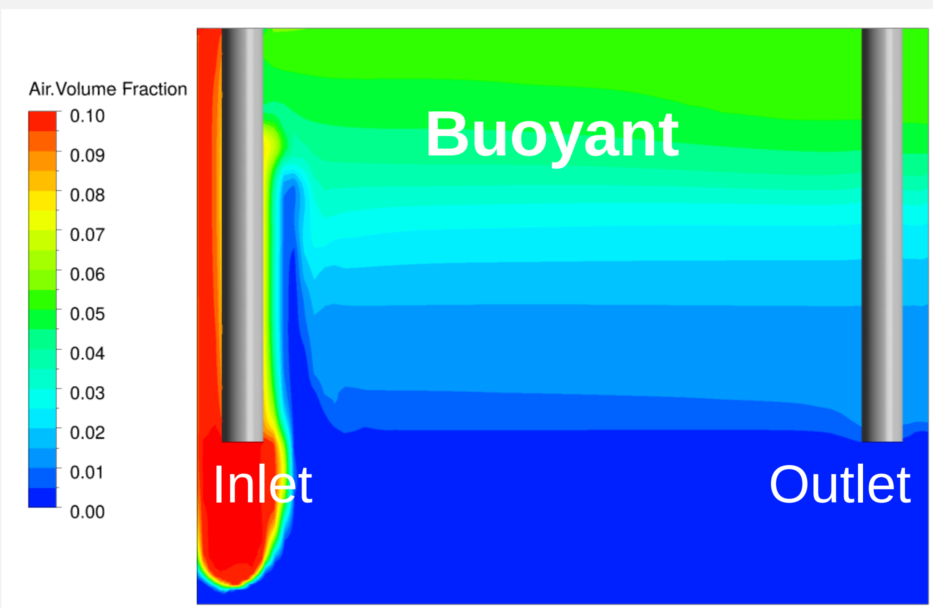
Computational Modelling

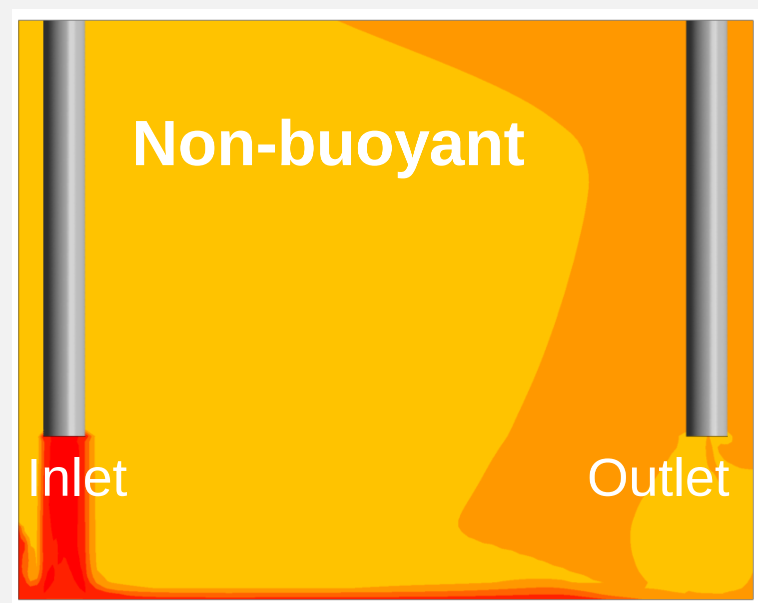




Computational vs. Experimental

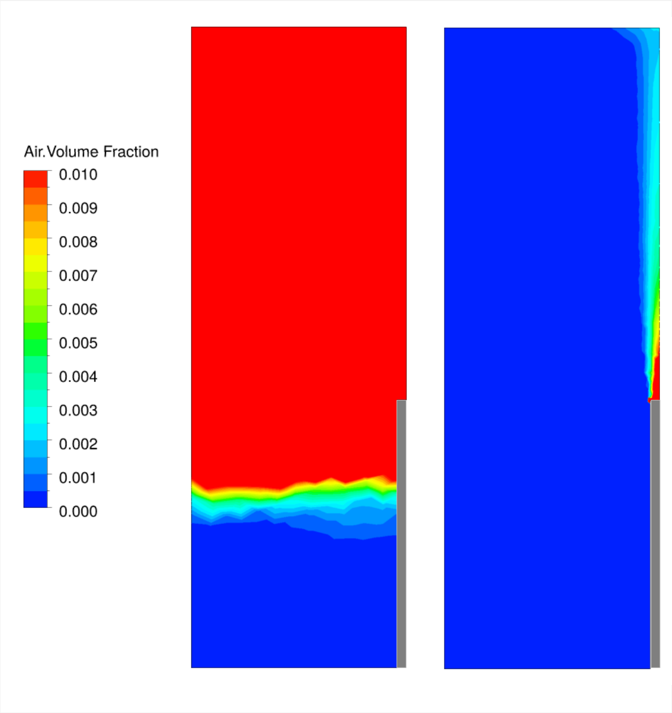




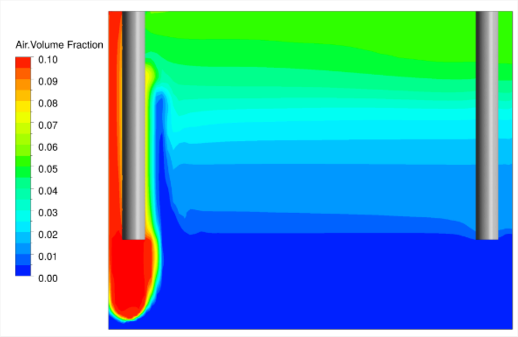


Limitations

Key Questions to Answer



- Inaccuracy of drag model – affects the rise velocity and bubble coalescence
- Buoyancy effect is less significant for MBs



Population Balance Method

Mass conservation:

$$\frac{\partial(\rho_i\alpha_i)}{\partial t} + \nabla(\rho_i\alpha_i\vec{u}_i) = 0$$

Momentum conservation:

$$\frac{\partial(\rho_i\alpha_i\vec{u}_i)}{\partial t} + \nabla(\rho_i\alpha_i\vec{u}_i\vec{u}_i) = -\alpha_i\nabla p + \nabla\left[\alpha_i\mu_i\left(\nabla\vec{u}_i + (\vec{u}_i)^T\right)\right] + F_{lg} + \alpha_i\rho_i\vec{g}$$

Multiple discrete bubble size groups:

$$\frac{\partial n_i}{\partial t} + \nabla\left(\vec{u}_g n_i\right) = \left(\sum_j R_j\right)_i$$

$$\left(\sum_j R_j\right)_i = (P_C + P_B - D_C - D_B)$$

Break-up rate:

$P_B = \sum_{j+1}^{N} \Omega\left(v_j : v_i\right) v_j$ $D_B = \Omega_i n_i$ with $D_B = \sum_{k=1}^{N} \Omega_{ik}$

Coalescence rate:

$P_C = \frac{1}{2}\sum_{k=1}^{1}\sum_{l=1}^{1} \eta_{jki}\chi_{ij}n_i n_j$ $D_C = \sum_{j=1}^{N} \chi_{ij}n_i n_j$

Garcia-Ochoa et al. (2009) *Ocean Engineering* **36** pp. 863–872