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COMSOL CONFERENCE ROTTERDAM2013

Water Quality Modelling of Drinking Water Storage Reservoir Noardburgum

Nico Wolthek, Vitens NV

Vitens water supply company

- Deliverance to 5.4 million customers
- 350 million m³/year

- 100 production sites
- Well fields : 0.5 – 15 million m3/y
- 100% use of fresh ground water

- Soil as a natural filter
- Stable quality
- No disinfection needed (e.g. chlorination)

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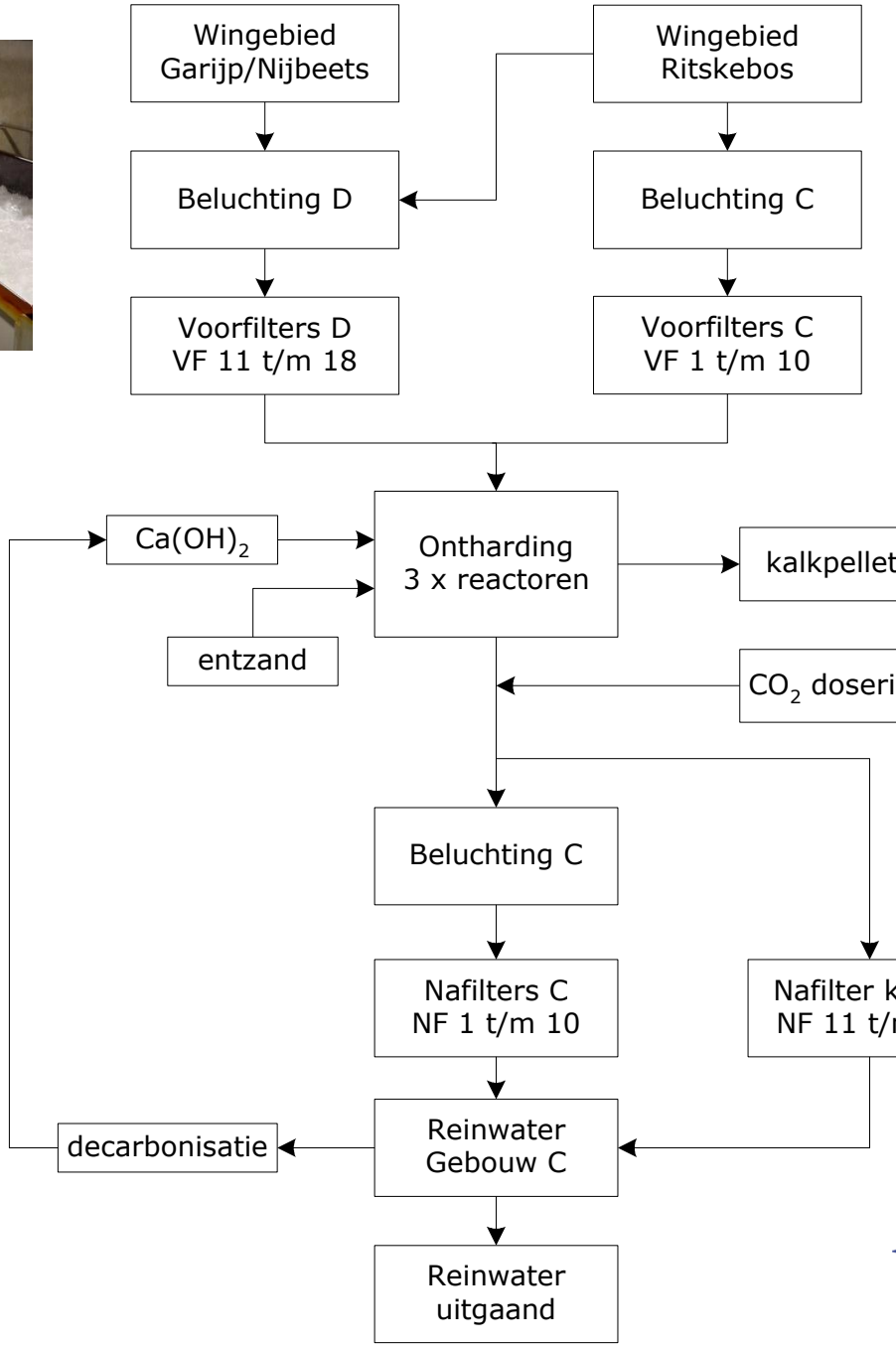
WTP

Noardburgum



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Water storage reservoir

- Even out demand and supply
- Stable production
- Emergency situations

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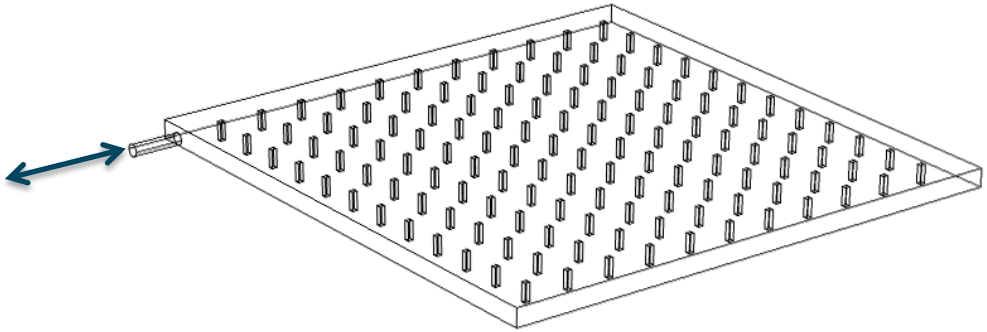
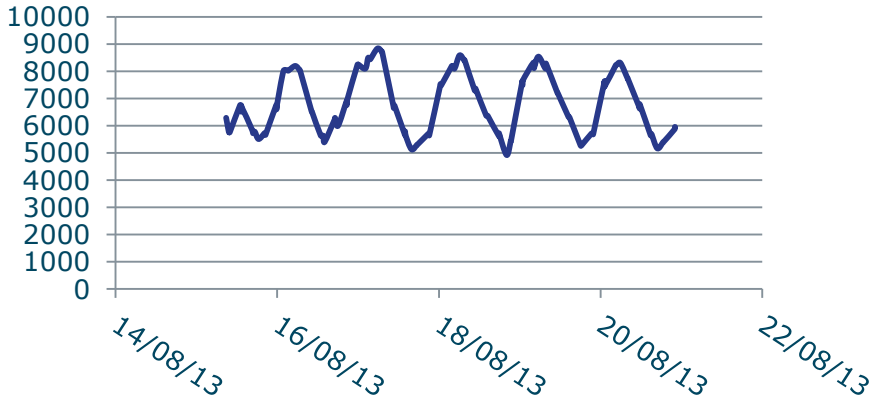
Current situation

Fill and Draw

- Fill time: t_f
- Mixing time: t_m
- Condition: $t_m < t_f$



Level WST Noardburgum



Length and width = 45 m
Height = 2.5 m
Inlet diameter = 1000 mm

During filling mixing takes place: Jet mixing

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Inspection en cleaning
WSR Noardburgum
29-1-2013

Problem

- Insufficient mixing: $t_m > t_f$?
  - Low velocities due to reduction production capacity
  - Inlet=outlet (LIFO)
  - Water aging (long residence time) (4 days)
  - Deterioration of water quality (bacteria count)
  - Accumulation of particles from treatment process
- Reservoir (full scale)
  - No measurements possible

Aims

- What are the mixing conditions in current situation
- How to improve mixing conditions by improving the existing design

→ Comsol Multiphysics model and scale model

Comsol Multiphysics

- 3D geometry
  - Pillars
- Transient turbulence model (k-ε/k-ω)
  - Inlet : velocity
  - Walls: wall functions
  - Pressure contraint point: p0=0
  - Wall (water surface) : moving wall in z-direction
- Transient convection-diffusion model
  - Continuous injection of tracer
  - Probe points

Scale model 1:25

- Validation Comsol model
- Similitude concept
- Dimensionless numbers Froude, Reynolds en Weber
- Not possible to achieve simultaneous equality
- Fr governing factor in flows with a free surface

$$Fr = \frac{U}{\sqrt{Lg}}$$

$$\mathrm{Re} = \frac{UL\rho}{\mu}$$

$$W = \frac{U^2 L\rho}{\sigma}$$

Length scale=L

Velocity scale=$L^{0.5}$

Area scale=L^2

Flow scale=$L^{2.5}$

Time scale=$L^{0.5}$

Volume scale=L^3

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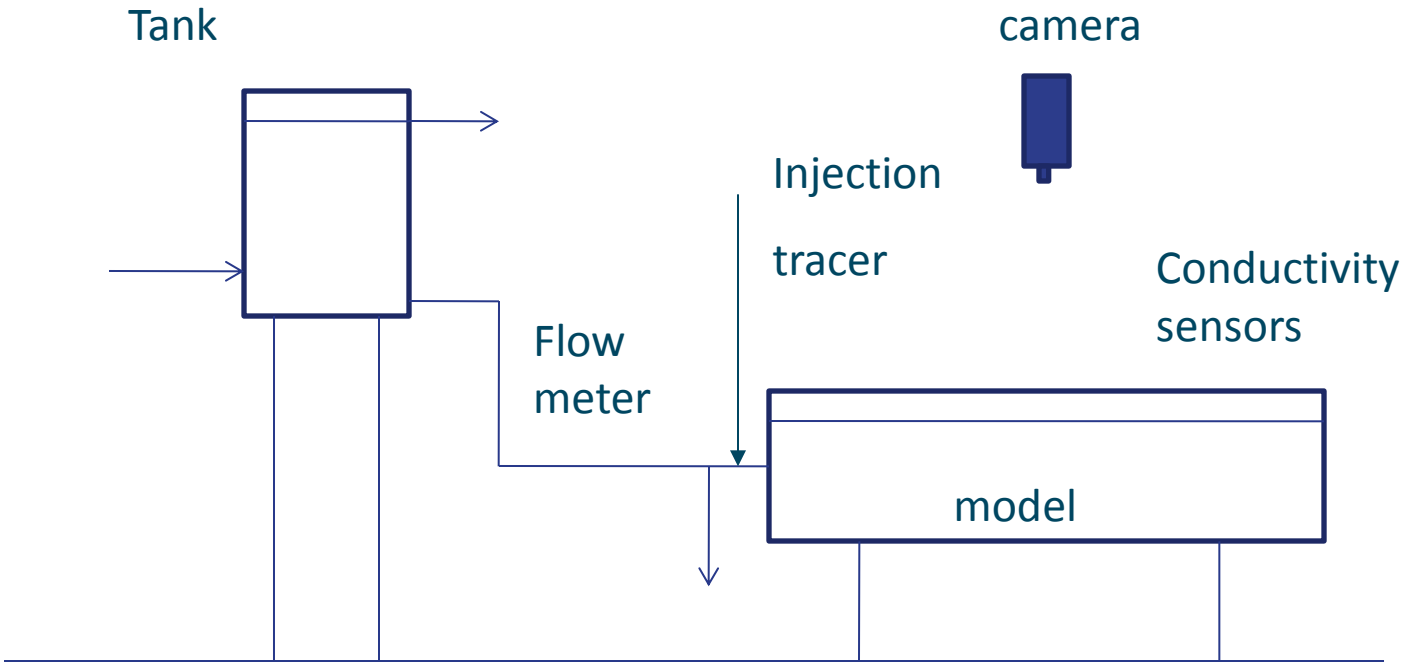
Scale model 1:25



- Dye (Rhodamine WT) and salt (NaCl) as tracer
- Comparison of camera images with Comsol model
- Determination of mixing time (conductivity sensors)

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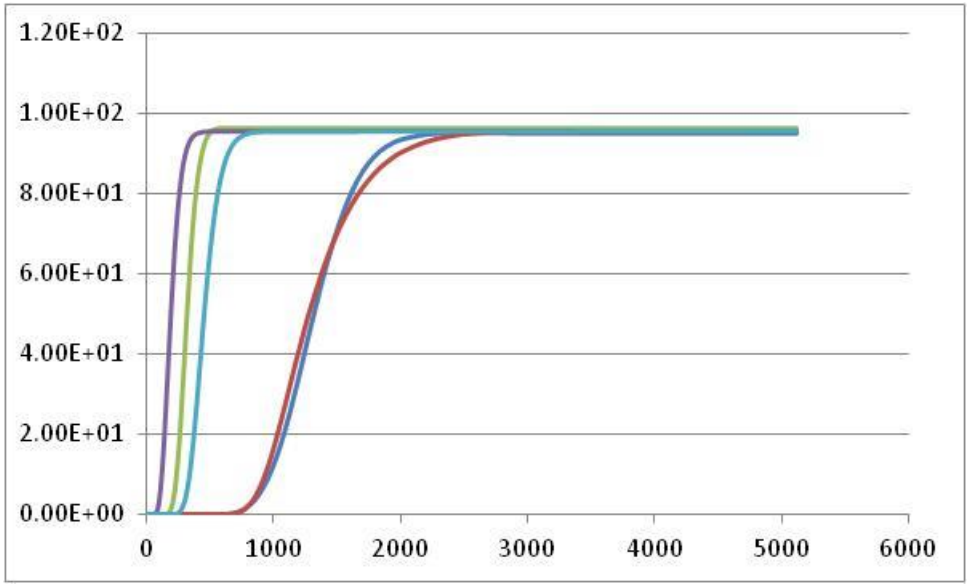
Scale model 1:25

Determining of mixing time

- Continuous injection of a tracer (NaCl) during filling (time dependent)

- Measuring concentration at different points (point probes) in reservoir and conductivity sensors in scale model



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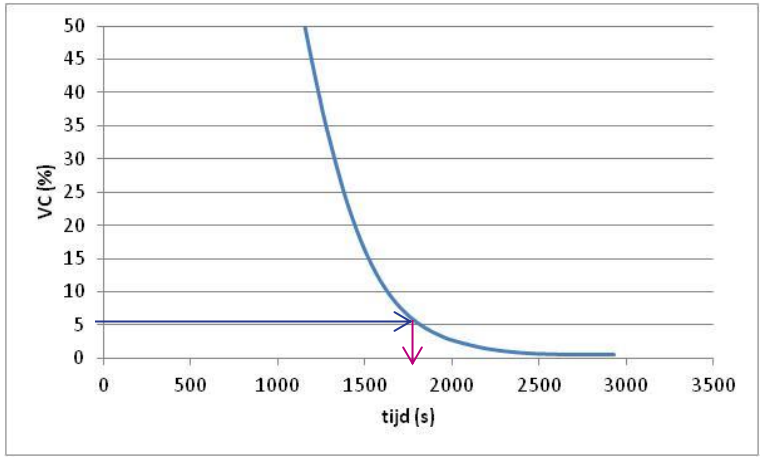
Determination of mixing time

- Tank tracer concentration homogeneous (95%) in tank
- Mixing time : Coefficient of variation CV drops to 5%

$$CV = \frac{\text{St. dev. local tracer concentration}}{\text{Average tracer concentration}}$$



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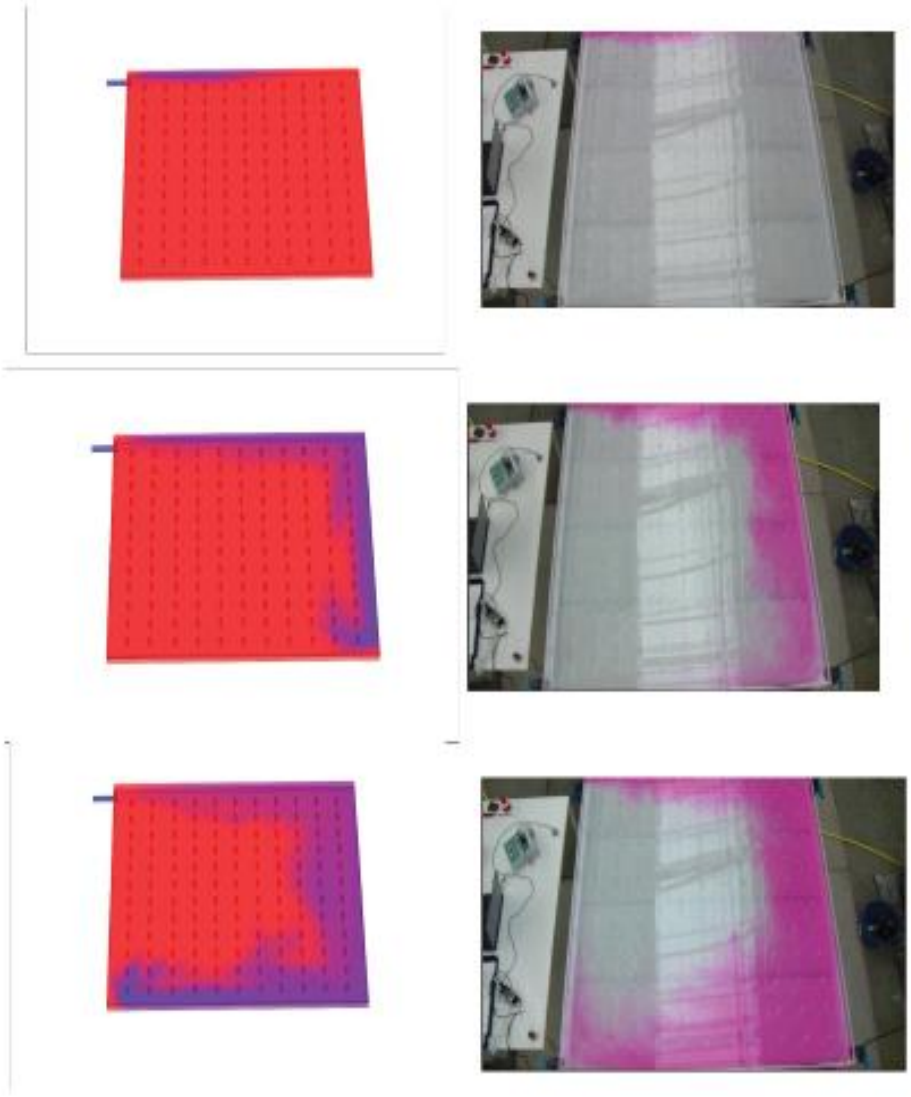

Figure 1: Snapshots of model and tracer experiment at 120 s, 240 s and 400 s

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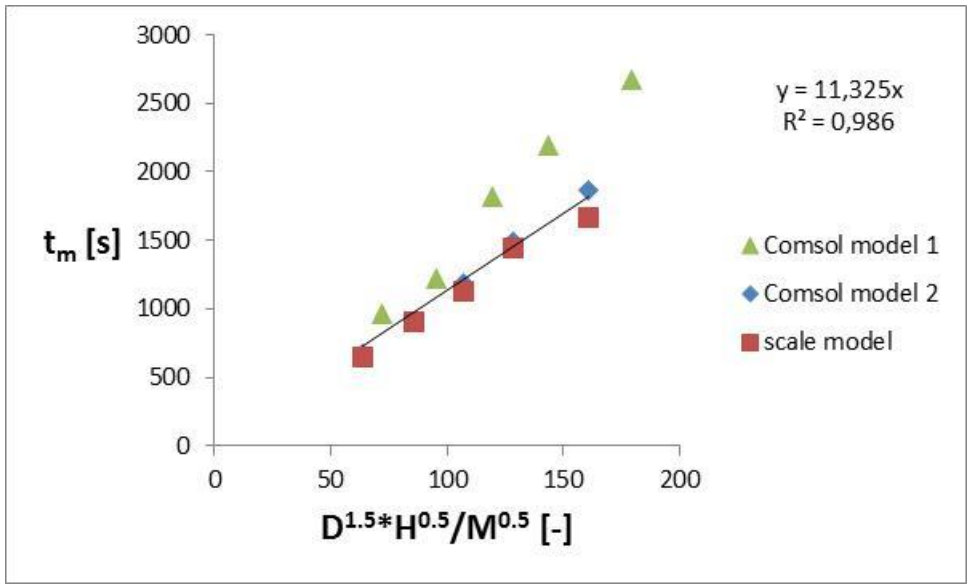
Mixing time : validation

- Model 1 no water level rising
- Model 2 including water level rising
- Scale model experiments



$$t_m = K \cdot \frac{D^{1.5} \cdot H^{0.5}}{M^{0.5}}$$

$$M = v \cdot Q_v$$

Okita en Oyama 1963	K=4.6
Rossman en Grayman 1999	K=10.7

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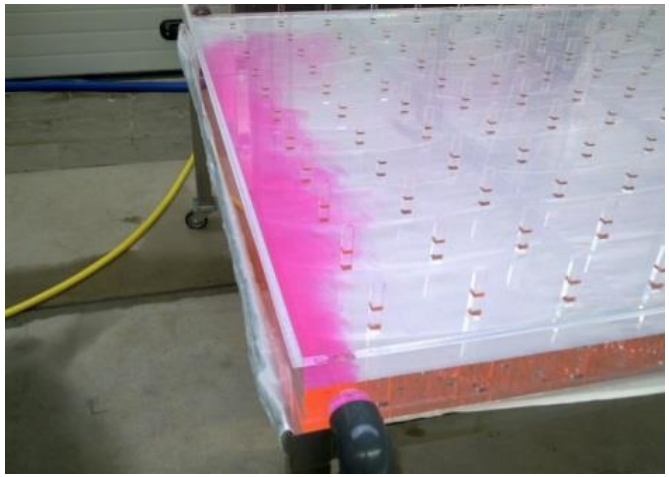
Design improvement: current situation

- Mixing time t_m = 13 h; Fill time t_f = 7 h
- No complete mixing during fill cycle $t_m > t_f$
- Velocity to low (0.07 m/s)
- Variables:
  - Velocity , momentum (diameter inlet)
  - Dimensions reservoir
  - Height initial water level
  - Location inlet

$$t_m = K \cdot \frac{D^{1.5} \cdot H^{0.5}}{M^{0.5}}$$

$$M = v \cdot Q_v$$



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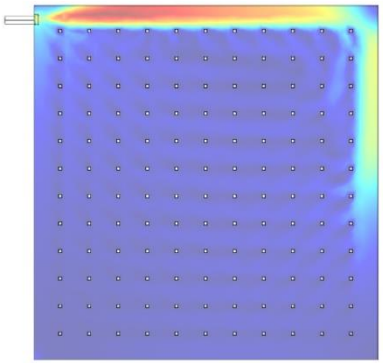
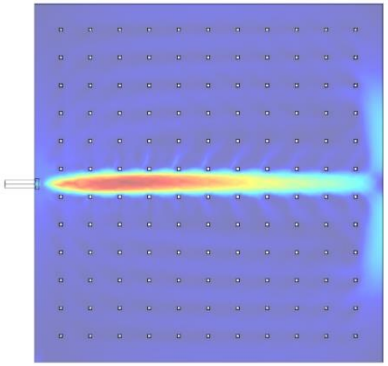
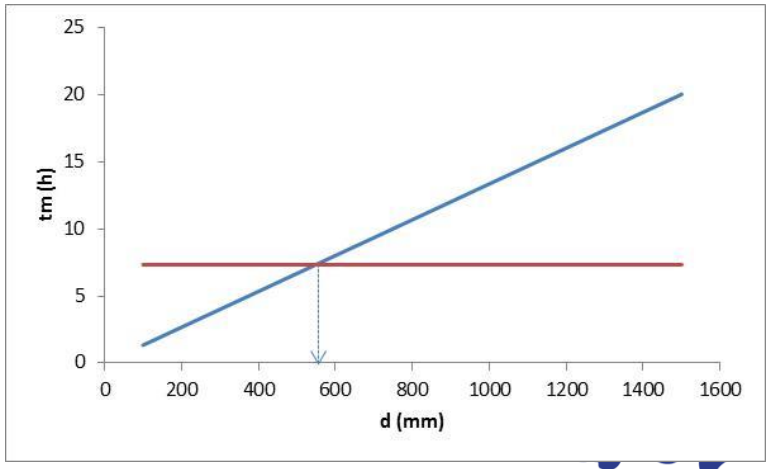
Design improvement

- Location of inlet/outlet
  - 25% improvement in mixing time





- Inlet/outlet pipe diameter
  - 1000 mm -> 500 mm



Conclusions

- Results Comsol Multiphysics are consistent with scale model results
- Condition $t_m < t_f$ is met if inlet/outlet diameter is 500 mm or less

- Comsol Multiphysics powerful (design) tool
- Validation necessary (experiments full scale on location or with scale model)

Further studies

- Complete Fill and draw cycle
- Coupling bacterial growth in relation to aging
- Particle Tracing (Calciumcarbonate particles)
- Coupling heat transfer
  - Water Storage reservoir above groundlevel
  - Influence Temperature on Water Quality

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