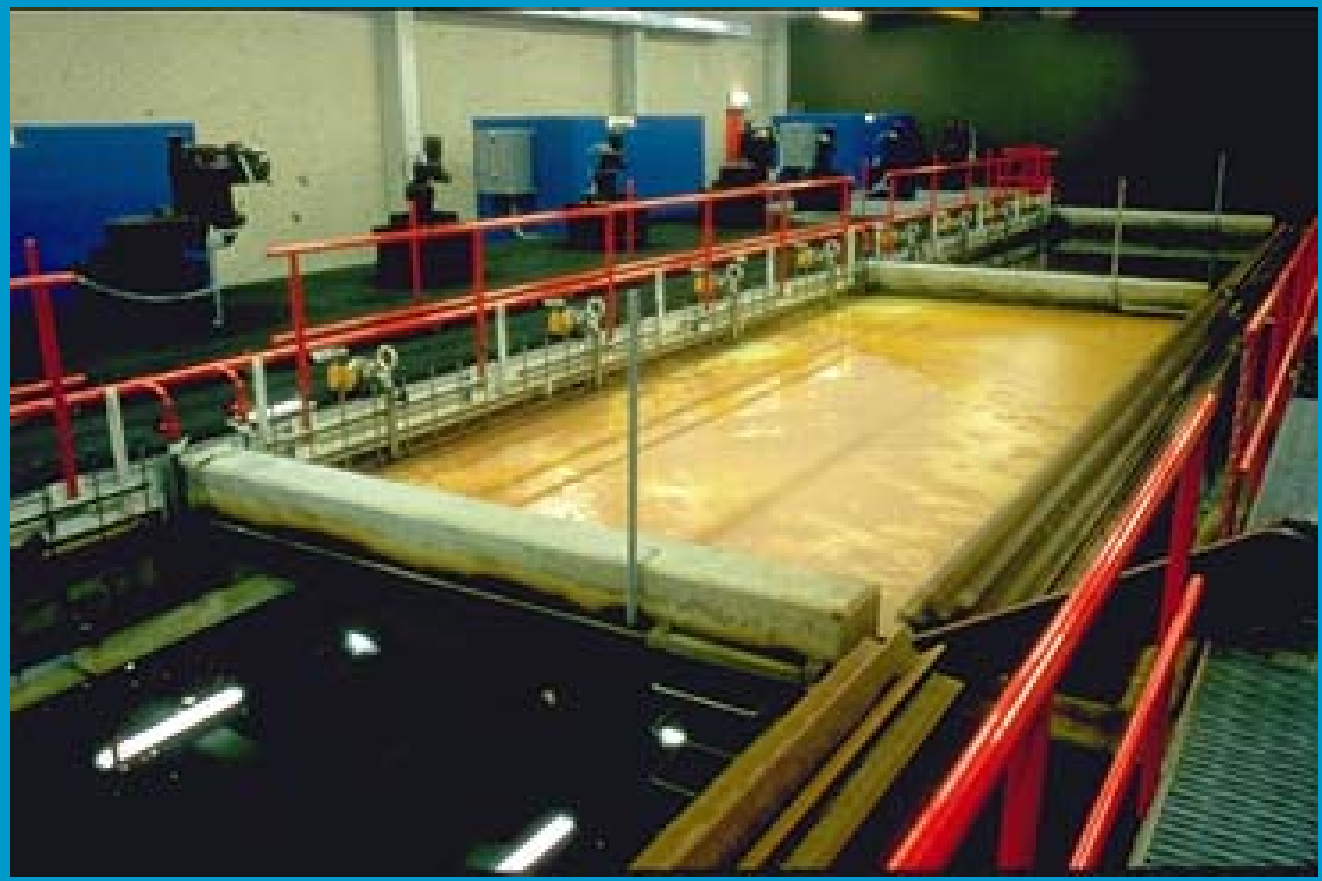
Drinking Water 1

Flotation



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Room 5.99

Saturday, 06 October 2007

TU Delft

Delft University of Technology

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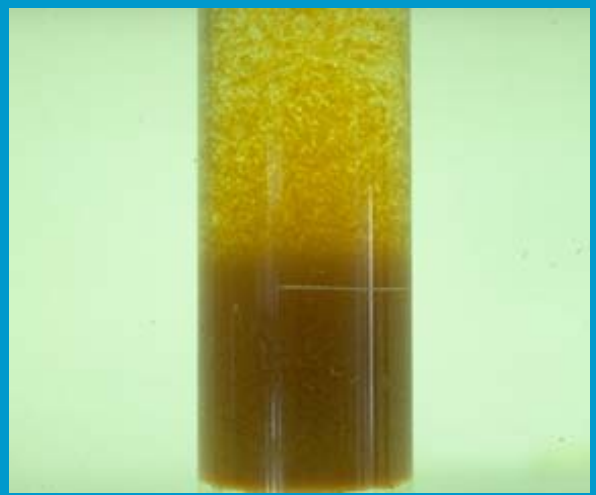
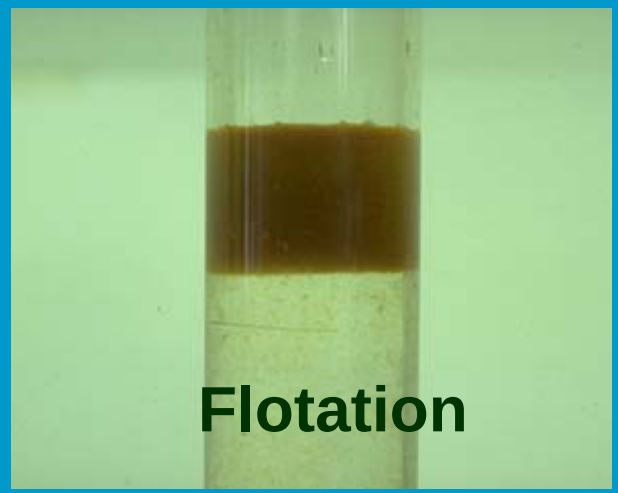
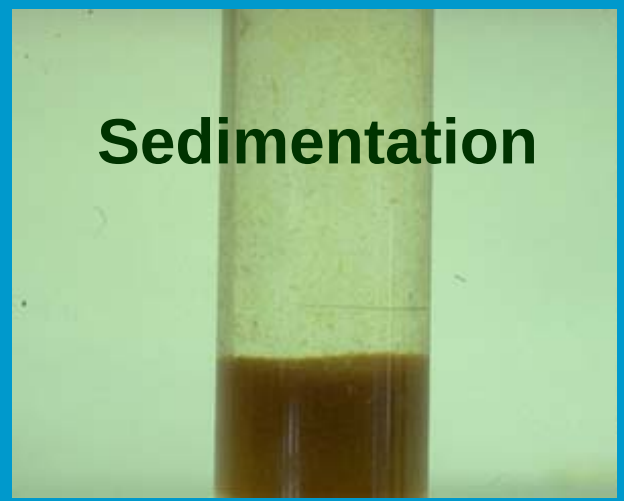
Introduction

Sedimentation or flotation



Flocculation





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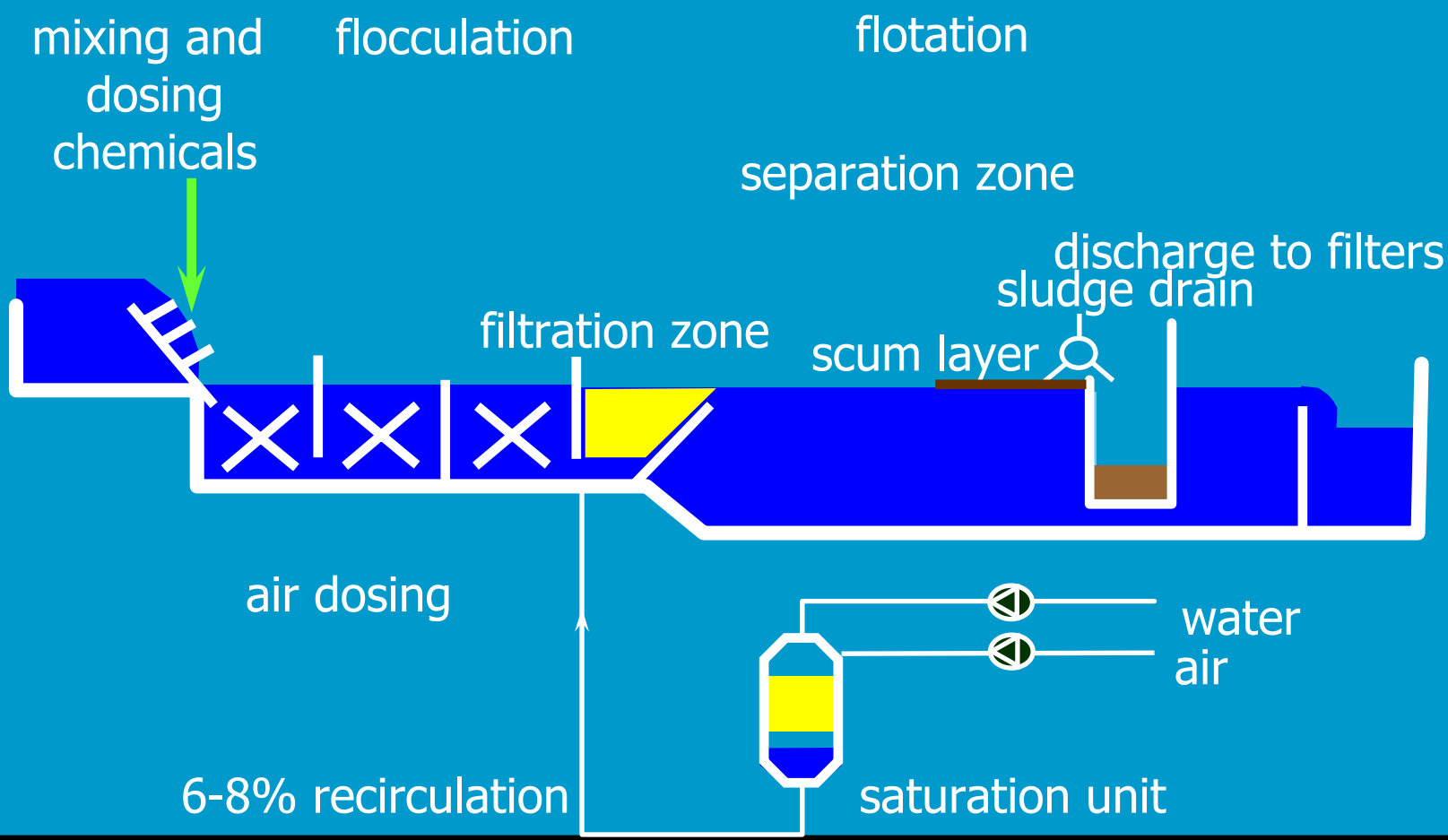
Introduction

Schematic representation of flotation



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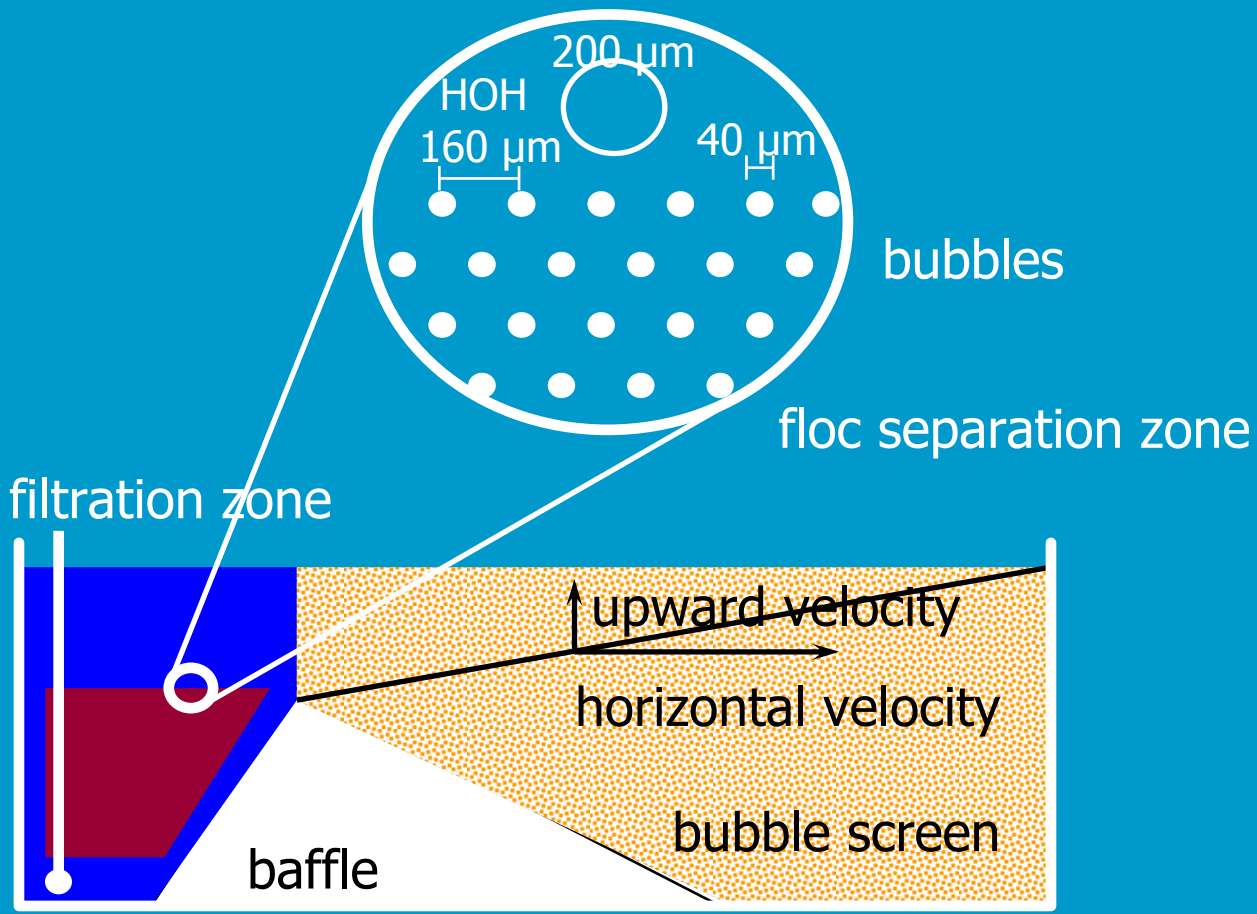
Introduction

Flotation tank



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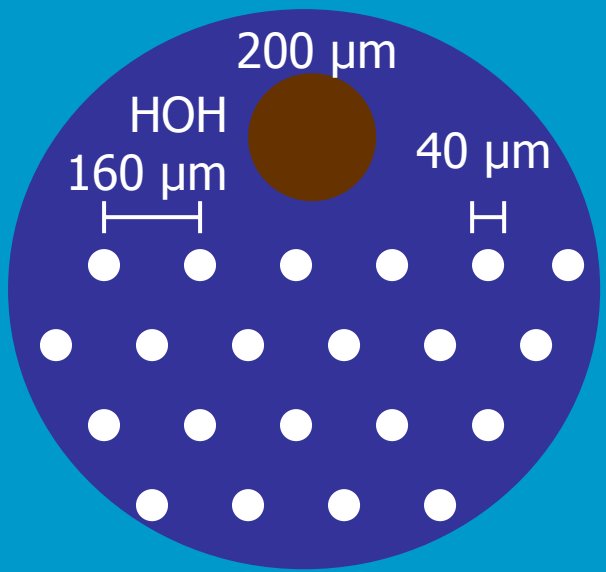
Filtration zone

Specific parameters



bubbles

diameter bubbles:	10 - 100 µm
air dosing:	5 - 10 l/m^3
bubble density:	(1.5 - 3.0)·10^{11} m^{-3}
bubble distance:	110 - 148 µm
diameter flocs:	100 - 200 µm
density flocs:	1003 - 1006 kg/m^3
particle concentration:	10 - 25 g/m^3
particle density:	(2.5 - 19) ·10^7 m^{-3}
particle distance:	3600 - 7300 µm

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Filtration zone

Saturation concentration

$$c_s = k_D \cdot c_g = k_D \cdot \frac{MW \cdot P}{R \cdot T}$$

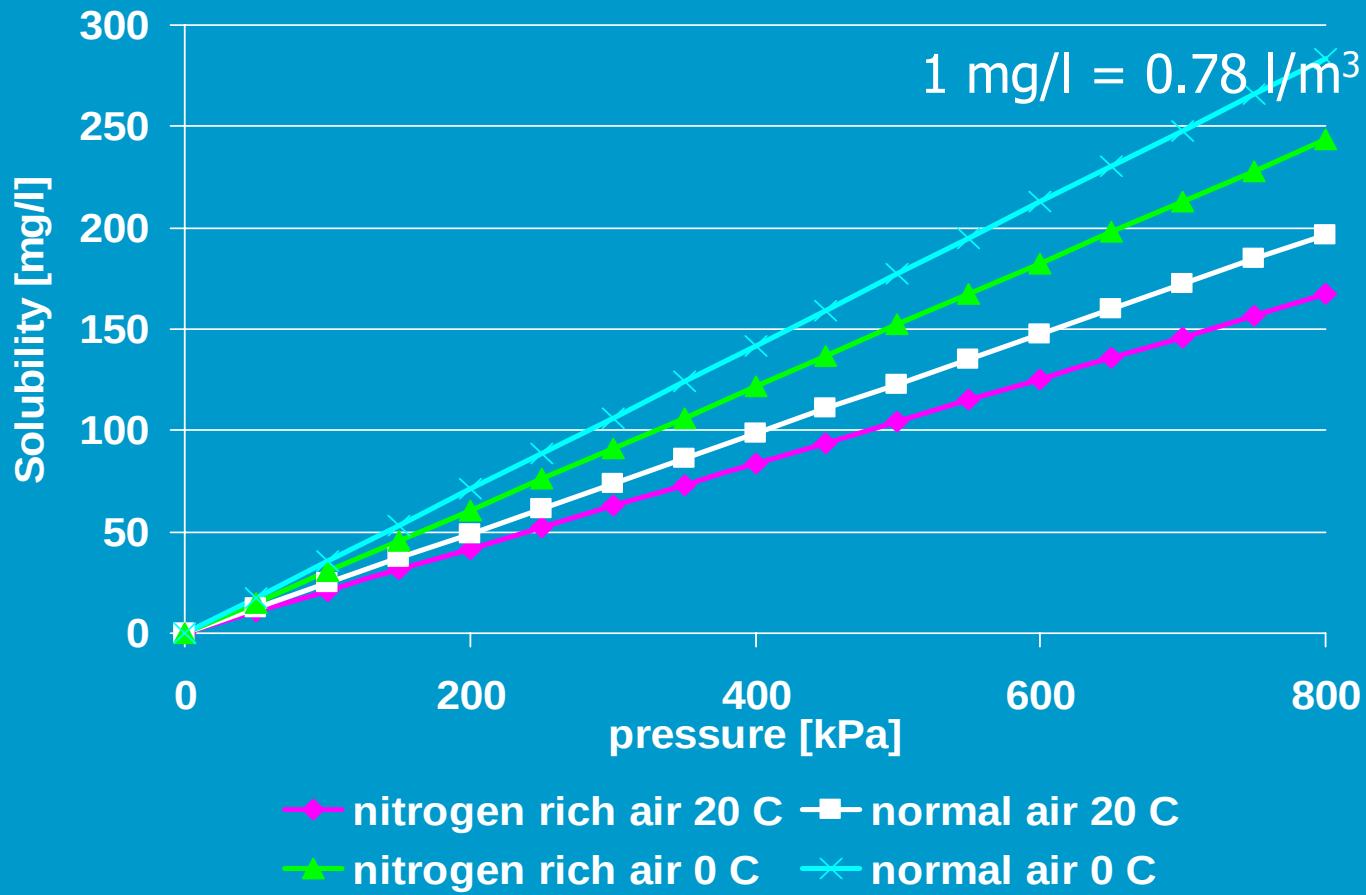
k_D = distribution coefficient [-]
c_s = saturation concentration [mg/l]
c_g = gas concentration [mg/l]
MW = molecular weight [g/mol]
P = pressure [bar]
R = constant = 8.3143 [J/K·mol]
T = temperature [K]

composition of air: 79% N_2, 21% O_2

T [°c]	0	10	20	30
$k_{D\ air}$	0.0288	0.0234	0.0200	0.0179

Filtration zone

Relation solubility - pressure



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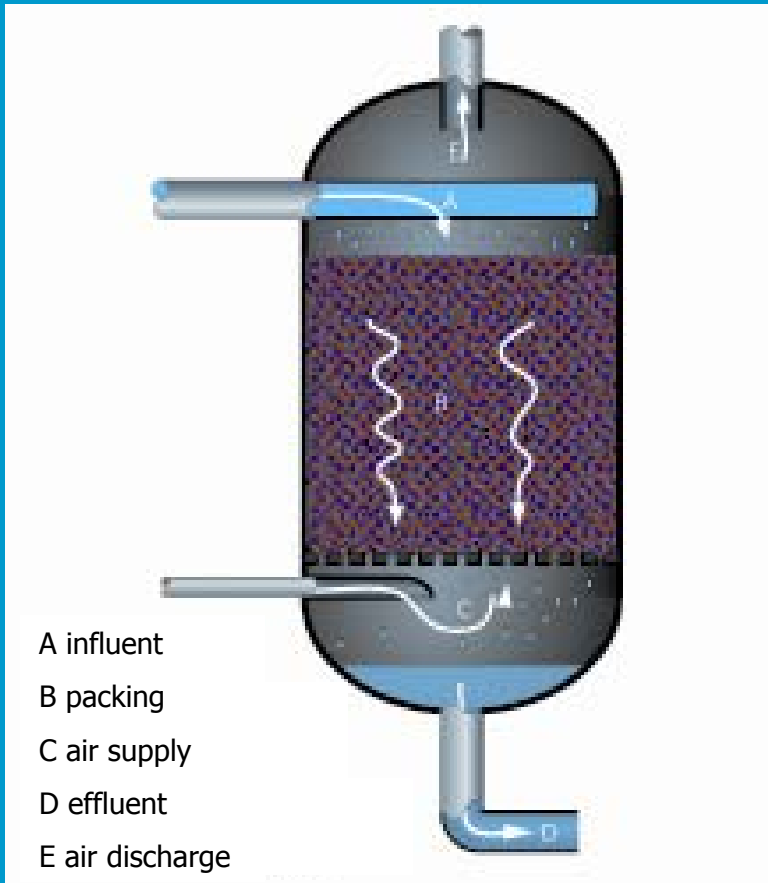
Filtration zone

Construction saturation tanks



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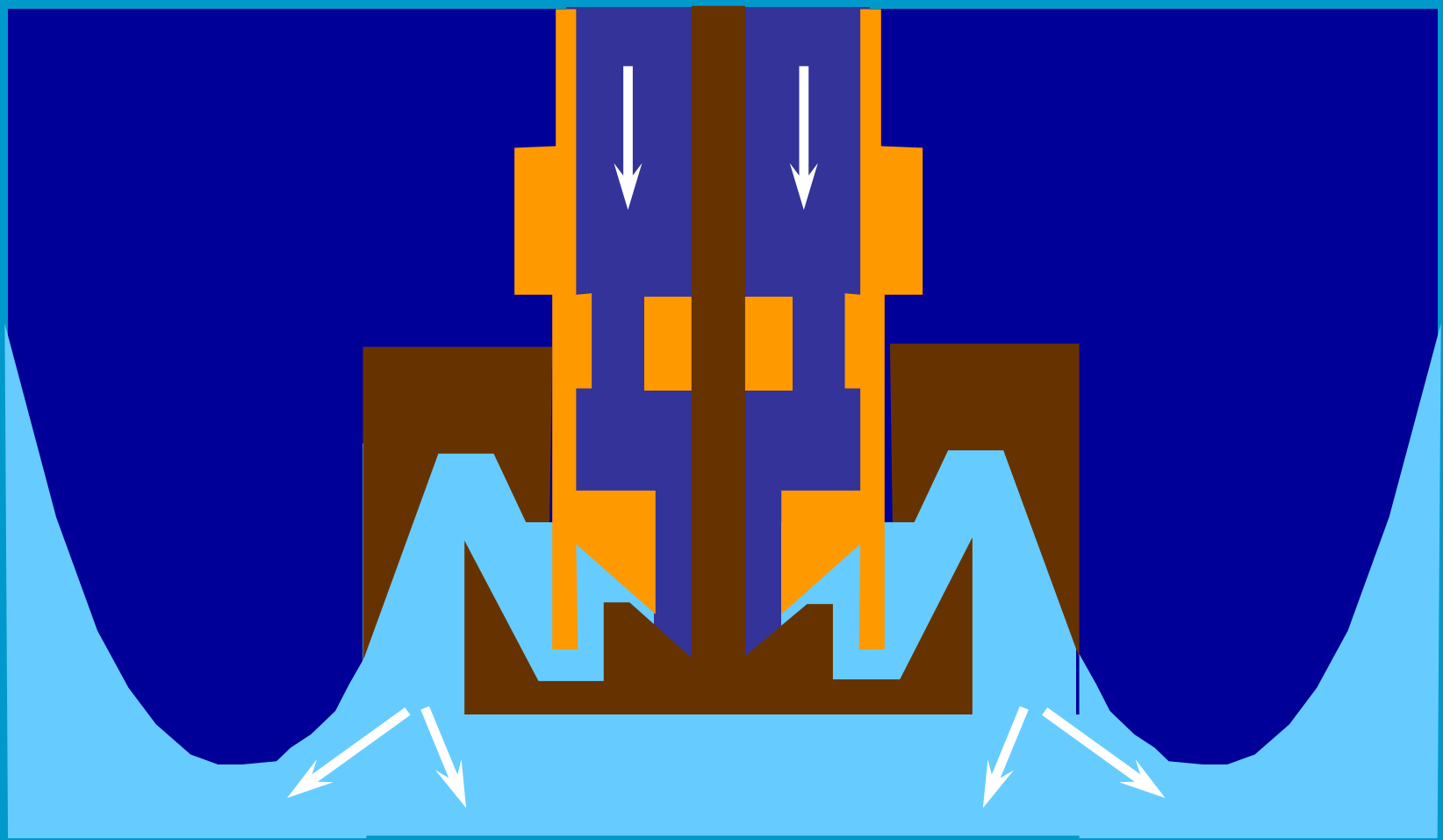
Filtration zone

Saturation vessels

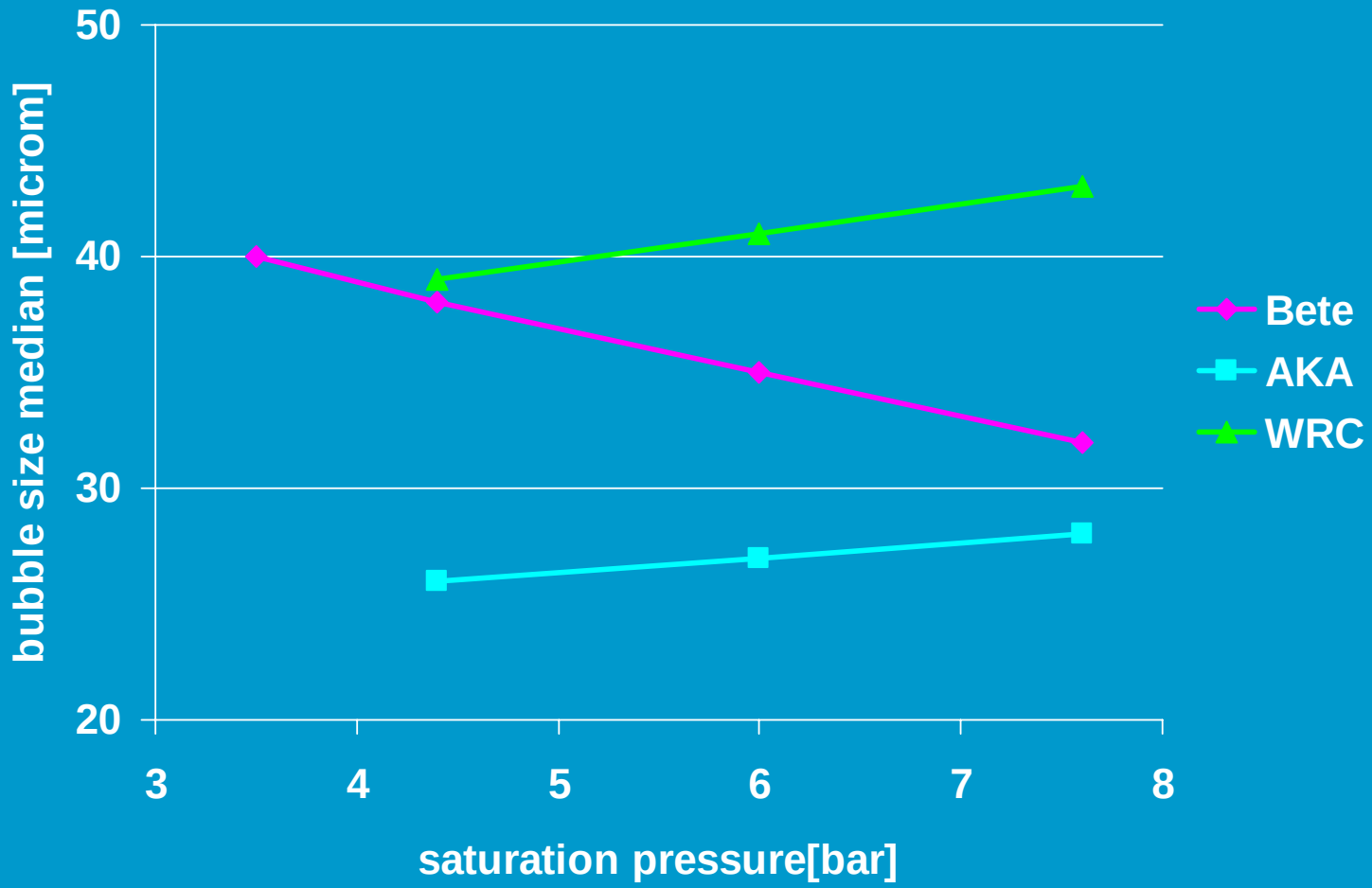
Filtration zone

Nozzle



Filtration zone

Performance nozzles



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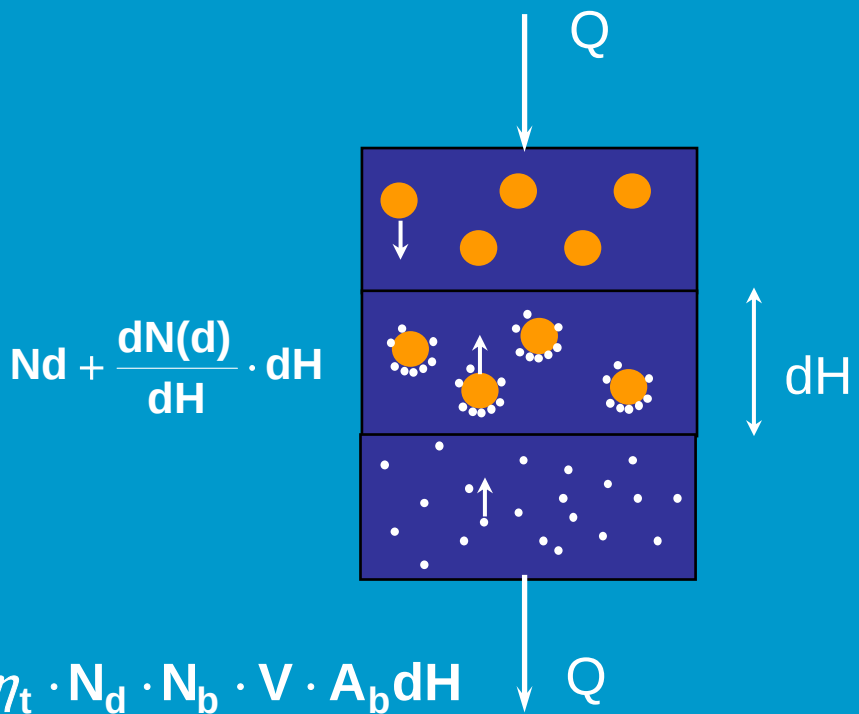
Filtration zone

Mass balance



in = out + storage

$$Q \cdot N_d dt = Q \cdot \left(N_d + \left(\frac{dN_d}{dH} \right) dH \right) dt + \alpha_{db} \cdot \eta_t \cdot N_d \cdot N_b \cdot V \cdot A_b dH$$

N_d = number of particles in bed; N_b = number of bubbles in bed
α_{db} = attachment coefficient for bubble and floc;
η_t = collision fequency

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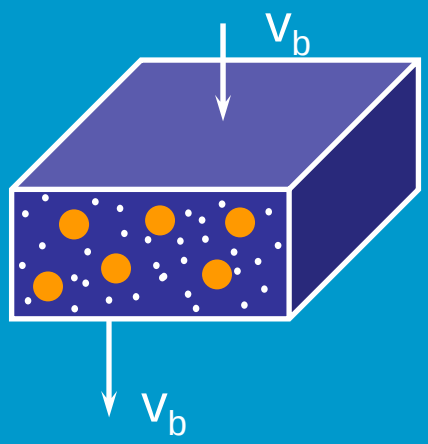
Filtration zone

Efficiency bubble filter



$$\frac{dN_d}{dH} = -\alpha_{db} \cdot \eta_t \cdot N_b \cdot N_d \cdot A_b$$

$$\frac{dN_d}{dt} = -\alpha_{db} \cdot \eta_t \cdot N_b \cdot N_d \cdot A_b \cdot v_{db}$$

$$\frac{dN_d}{N_d} = -\frac{1}{12} \cdot \frac{\alpha_{db} \cdot \eta_t \cdot d_b \cdot \phi_b \cdot g}{\mu} dt$$

$$X = 1 - \exp\left(-\frac{1}{12} \cdot \frac{\alpha_{db} \cdot \eta_t \cdot d_b \cdot \phi_b \cdot g}{\mu} \cdot \tau \right)$$

influence:

- air dosing (ϕ)
- contact time (τ)
- flow conditions (plug flow)
- temperature (μ)

Filtration zone

Collision frequency

Trajectory

Streamline

Collector = bubble

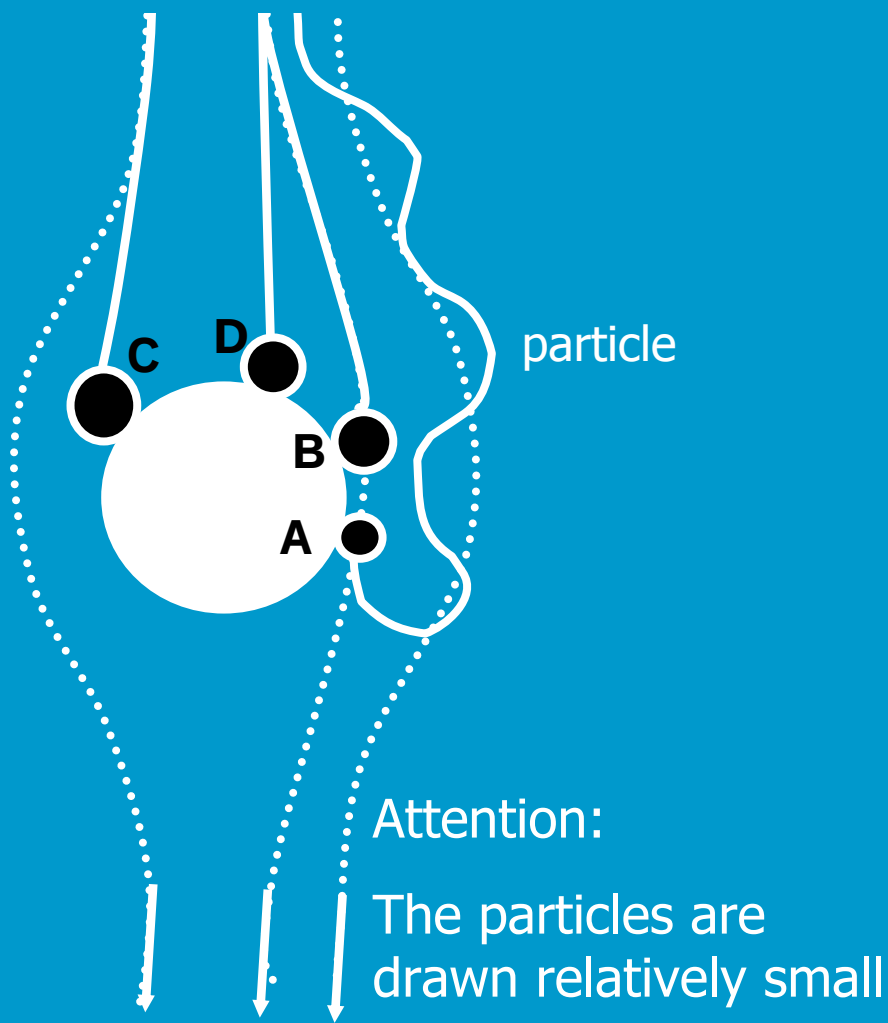
Trajectory mechanisms:

A = Diffusion

B = Interception

C = Gravity settling

D = Inertia



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Filtration zone

Transport mechanisms

$$\eta_d = 6.18 \cdot \left(\frac{k_b \cdot T}{g \cdot \rho_w}\right)^{0.66} \cdot \left(\frac{1}{d_d}\right)^{0.66} \cdot \left(\frac{1}{d_b}\right)^{2}$$

$$\eta_i = \frac{3}{2} \cdot \left(\frac{d_d}{d_b}\right)^{2}$$

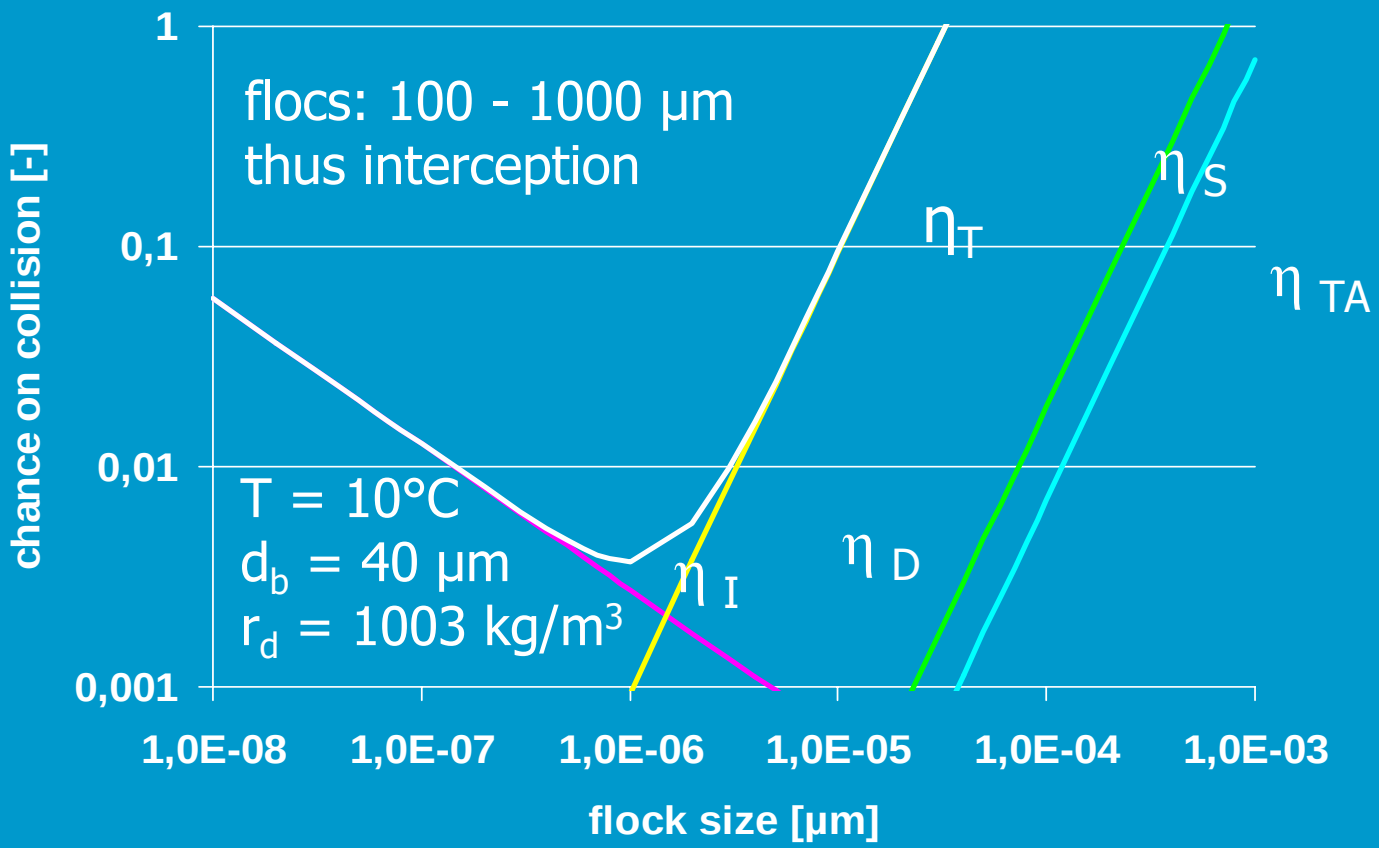
$$\eta_s = \left(\frac{\rho_d - \rho_w}{\rho_w}\right) \cdot \left(\frac{d_d}{d_b}\right)^{2}$$

$$\eta_{TA} = \frac{g \cdot \rho_d \cdot d_b \cdot {d_d}^2}{324 \cdot \nu \cdot \rho_w}$$

d_d = diameter floc [m]
d_b = diameter bubble [m]
k_b = constant of Bolzmann
= $1.38*10^{-23}$ J/K
ρ_w = 1000 kg/m^3
ρ_d = 1003 kg/m^3
ρ_b = 1.24 kg/m^3

Filtration zone

Collision frequency



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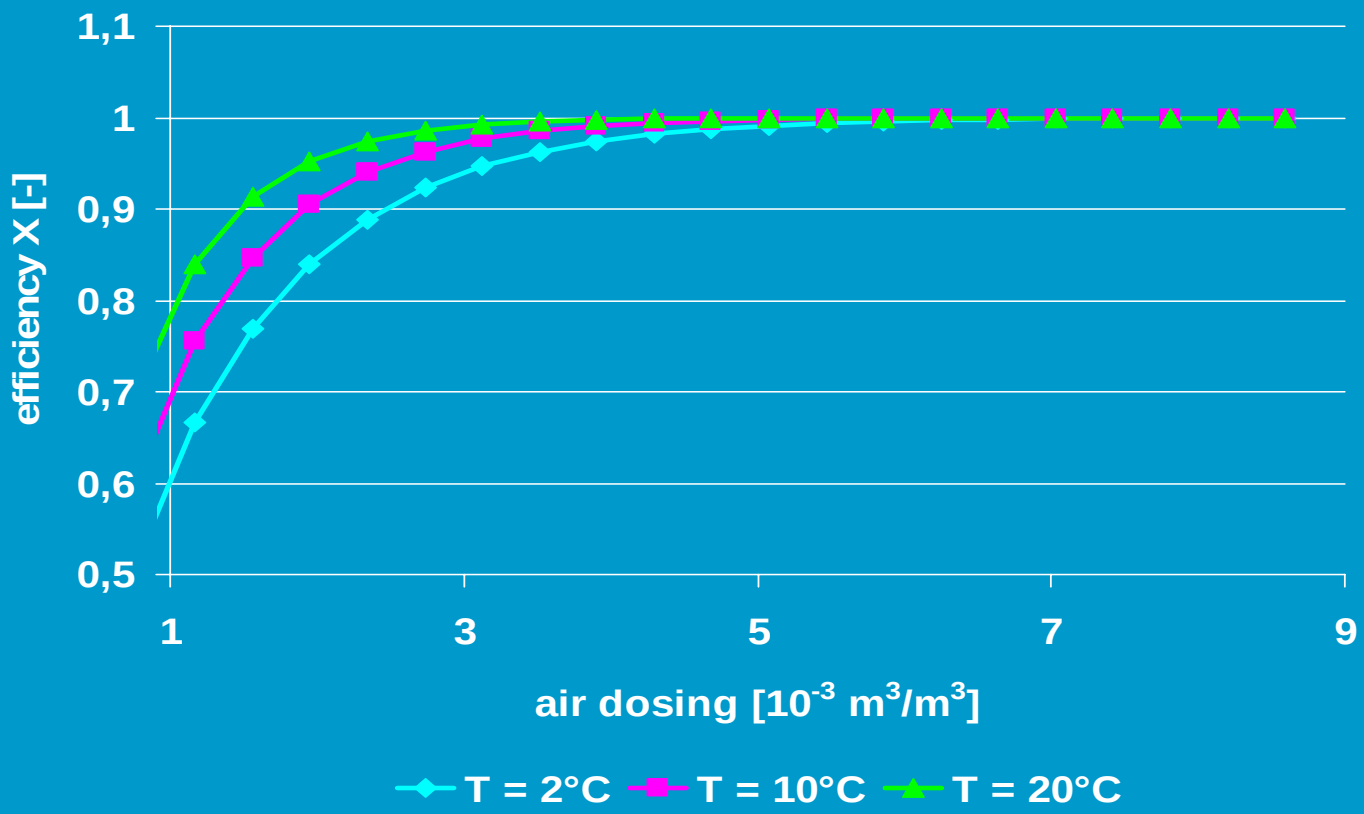
Filtration zone

Influence air dosing: theory



T = 1.6 min
d_b = 40µm
d_d = 100 µm
ρ_d = 1003 kg/m^3
α_{db} = 0.5

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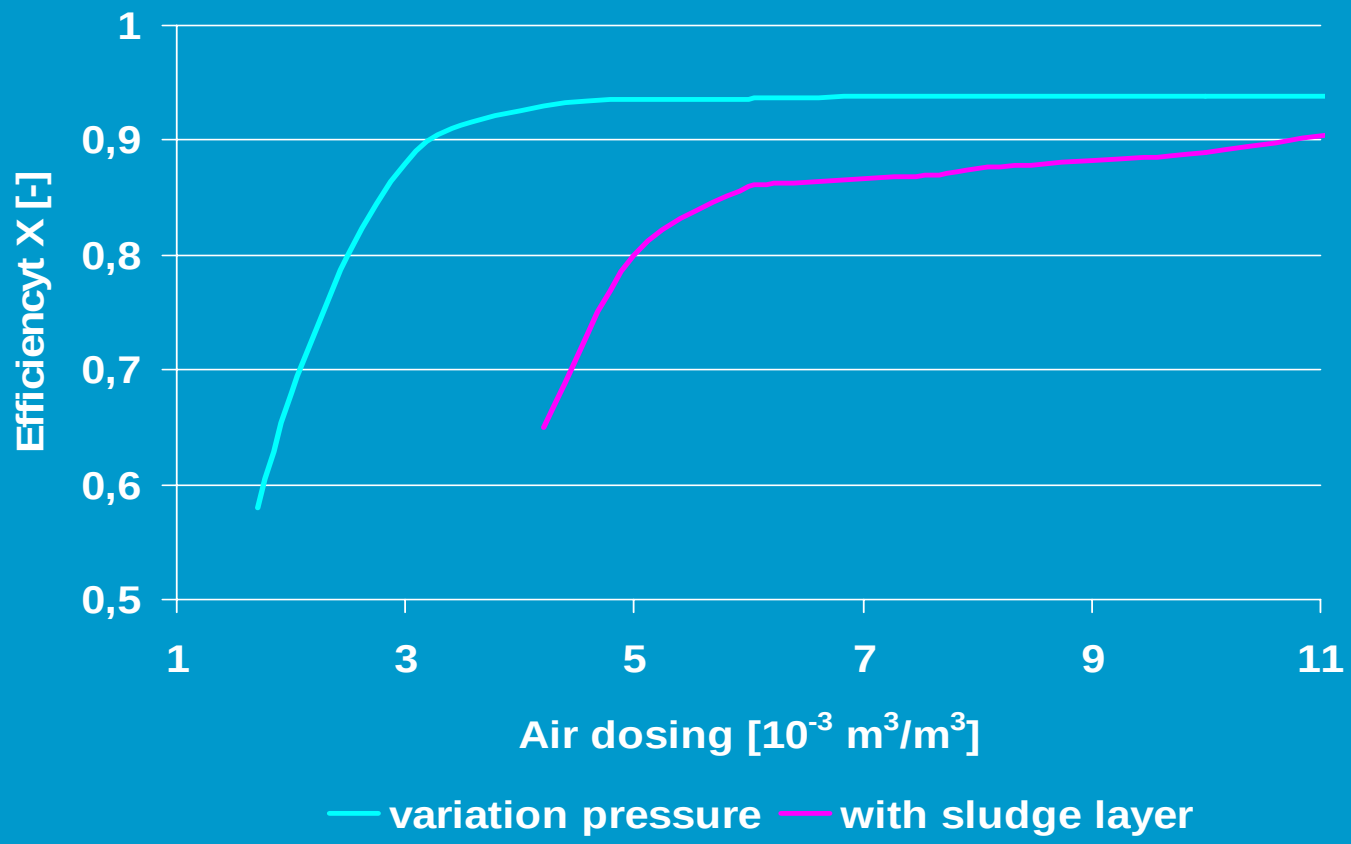
Filtration zone

Influence air dosing: practice



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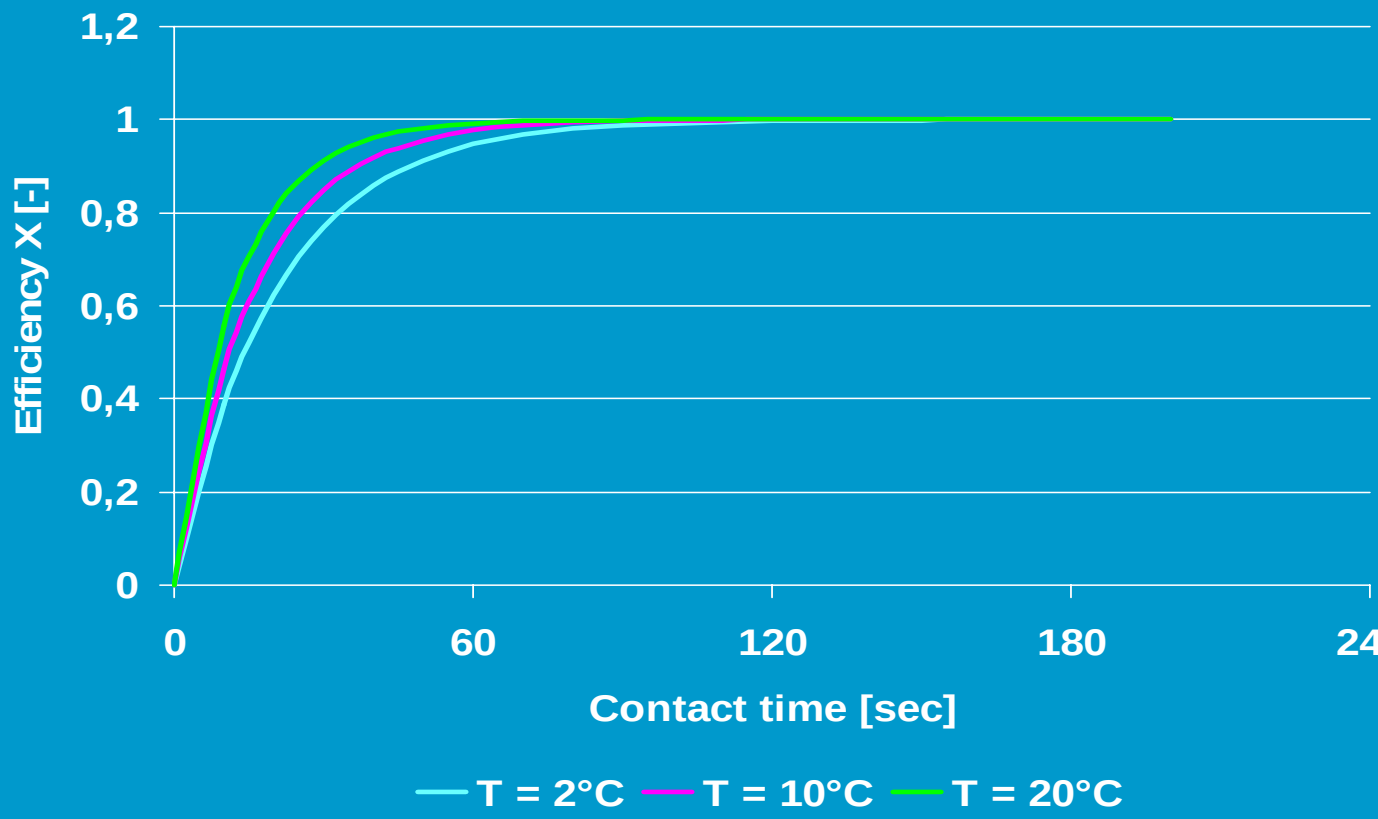
Filtration zone

Influence air dosing: practice

Filtration zone

Influence contact time: theory



d_b = 40µm
d_d = 100 µm
ρ_d = 1003 kg/m^3
α_{db} = 0.5
ϕ_b = 5.0·10^{-3} m^3/m^3

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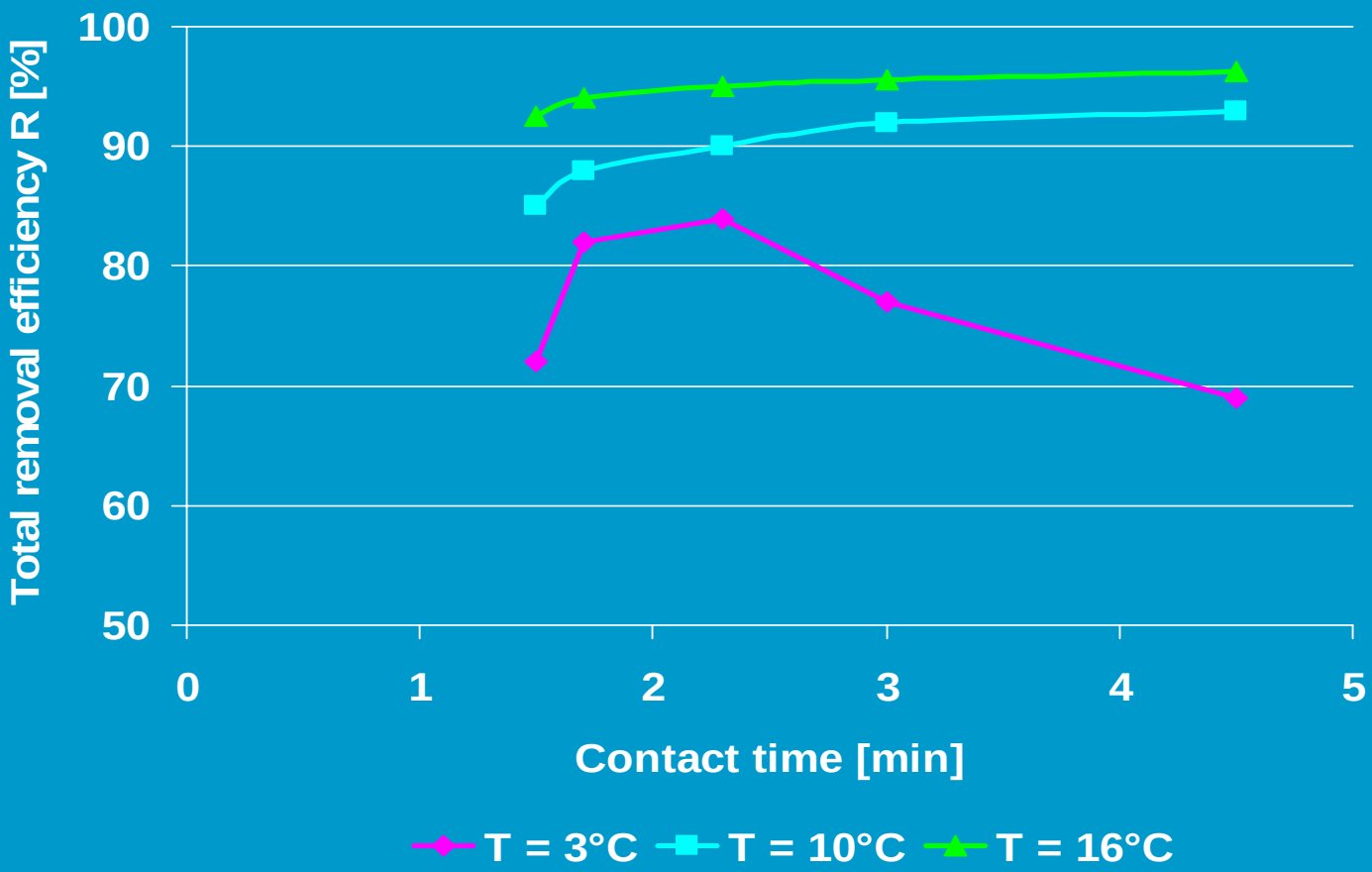
Filtration zone

Influence contact time: practice



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Filtration zone

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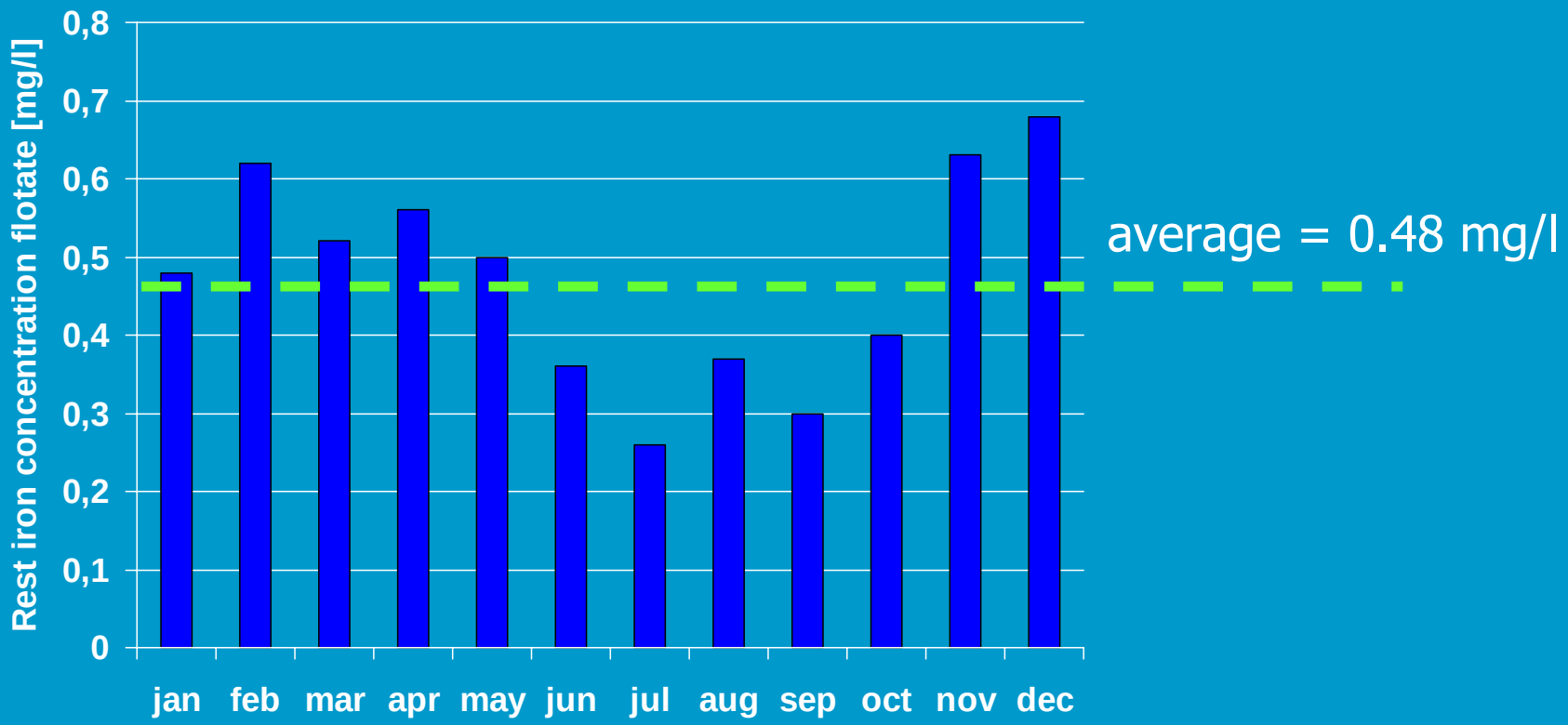
Filtration zone

Influence contact time: practice



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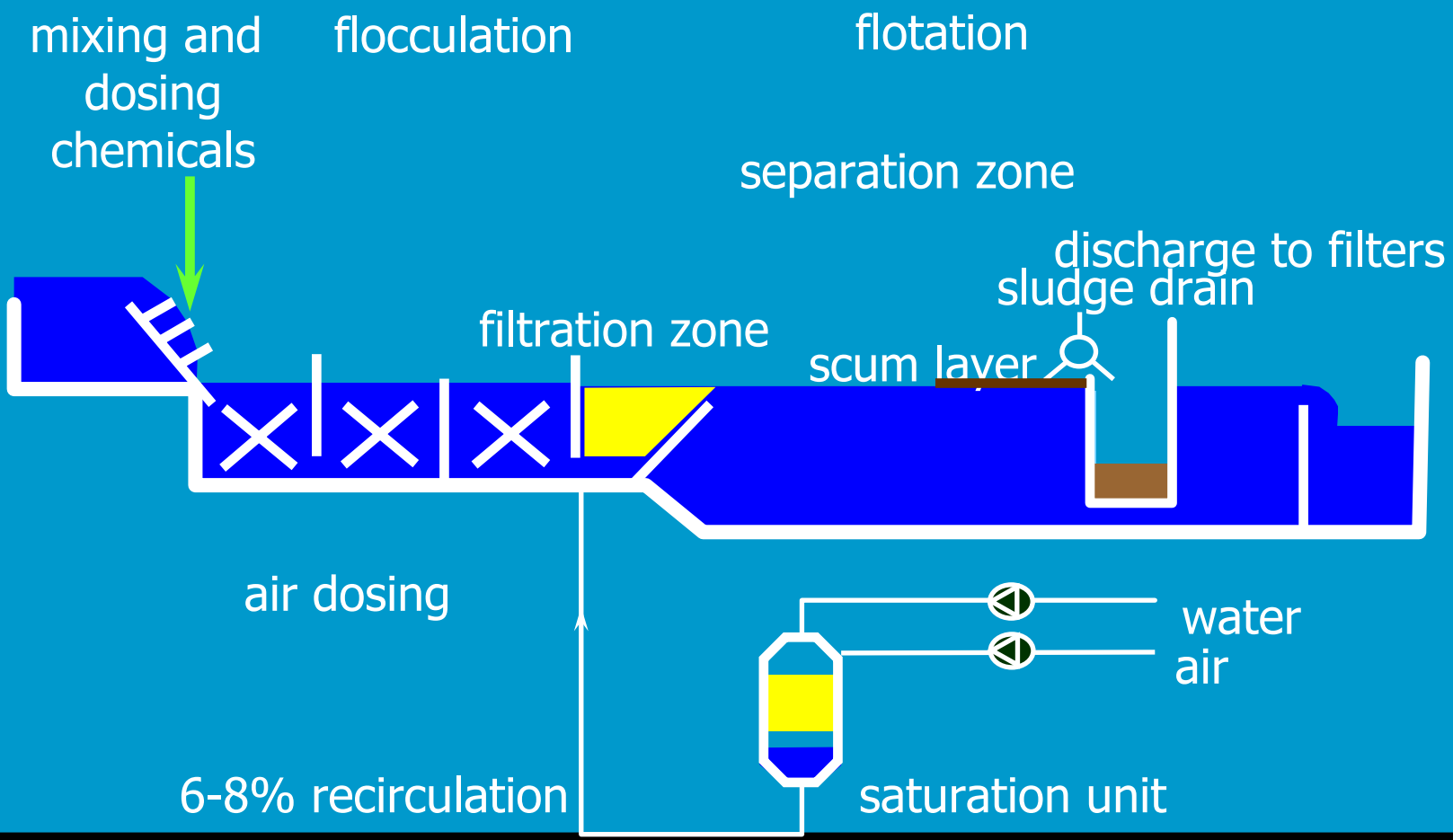
Separation zone

Schematics flotation



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Separation zone

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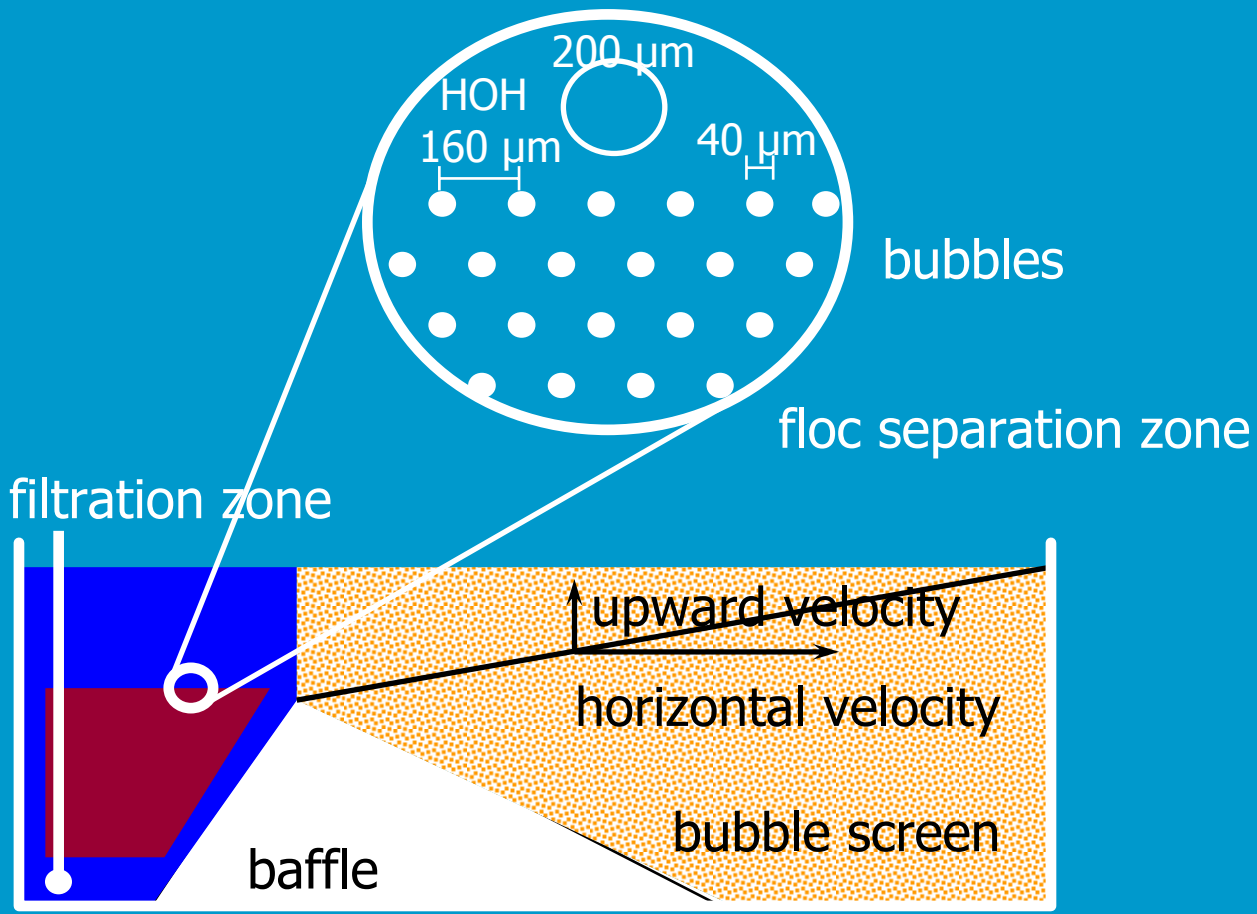
Separation zone

Introduction

Flotation tank



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Separation zone

Surface loading

most important parameter

$$\frac{t_b}{t_{st}} > 1$$

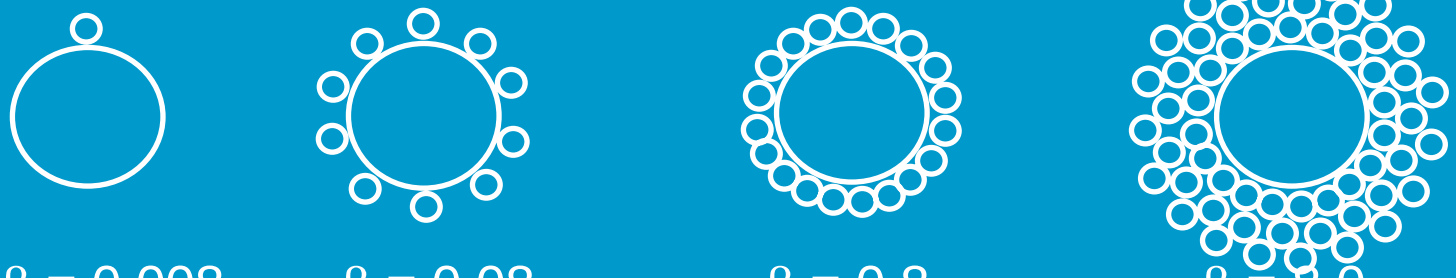
$$V_{st} > S_0 \cdot \frac{1}{1-m}$$

$$V_{st} = \frac{1}{18} \cdot \frac{g}{\mu} \cdot \left(\frac{\rho_w - \rho_a}{\rho_w} \right) \cdot d_a{}^2$$

Separation zone

Air/floc ratio β

diameter bubble = 40 µm
diameter floc = 200 µm



β = 0.008	β = 0.08	β = 0.8	β = 8.0
$\frac{d_a}{d_d} = 1.00$	$\frac{d_a}{d_d} = 1.03$	$\frac{d_a}{d_d} = 1.21$	$\frac{d_a}{d_d} = 2.08$
ρ_a = 995.1	928.8	557.8	112.5 kg/m^3
v_{st} = 0.4	6	44.7	152 m/s

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Separation zone

Surface loading

floc diameter d_d
air/floc ratio β

$$d_a = \sqrt[3]{1+\beta} \cdot d_d$$

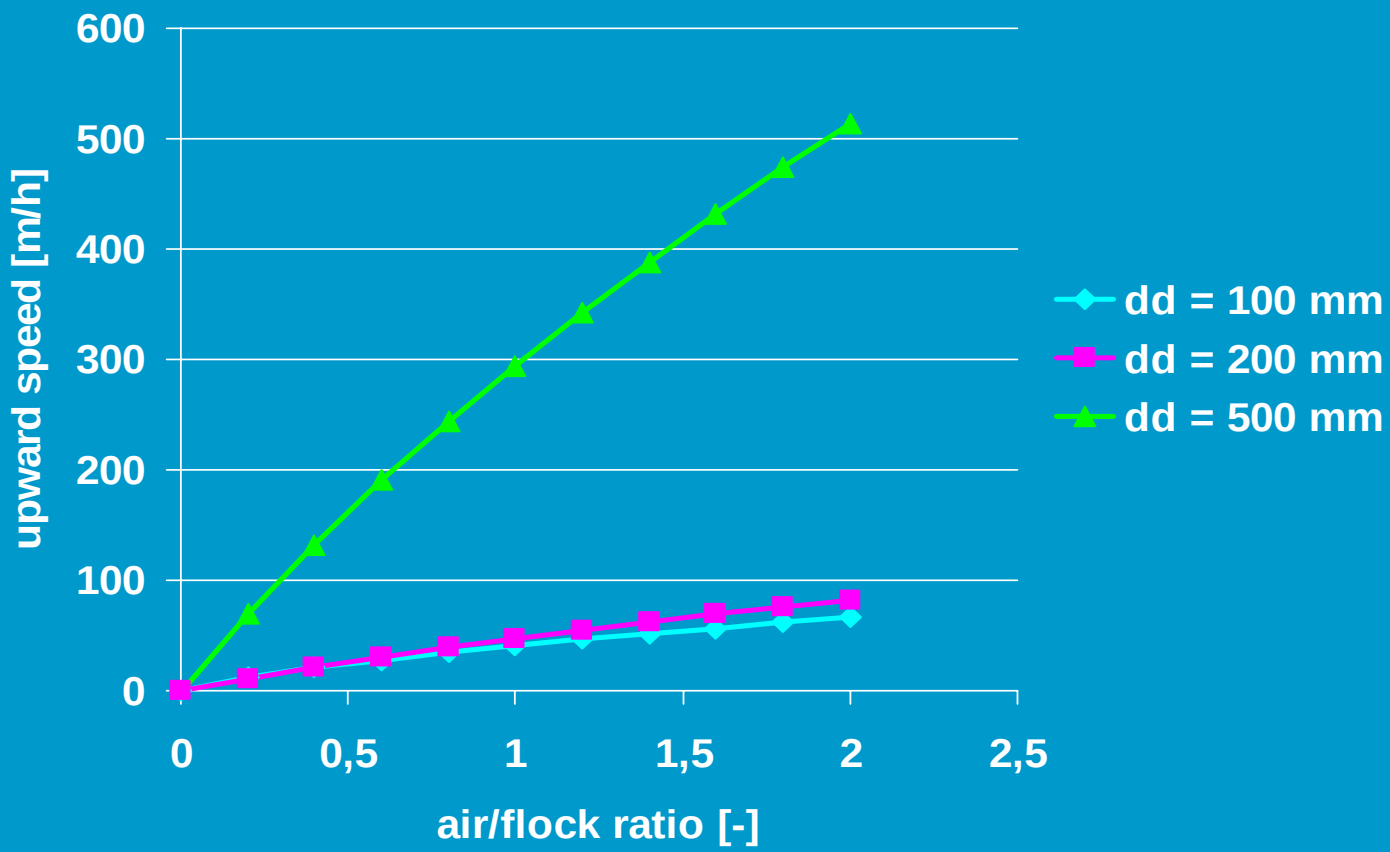
$$\rho_a = \left(\frac{\beta}{\beta+1}\right) \cdot \rho_b + \left(\frac{1}{\beta+1}\right) \cdot \rho_d$$

ρ_b = 1.24 kg/m^3
ρ_d = 1003 kg/m^3

t_b = residence time in separation zone [s]
t_{st} = time that a particle needs to reach the surface [s]
v_{st} = upward velocity bubble-bubble agglomerate [m/s]
s_o = surface loading [m^3/(m^2·s)]
m = fraction of dead zones [-]
ρ_a = density agglomerate [kg/m^3]
d_a = diameter agglomerate [m]

Separation zone

Upward velocity



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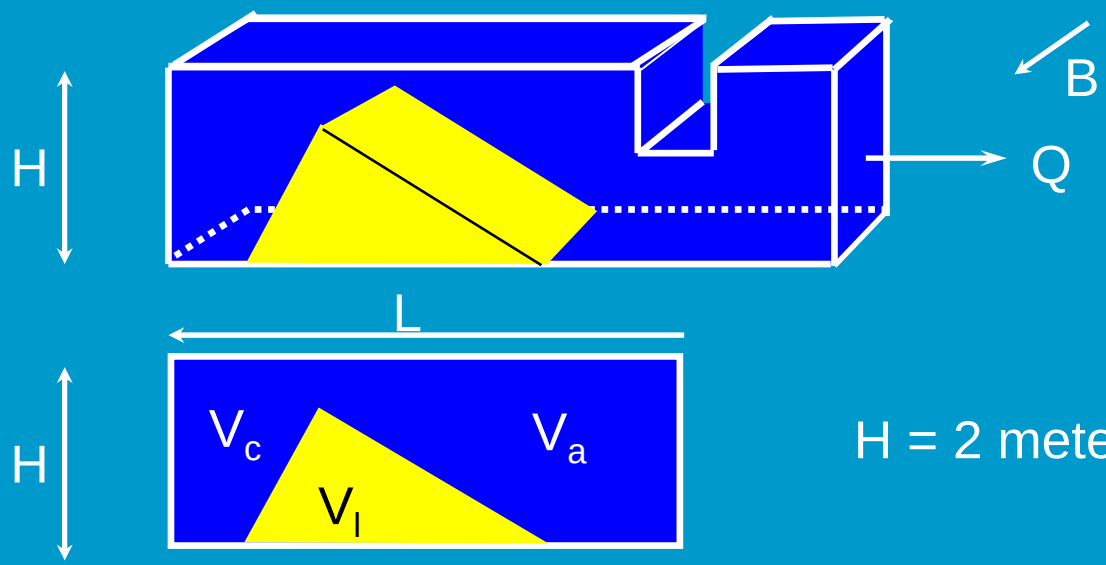
Separation zone

Design of flotation tank



H = 2 meter

$$T_{gros} = \frac{Q}{V_{br}} = \frac{Q}{L \cdot B \cdot H}$$

$$= \frac{Q}{V_c} + \frac{Q}{V_a} + \frac{Q}{V_l}$$

V_c design on residence time
V_a design on surface loading

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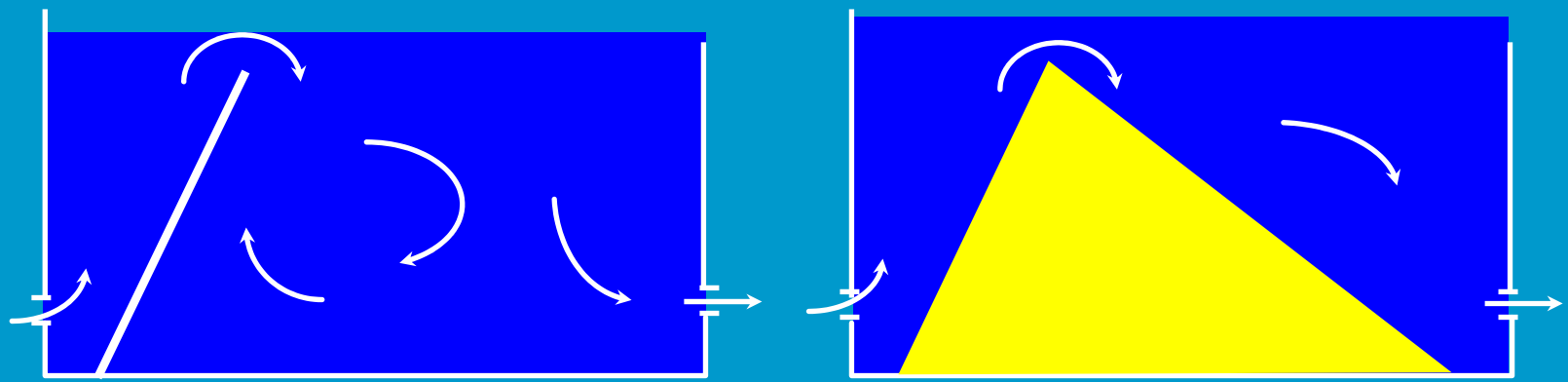
Separation zone

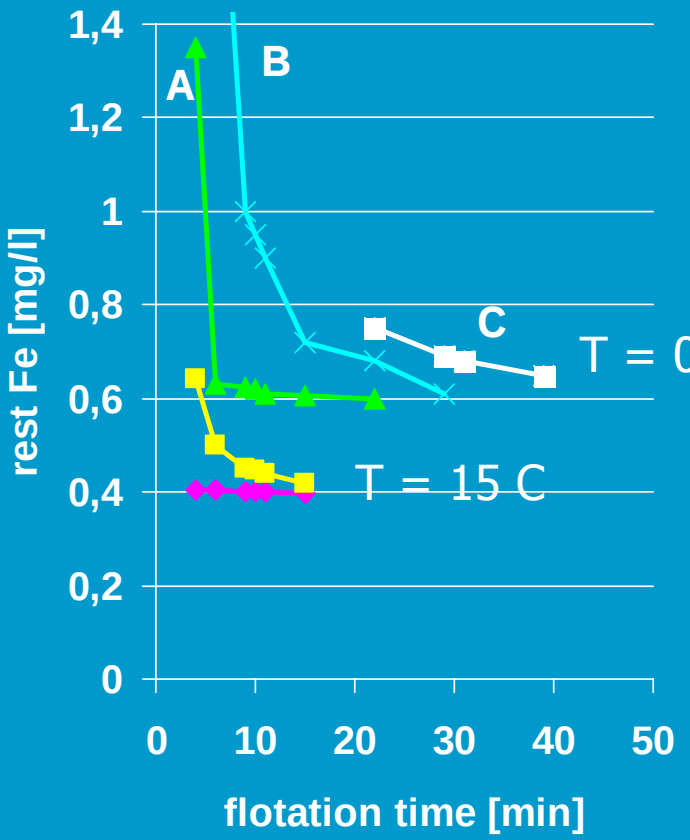
Construction alternatives flotation basin

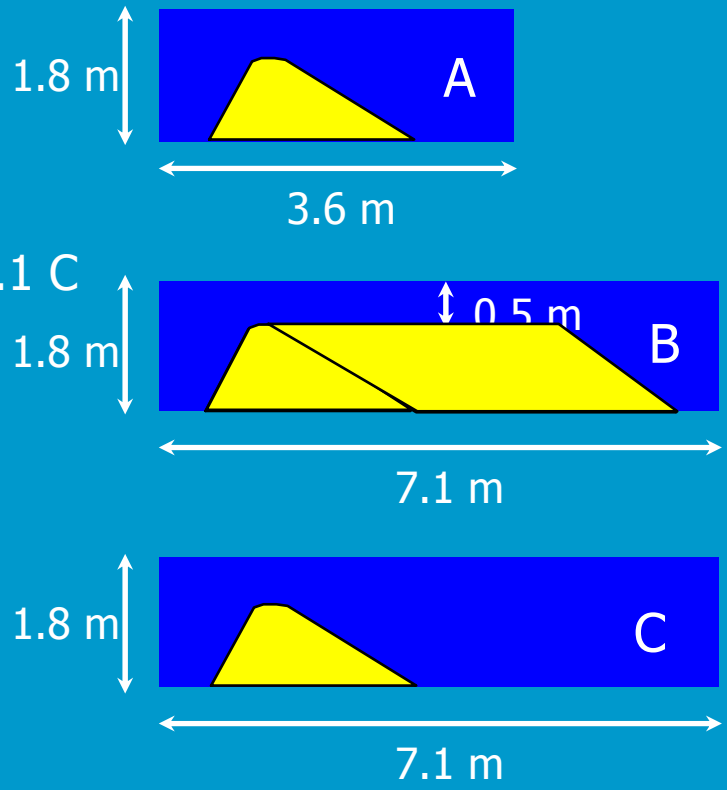


- residence time 70%
- improved flow conditions
- less sludge on bottom
- equivalent effluent quality

Separation zone

Construction alternatives flotation basin





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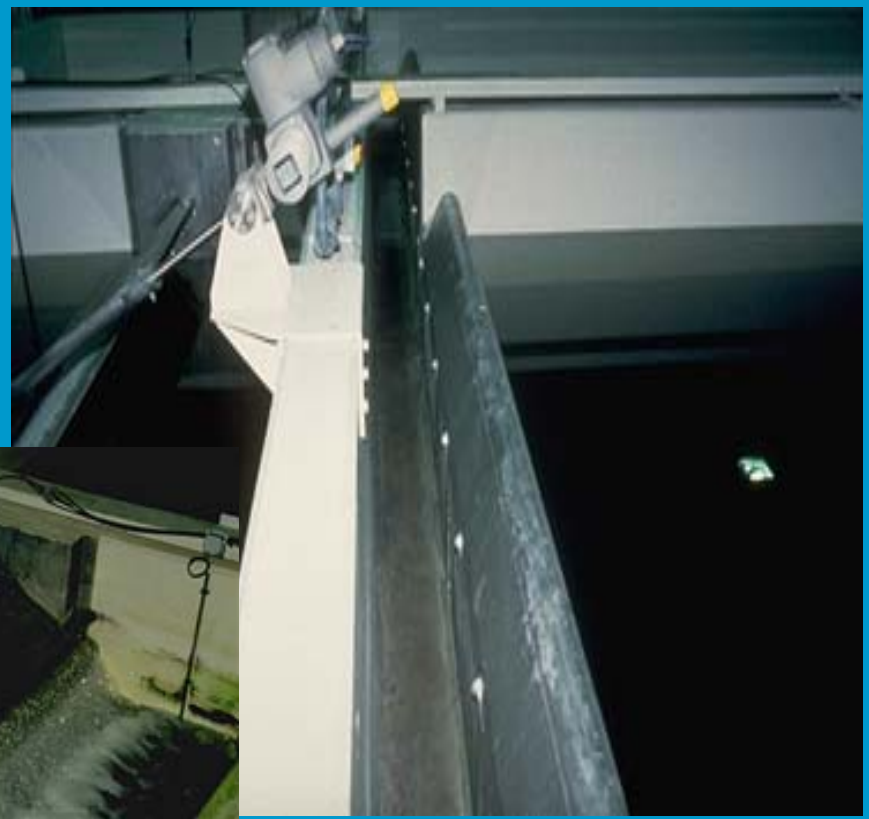
Water outlet



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Conclusions

Filtration zone

air dosing:	15 - 20 mg/l (11.7 - 15.6 l/m3)
contact time:	1.5 - 2 min
L/B:	> 5
saturation pressure	4 - 8 bar
re-circulation:	6 - 8%

Separation zone

s_0:	25 - 30 m/h
residence time:	5 - 10 min
depth	2 m
weir loading:	100 - 200 m3/(m·h)