

Coagulation and Flocculation

CTB3365x Introduction to water treatment

Prof.dr.ir. Luuk Rietveld

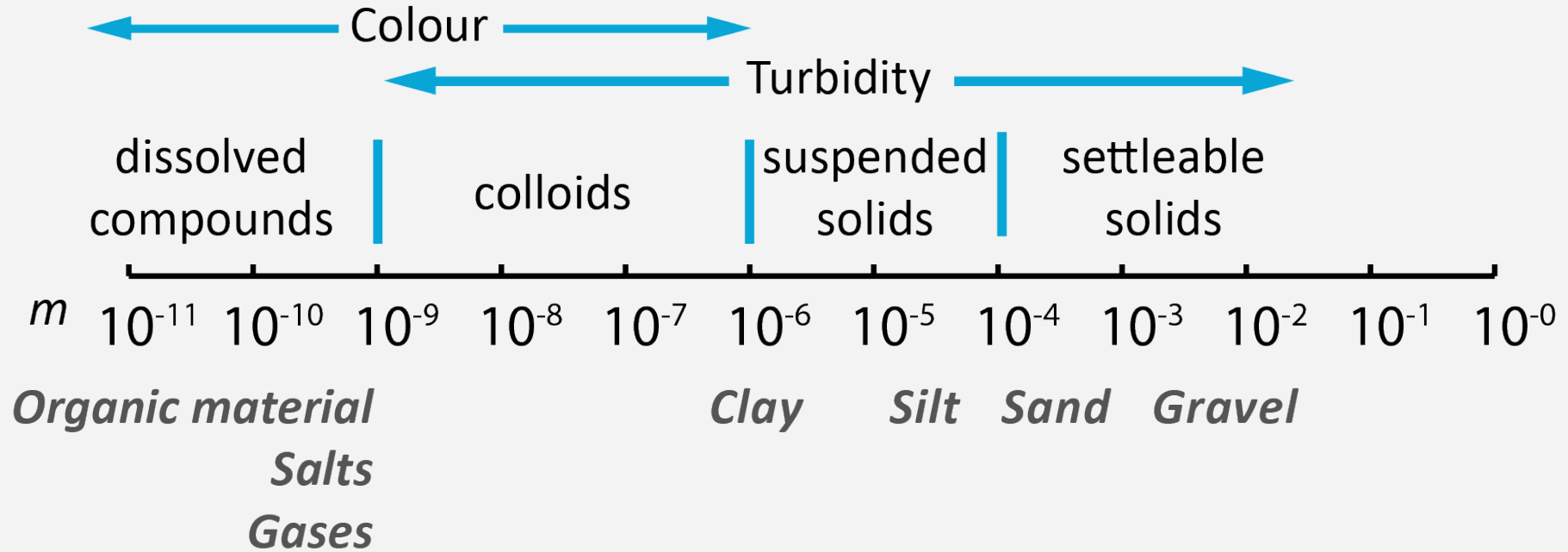


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Classification of particles



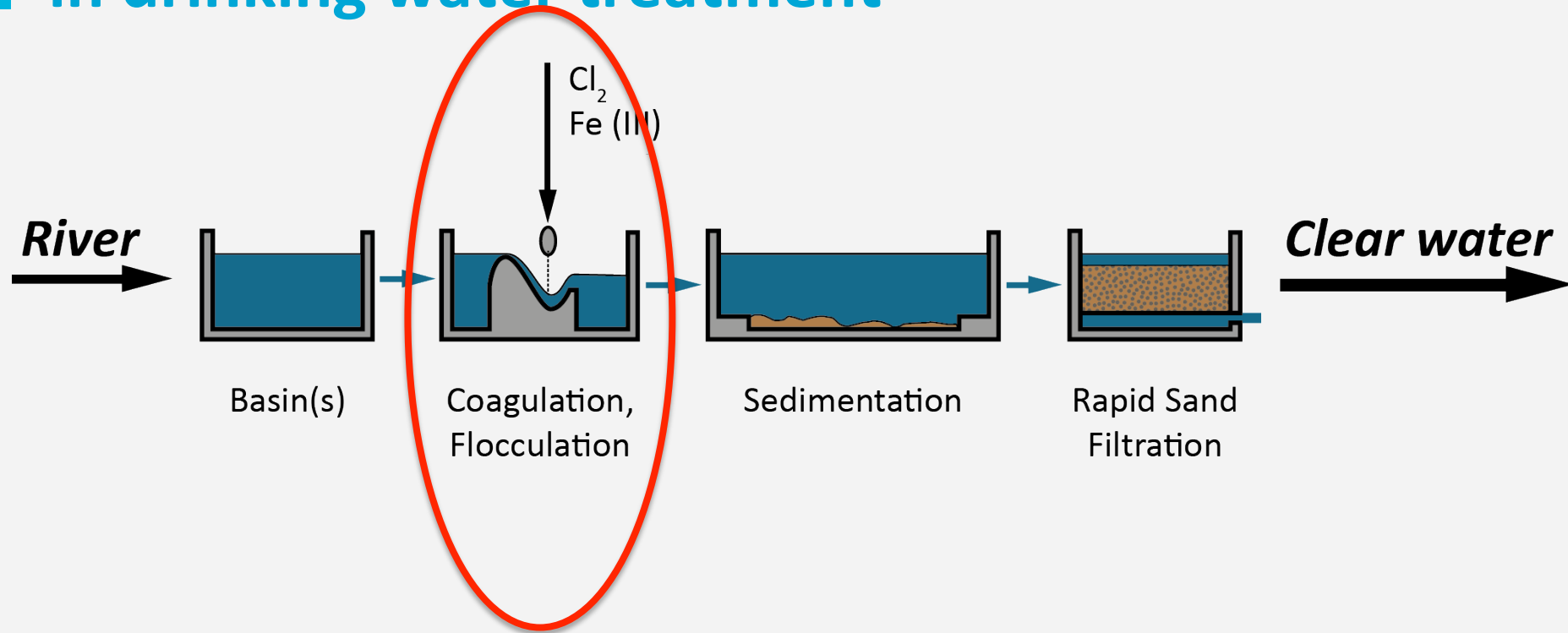
Coagulation and Flocculation: Why?

In drinking water:

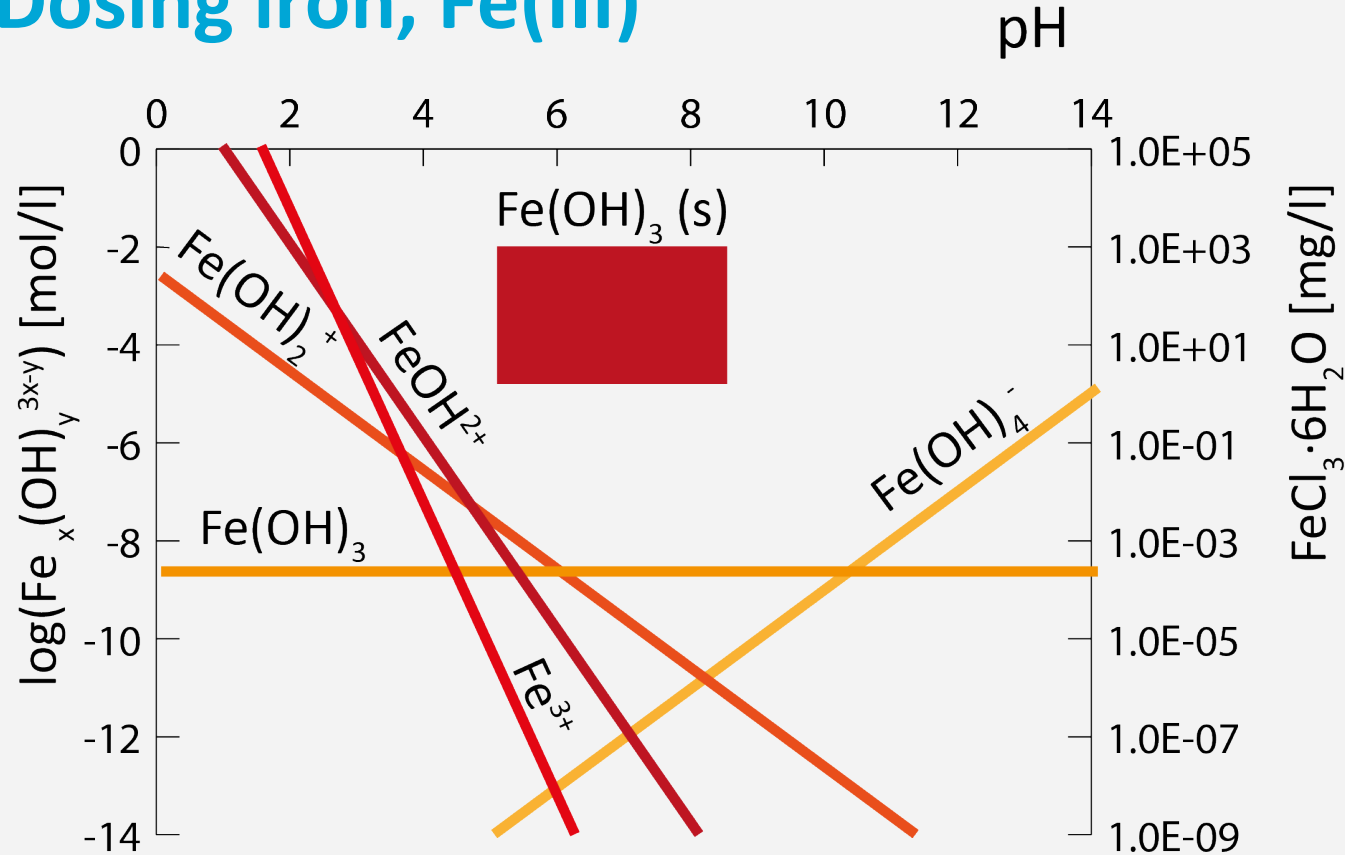
- Removal of turbidity (*clay*) and colour (*humic acids*)
- *Public health:*
removal of heavy metals
- *Aesthetics:*
attractiveness of water



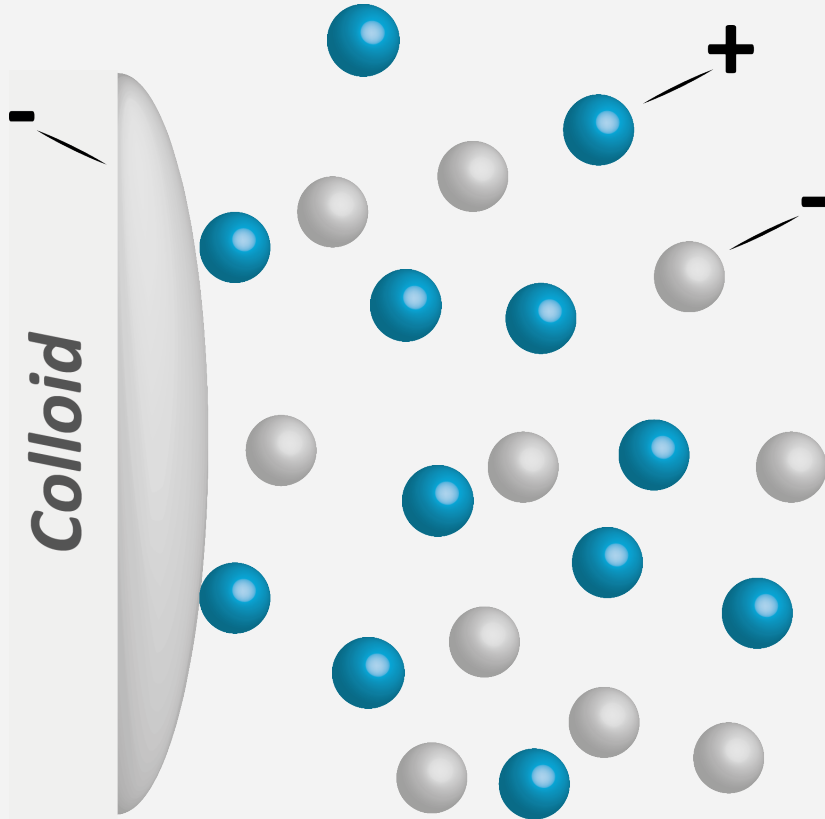
Principle of coagulation & flocculation in drinking water treatment



Dosing iron, Fe(III)



Electrostatic Coagulation



High dosage:

- 0.024 mol/m^3
- Trivalent ions (Fe^{3+})

After Coagulation:

- Charge 4-

Adsorbtive Coagulation



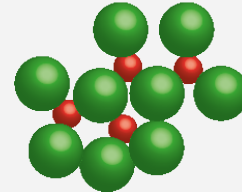
Iron: FeOH^{2+} , $\text{Fe}(\text{OH})_2^+$

Humic acid
(- charged)

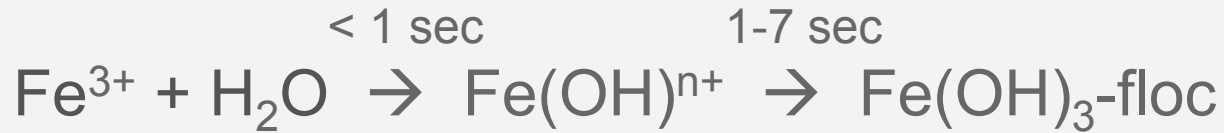
$\text{Fe}(\text{OH})^{2+}$
(+ charged)



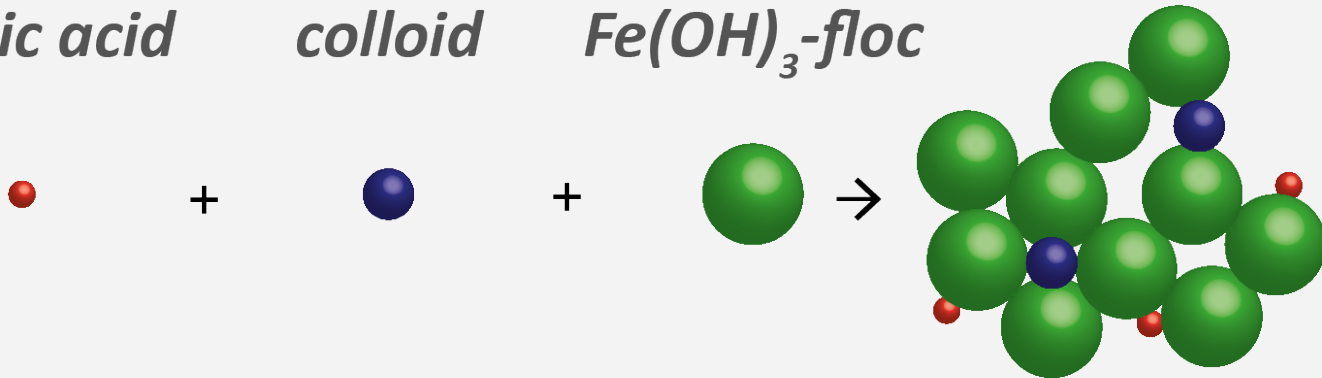
+



Precipitation (Sweep) Coagulation

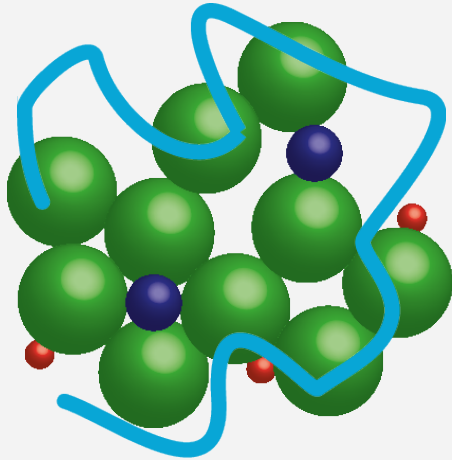


humic acid *colloid* *Fe(OH)₃-floc*

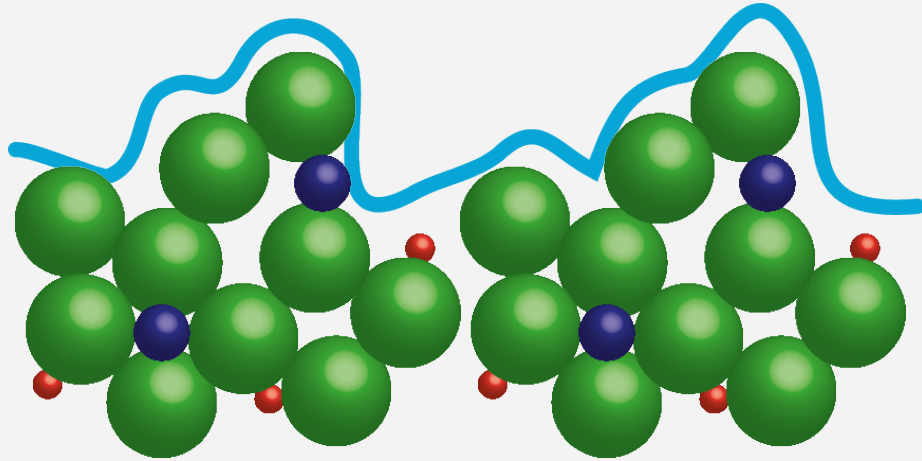


Polyelectrolytes (flocculant aid): long organic polymers

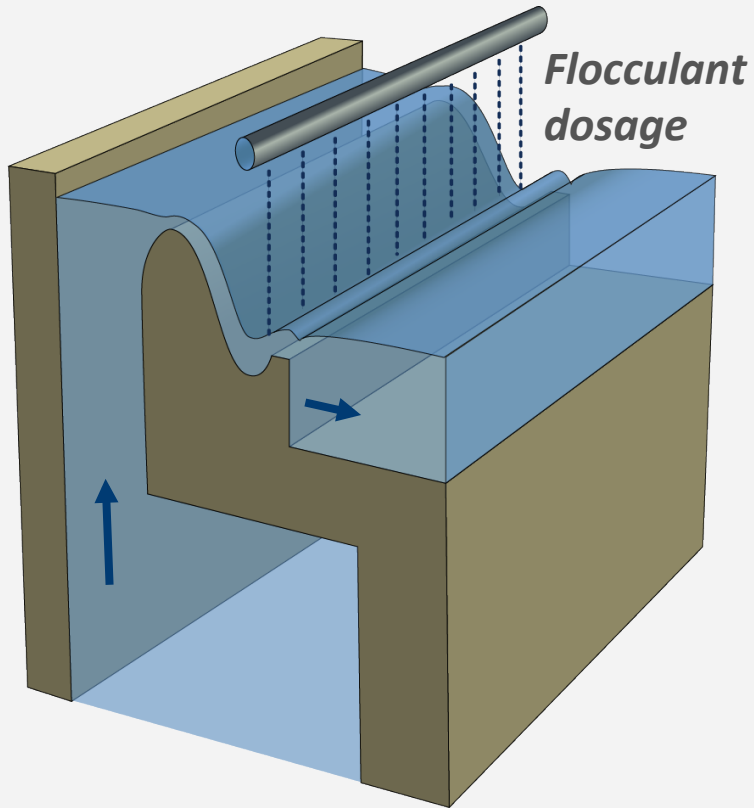
Stronger flocs



Larger flocs



Coagulant dosage



Suspended solids

Particle size distribution

Organic matter

pH

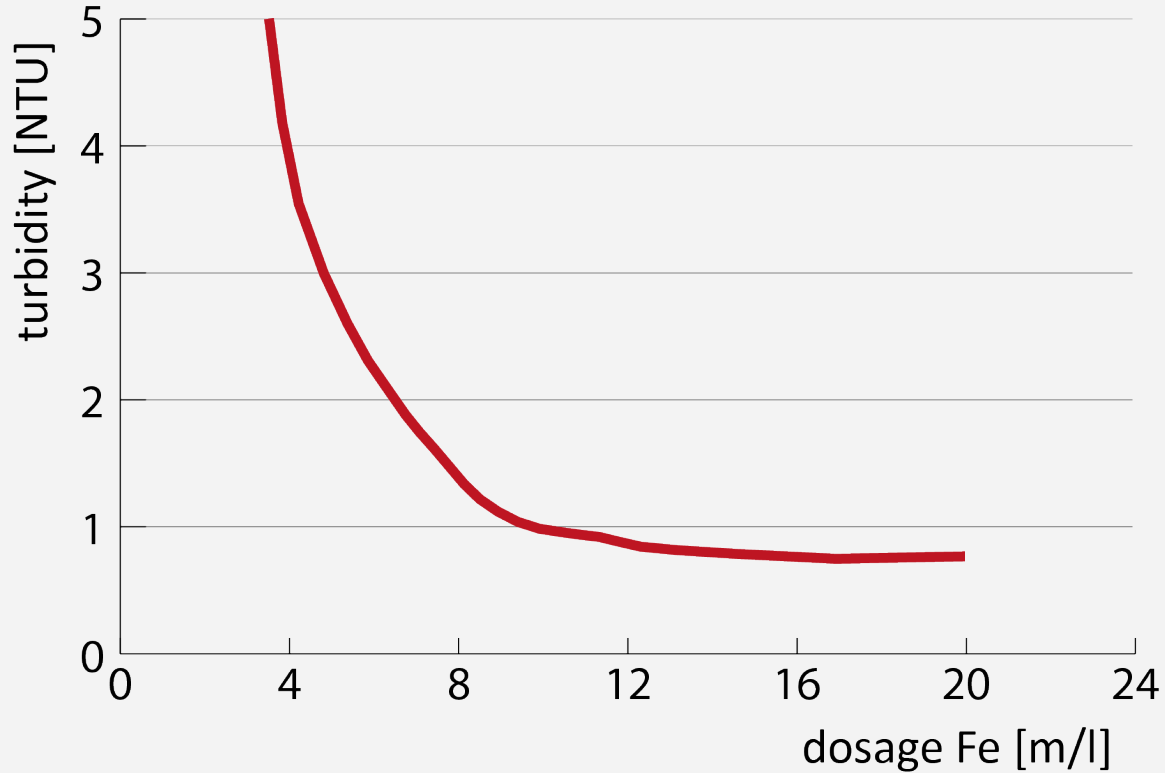
Salt

Temperature

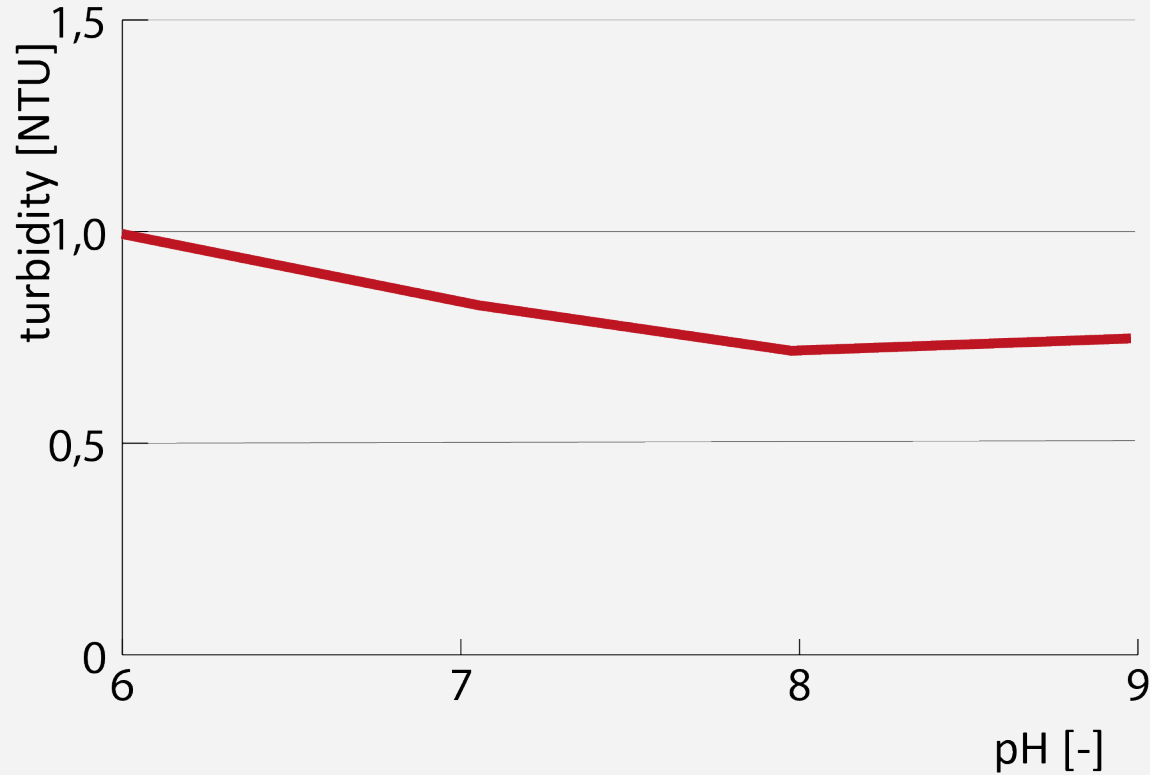
Jar test



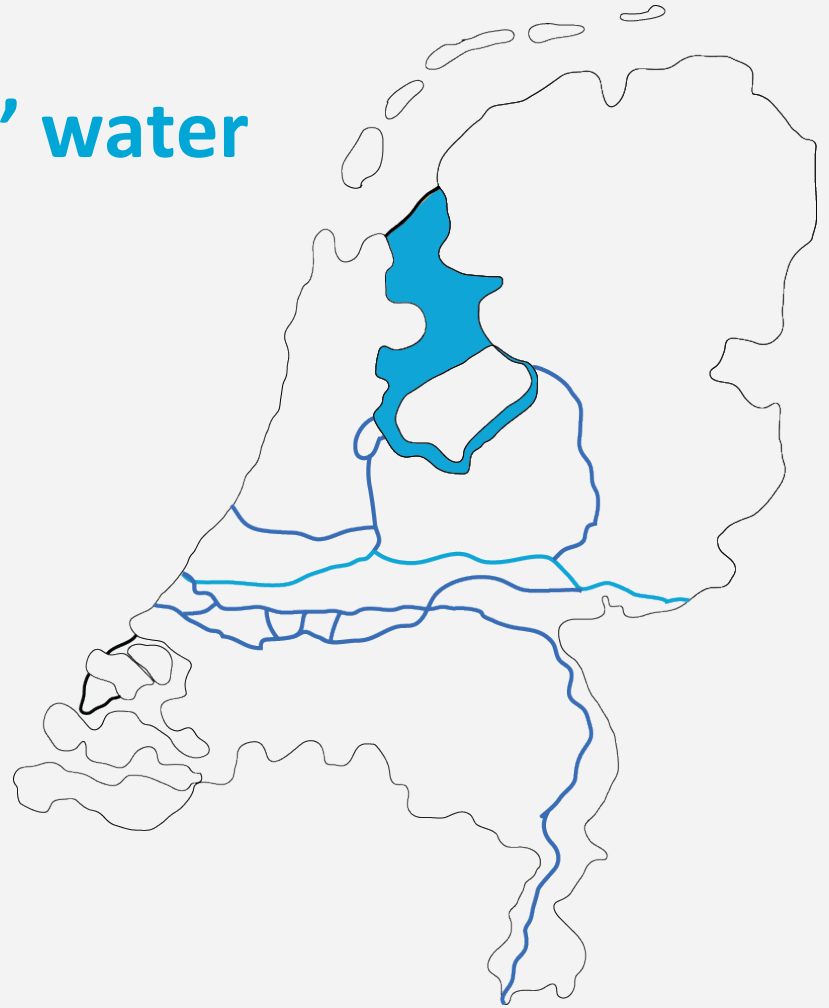
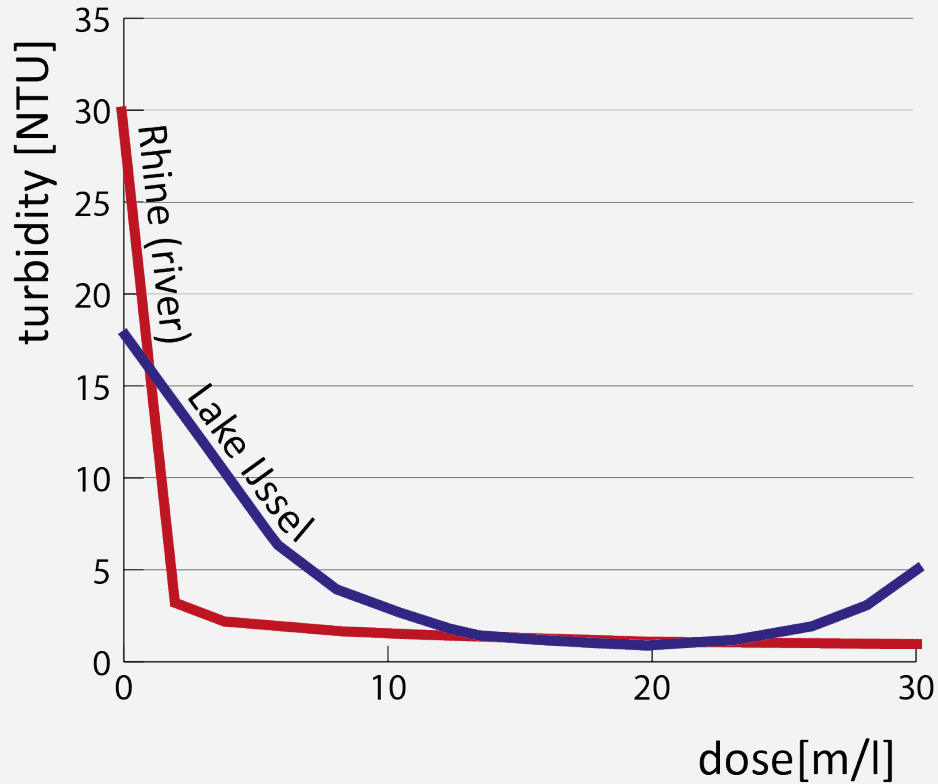
Optimization: dosage



Optimization: pH

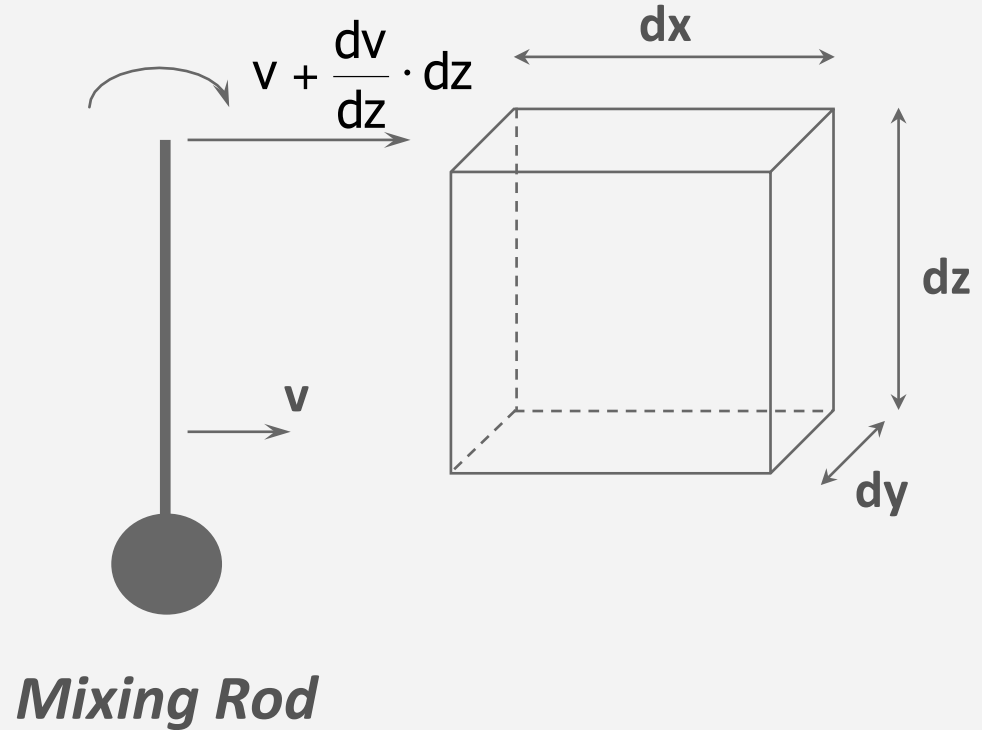


Rhine water vs 'IJsselmeer' water



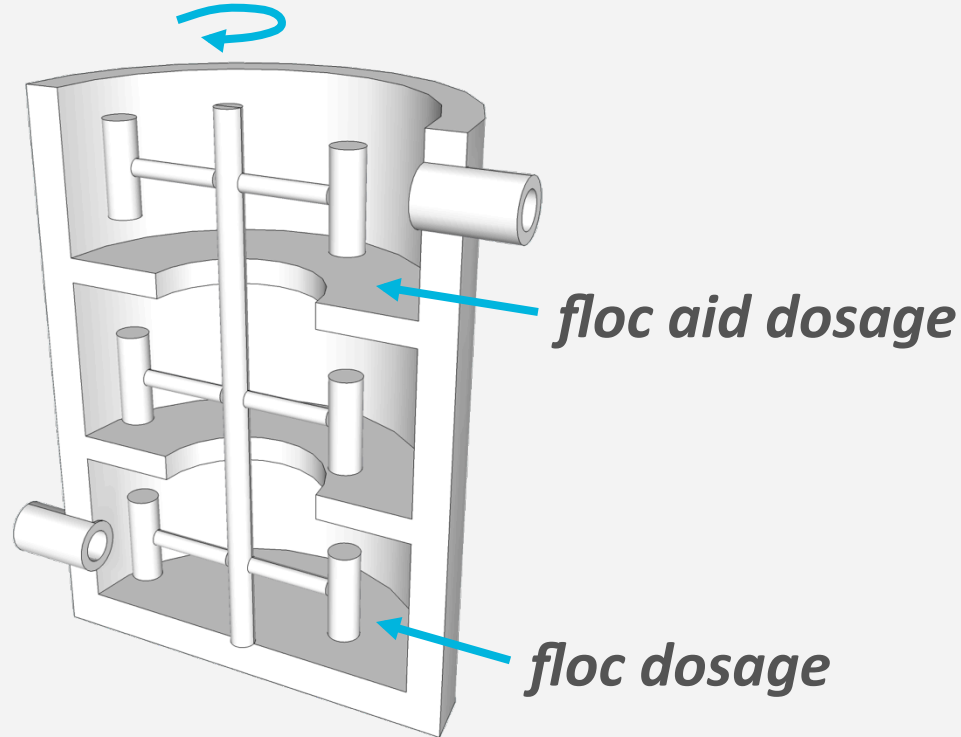
Mixing velocity gradient

$$\rightarrow G = \sqrt{\frac{P}{\mu \cdot V}}$$

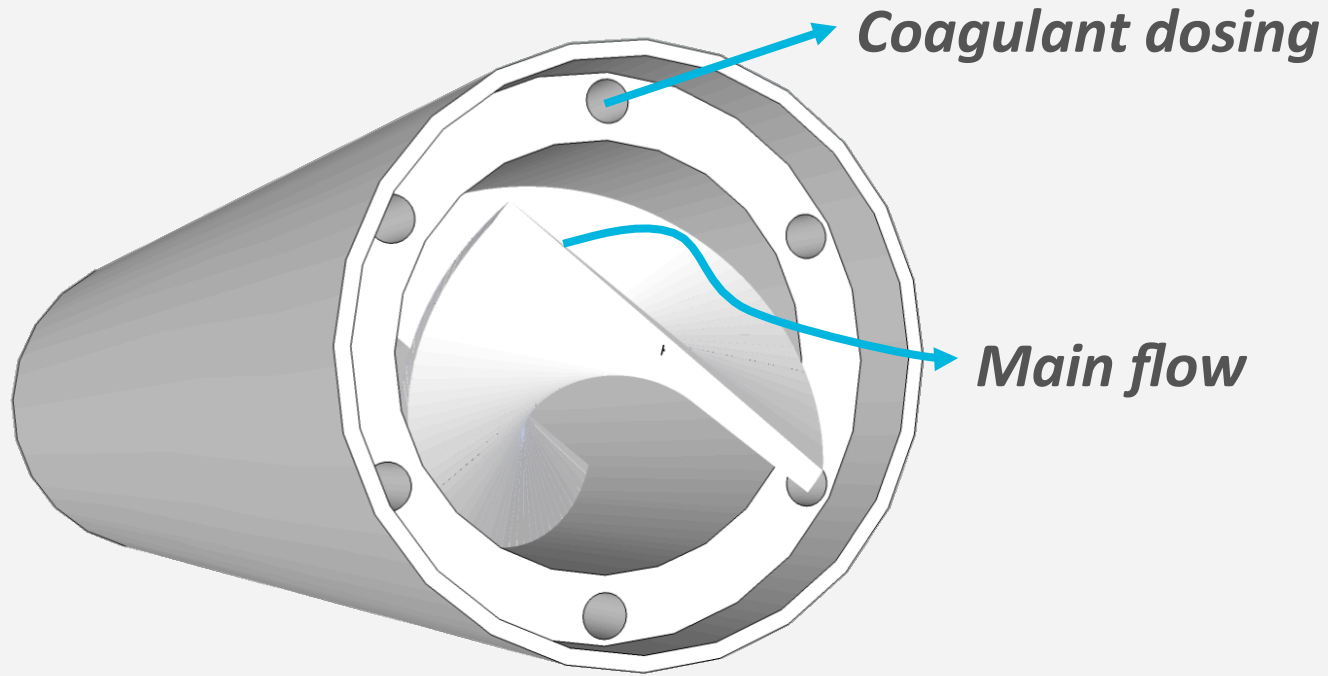


Mechanical Mixer

$$G_c = \sqrt{\frac{P}{\mu \cdot V}}$$



Static Mixer



Flocculation Theory

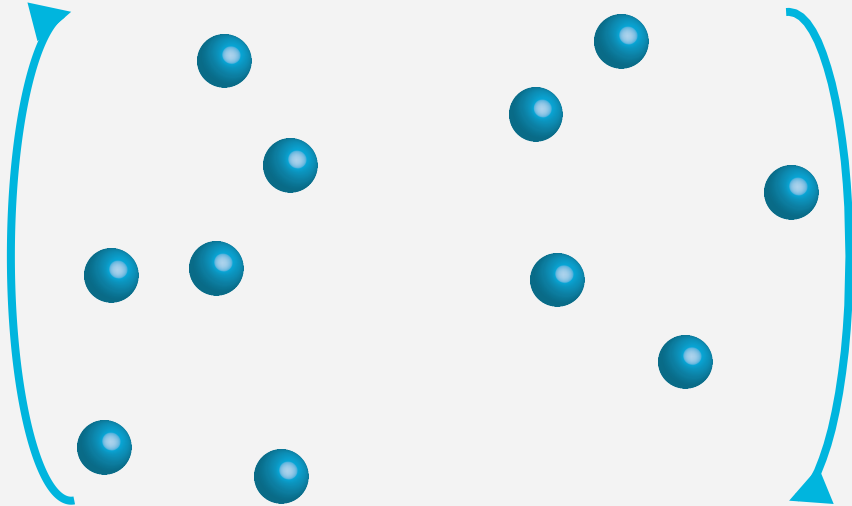


Flocculation Theory



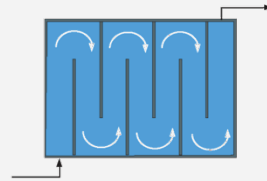
Orthokinetic flocculation

Driving force: turbulence



$$-\frac{dn}{dt} = \frac{4}{3} \cdot n_1 \cdot n_2 \cdot R^3 \cdot G_v$$

Plug flow:



$$\frac{n}{n_0} = e^{-k_a \cdot c_v \cdot G_v \cdot t}$$

Completely mixed:

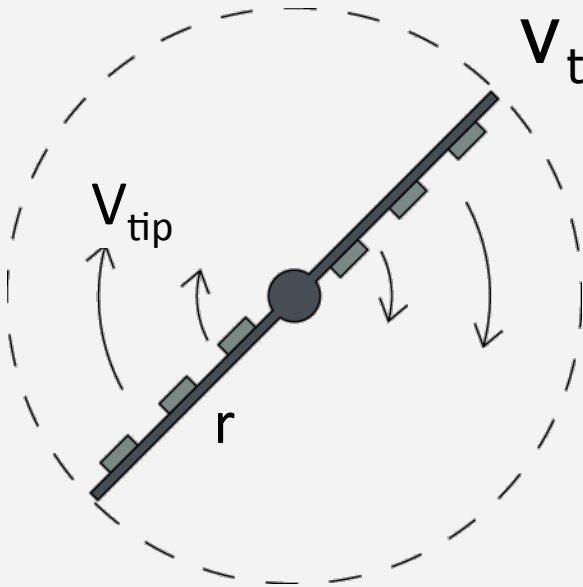


$$\frac{n}{n_0} = \frac{1}{1 + k_a \cdot c_v \cdot G_v \cdot t}$$

Flocculation practice



Tip Velocity



$$V_{\text{tip}} = 2 \cdot \pi \cdot r \cdot N$$

$N = 4 \text{ rotations/min}$

$v_{\text{max}} = 1 \text{ m/s}$

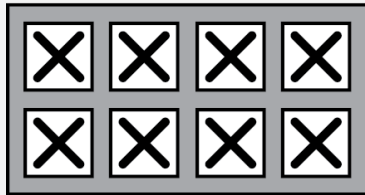
$$r < \frac{v}{2 \cdot \pi \cdot N} < \frac{1}{2 \cdot \pi \cdot \frac{4}{60}} < 2.4 \text{ m}$$

Optimal design of flocculators

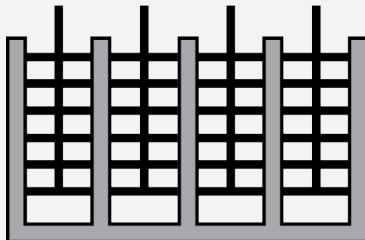
*Length/width
ratio: ≥ 3*

Vertical

Top View

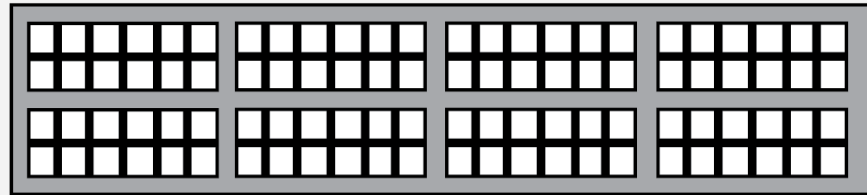


Side View



Horizontal

Top View

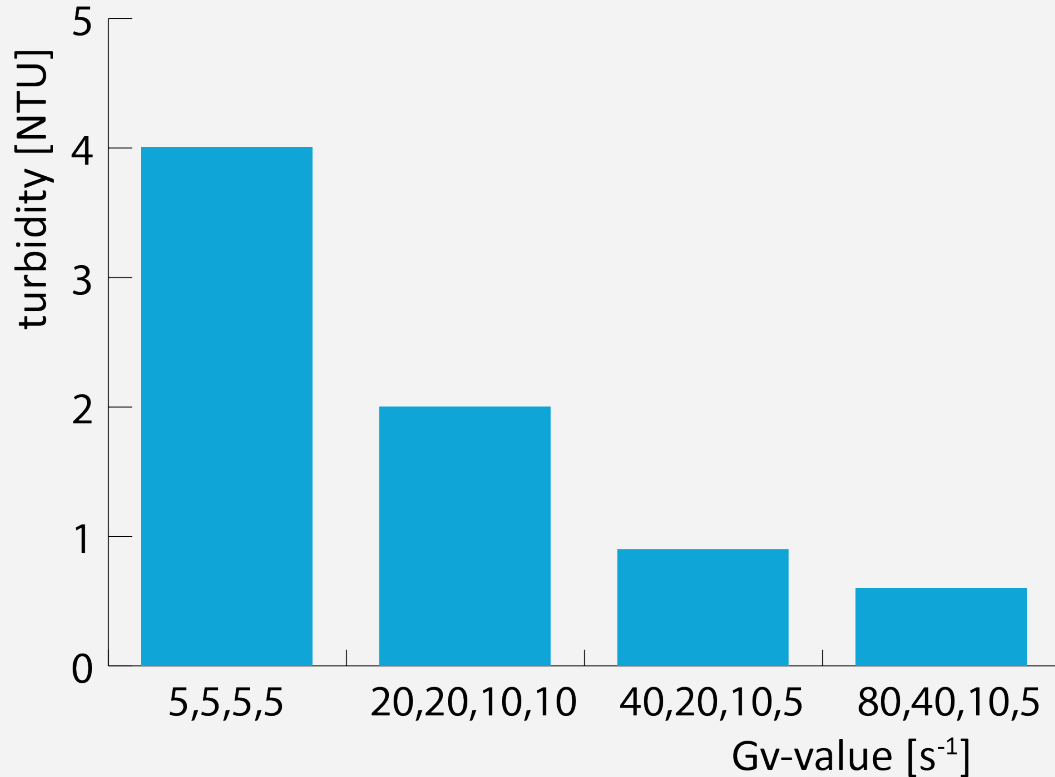


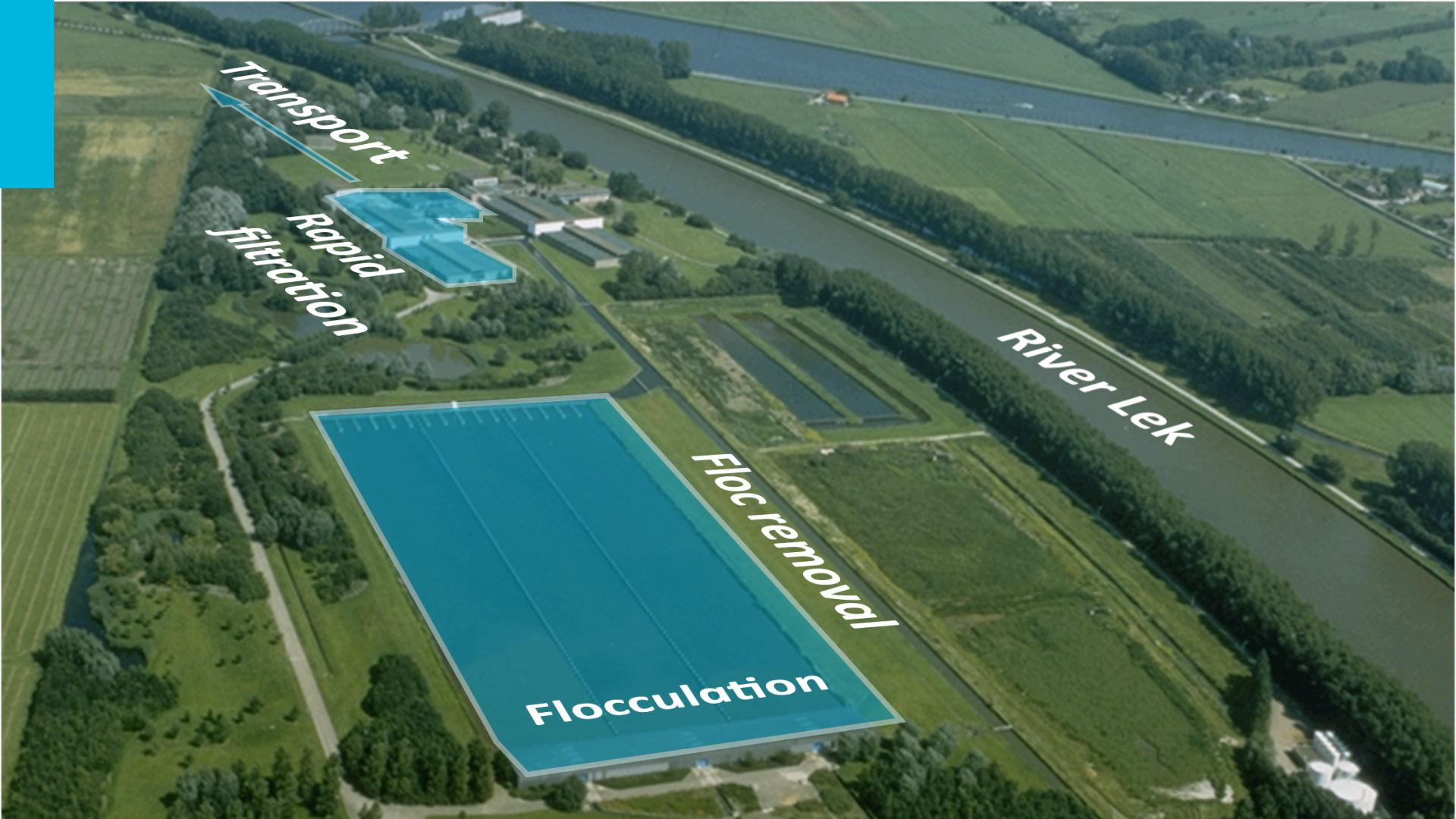
Side View



Variations in velocity gradient

$$G_v = \sqrt{\frac{P}{\mu \cdot V}}$$





Transport

Rapid
filtration

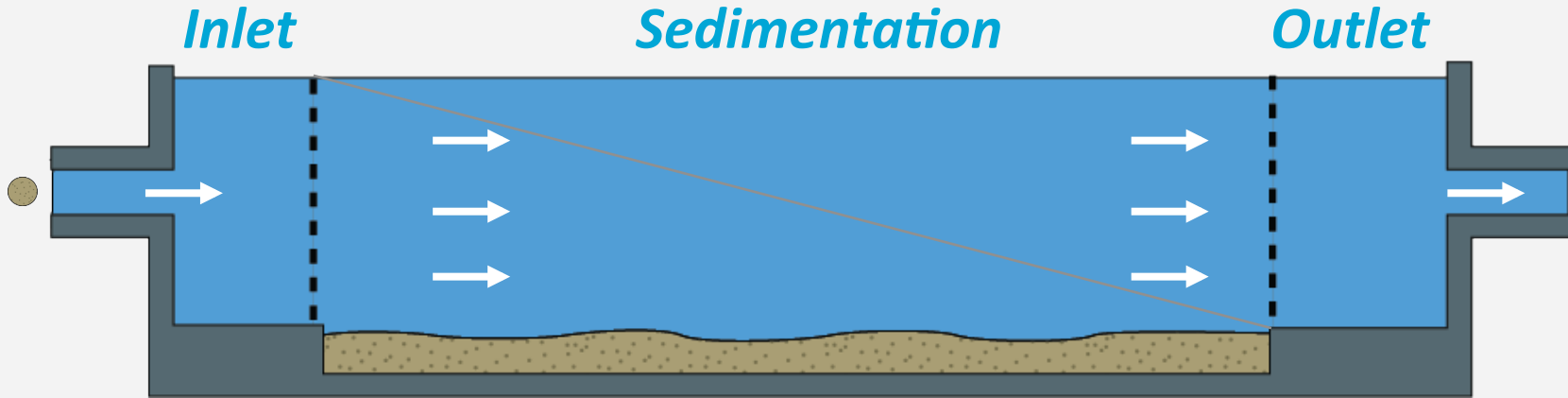
River Lek

Floc removal

Flocculation



Sedimentation



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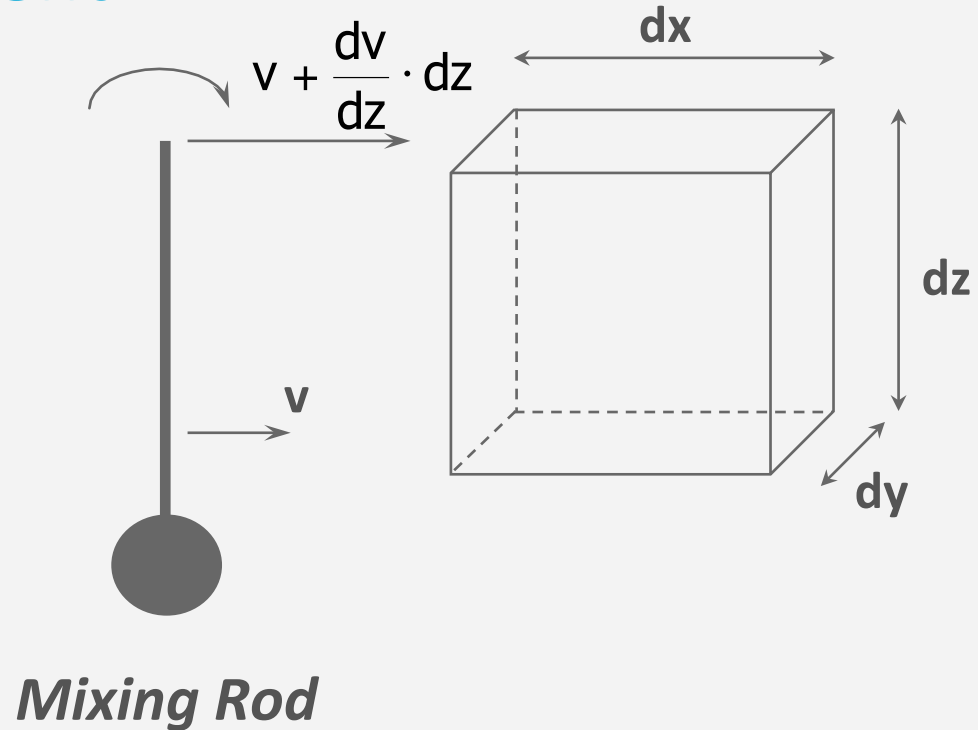
Mixing velocity gradient

$$F = \mu \cdot \frac{dv}{dz} \cdot dx \cdot dy$$

$$P = F \cdot dv = \mu \cdot \frac{dv}{dz} \cdot dx \cdot dy \cdot dv$$

$$= \mu \cdot \left(\frac{dv}{dz} \right)^2 \cdot dx \cdot dy \cdot dz = \mu \cdot G^2 \cdot V$$

$$\rightarrow G = \sqrt{\frac{P}{\mu \cdot V}}$$



Flocculation Theory

Foto??

