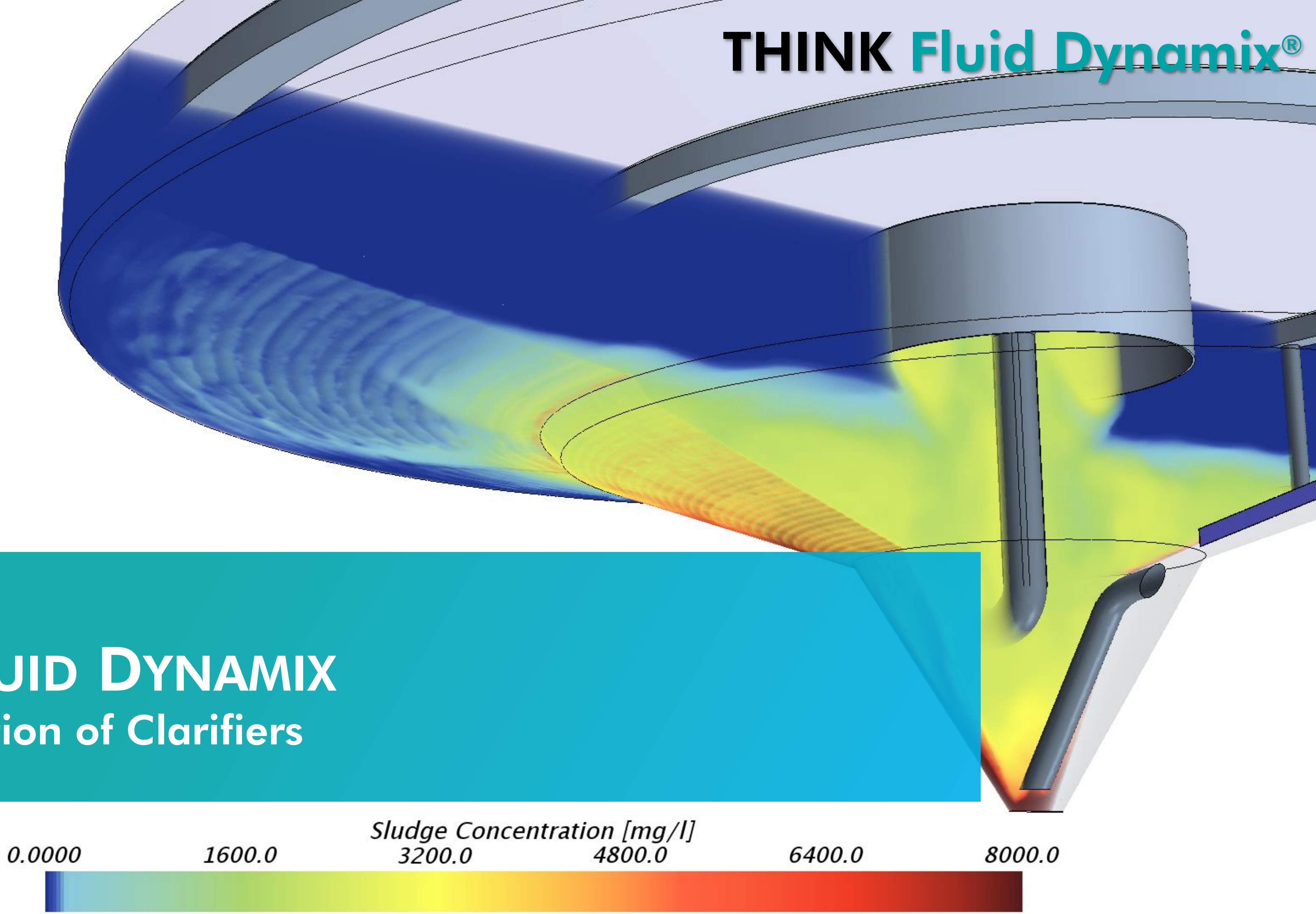
THINK Fluid Dynamix®



THINK FLUID DYNAMIX

CFD Simulation of Clarifiers

THINK Fluid Dynamix®

CFD Engineering & Consulting

Provided by:
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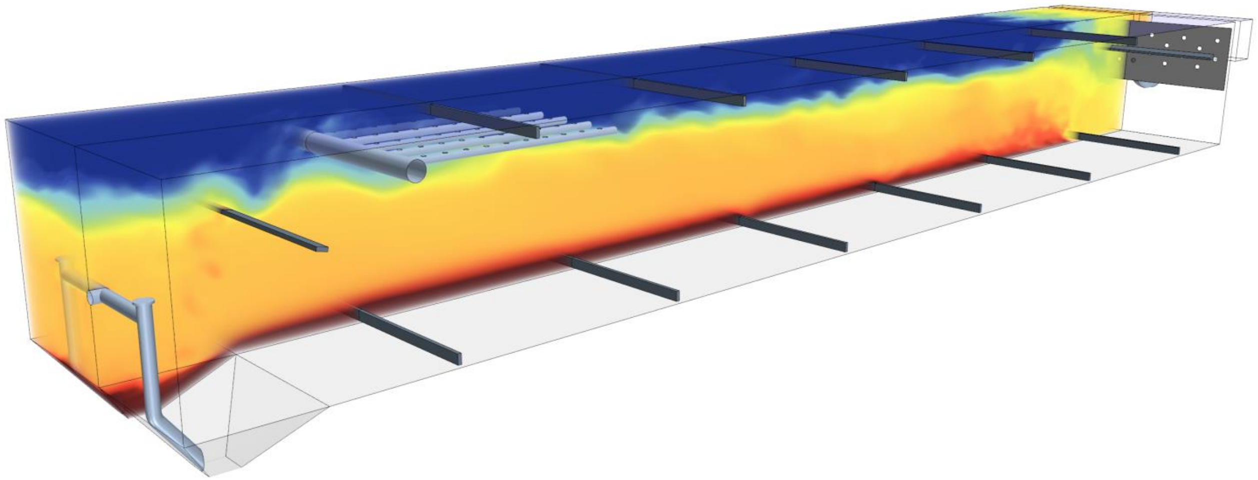
THINK Fluid Dynamix is the CFD based engineering and consulting business unit of **INVENT** Umwelt- und Verfahrenstechnik AG.

Definitions & Concepts

- What is a clarifier?
- Which is its principle of operation?
- Which are the most common shapes?

Clarifiers are settling tanks built with mechanical means for continuous removal of solids being deposited by sedimentation. Gravity separation of solids from liquid, producing a clarified overflow and a thickened solids underflow, has long been used in the wastewater treatment industry.

The shape of the clarifier determines whether the actual flow pattern approaches radial or plug-flow. Circular and rectangular clarifiers are the most popular. Circular clarifiers show a more reliable sludge-collecting performance while rectangular clarifiers can help to save surface area in the plant.



Example of rectangular clarifier

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Definitions & concepts

- Types of clarifiers

PRIMARY SEDIMENTATION

The objective of treatment by sedimentation is to remove readily settleable solids and floating material found in wastewater and thus reduce the suspended solids content. Efficiently designed and operated primary sedimentation tanks, can remove 50 to 70 percent of the suspended solids and from 25 to 40 percent of the BOD.

SECONDARY SEDIMENTATION

For activated sludge sedimentation tanks, the primary function is the removal of biological floc from the liquid stream. By means of gravity settling it is possible to remove over 99.5 percent of the mixed liquor TSS from the treated effluent. A secondary function is the thickening of the settled activated sludge to reduce the volume before returning it to the process for mixing and treatment with the influent wastewater.

Settling theory

- Types of settling based on solids concentration and flocculation tendency

Sedimentation Process

Settling basins handling wastewater must separate a variety of materials in the clarification zone. Depending on the concentration of the suspended solids and the tendency of the particles to flocculate, four distinct types of settling processes are typically recognized in wastewater treatment plant design:

Type I: Discrete nonflocculent settling

The settling of discrete, nonflocculating particles can be analyzed by means of the classic laws of sedimentation formed by Newton and Stokes. These particles settle independently at their terminal velocity. Newton’s law yields the terminal particle velocity be equating the gravitational force of the particle to the frictional resistance, or drag.

Type II: Flocculent Settling

Particles in relatively dilute solutions will not act as discrete particles but will coalesce during sedimentation. As coalescence or flocculation occurs, the mass of the particle increases, and it settles faster. As the settling velocities of the aggregates formed change with time and a strict mathematical solution is not possible, laboratory testing is required to characterize the settling behavior.

Settling theory

- Types of settling based on solids concentration and flocculation tendency
- Sludge Rheology

Type III: Hindered Settling or Zone Settling

Type III settling is the predominant mechanism in secondary clarifiers. The solid concentration is much higher than in discrete or flocculent processes. As a result, the contacting particles tend to settle as a zone or blanket and maintain the same position relative to each other.

Type IV: Compression Settling

Particles have reached such a concentration that a structure is formed and further settling can only occur by compression. This type of settling typically occurs in the lower layers of a deep sludge mass such as near to bottom of secondary clarifiers and sludge thickeners.

Sludge Rheology

Wastewater sludges behave as non-Newtonian fluids at high solids concentration such as those often found at the bottom of the sludge blanket. This has an important implication in collection and removal of thickened sludge. Geinopolos and Katz (1964) showed that primary, secondary , and also digested sludges behave as visco-plastic materials.

Measurement of Sludge Settleability

- Sludge Volume Index

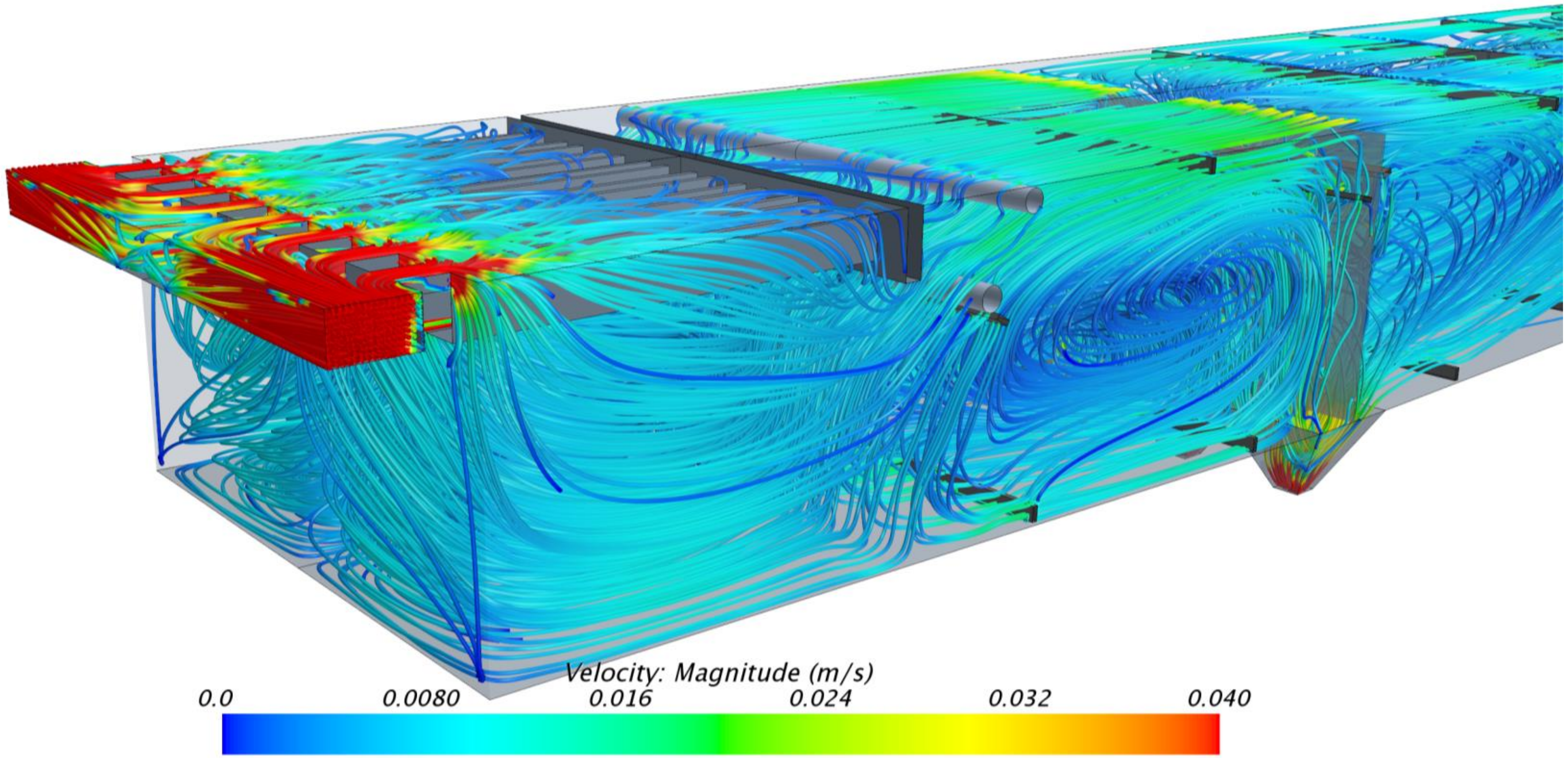
Sludge settleability is central to the health of the biological system. Poor settling sludge causes lower underflow (RAS) solids concentration because of poor compaction. As fewer solids are removed from the tank than applied to it, the sludge blanket can propagate to the surface of the clarifier, resulting in loss of solids in the effluent. Consequently, measuring sludge settleability is fundamental to the operation and control of the biological system.

Sludge Volume Index

Historically, the SVI has been used most commonly as a measurement of sludge settleability. It is the volume in milliliters occupied by 1gramm of a suspension after 30 minutes of settling. Standard methods specifies gently stirring the sample during settling to eliminate or minimize wall effects. Dick and Vesilind (1969) noted that, for the same samples, slow stirring yielded consistently lower SVI values than the unstirred tests.

Numerical Modeling

- What is CFD?



Computational Fluid Dynamics (CFD) is an advanced computer-based technique which uses numerical procedures to solve and analyze problems that involve fluid flow.

Numerical simulations are the perfect environment to identify problems, to perform parameter studies and to optimize existing designs.

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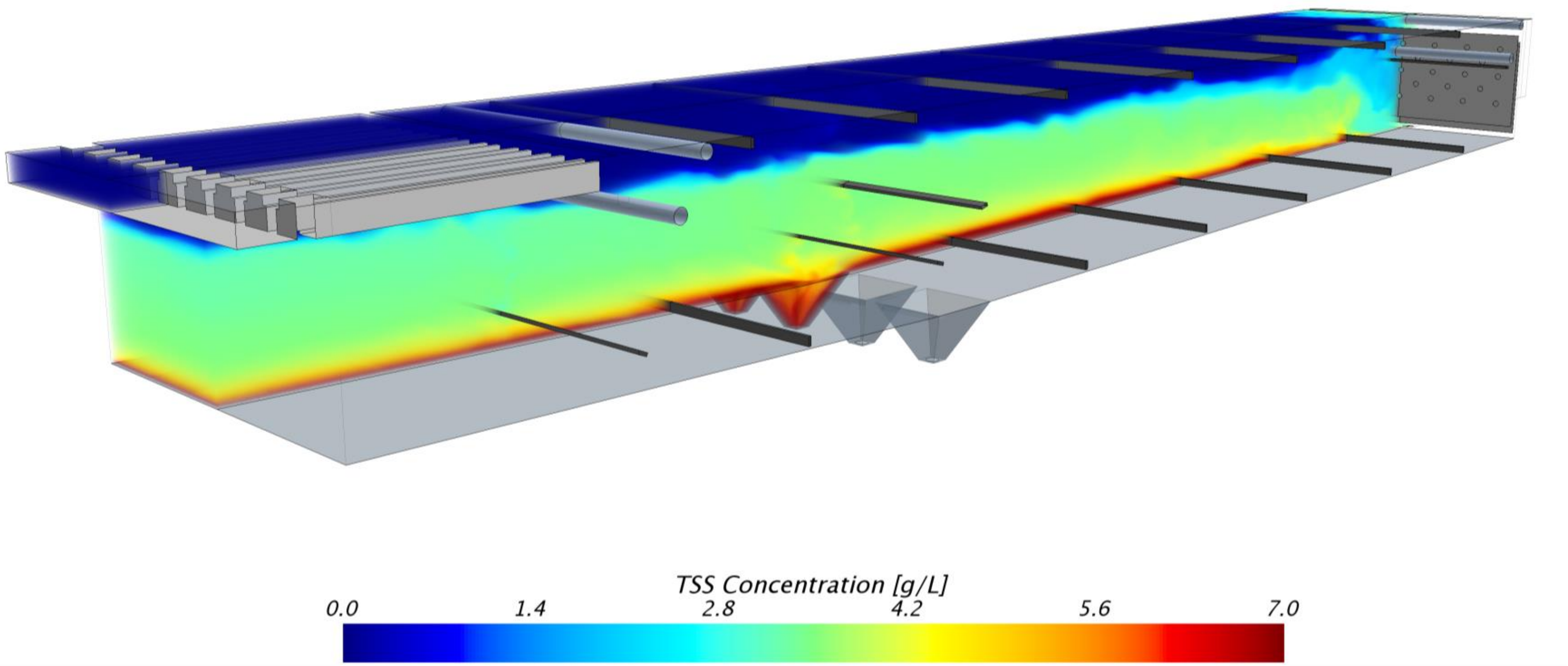
Computational Fluid Dynamics

- How to model settling tanks?



An accurate CFD simulation of a settling tank requires the following models:

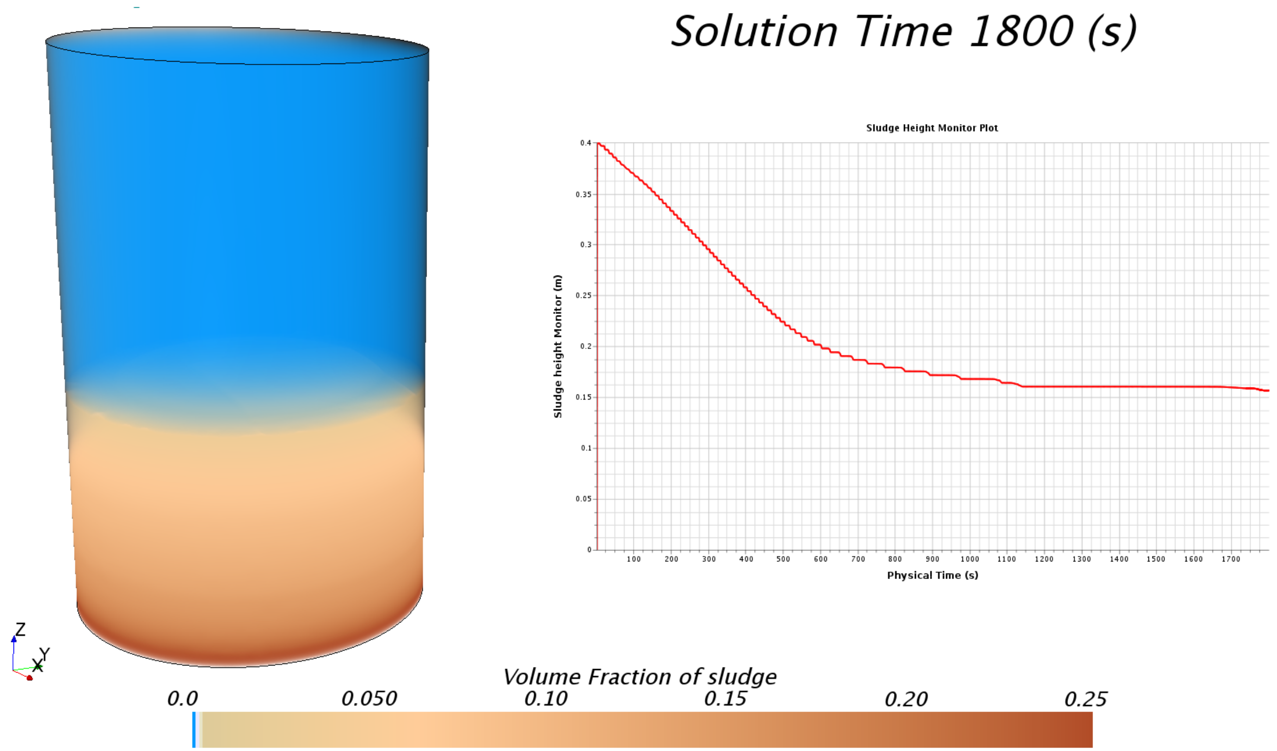
- 3 Dimensional domain
- Time-dependent analysis
- Motion of mechanical parts
- Multiphase modeling
- Settling model (which takes into account flocculation and rheology effects)

Numerical Modeling

- Settling behavior

- Sludge Volume Index

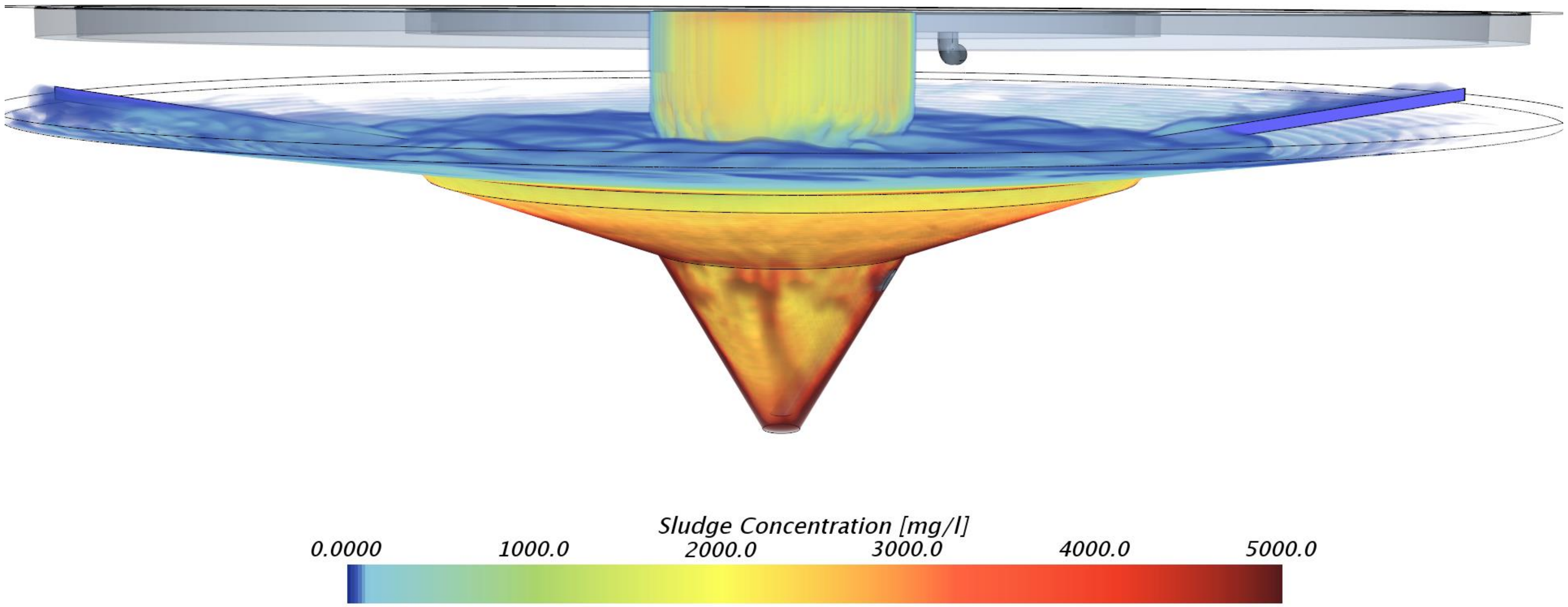
CFD animation in YouTube



The results obtained by settling test (such as the SVI) carried out in a laboratory can be also numerically reproduced by means of a "Multiphase Simulation". By proper setup of the numerical parameters a correct agreement between numerical and physical test can be achieved. The accurate modeling of the settling characteristics of solid matter in the clarifier is essential in order to produce reliable results and been able to simulate the process operation correctly.

Simulation of Reactor Operation

Correct set of parameters based on experimental data



For any clarifier, the sludge settling characteristics can be numerically modeled based on experimental data such as the SVI and the average Total Suspended Solids at the inlet.

After all process parameters are correctly defined an accurate simulation of the reactor operation is possible.

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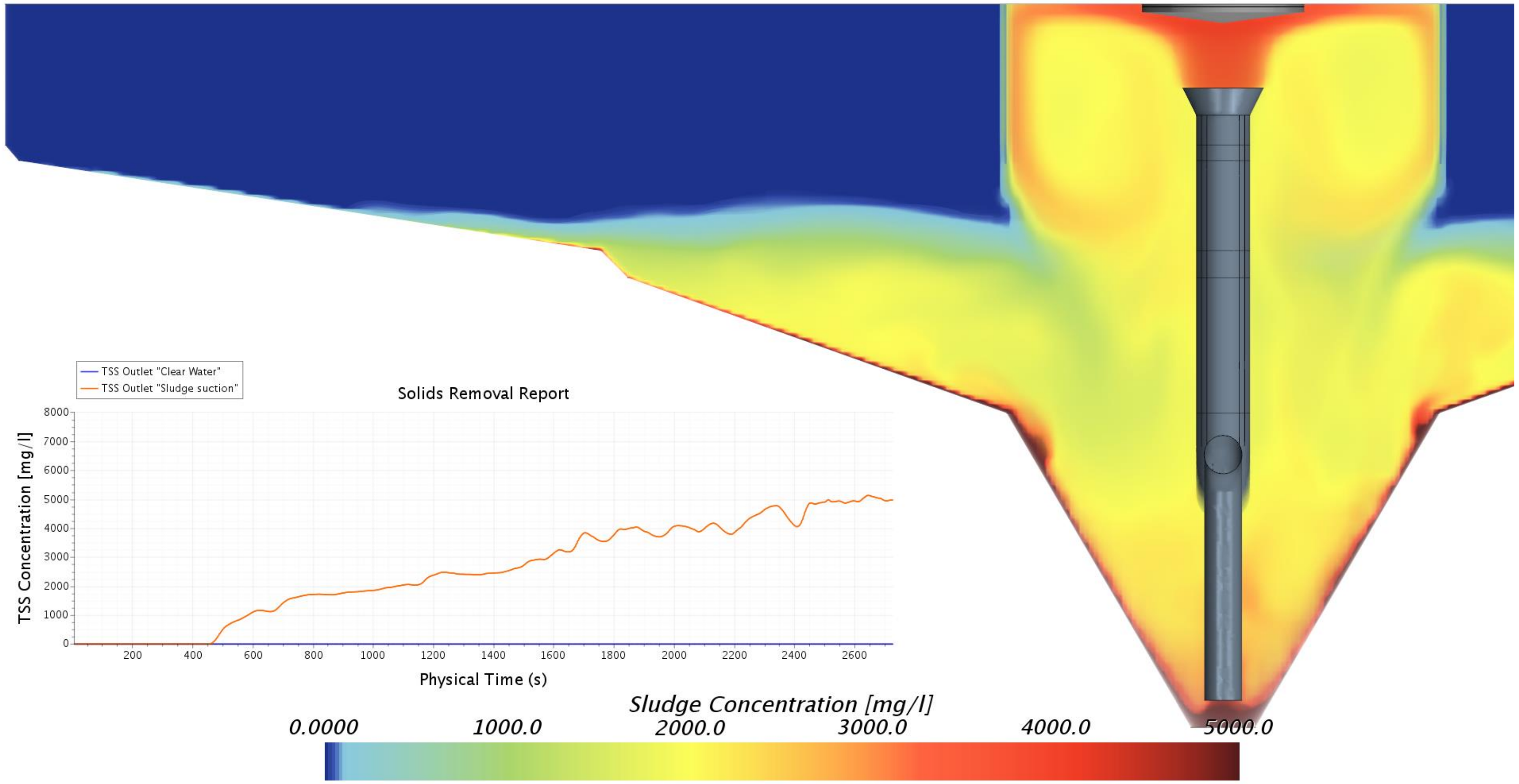
Real Time Simulation

An unparalleled way of studying and understanding process operation

CFD animation in YouTube



High resolution real time simulations open up completely new ways to study and to understand process operation: the evolution of the TSS profile can be analyzed over time for the complete system and the solid concentration can be tracked for all outlets. Time fluctuations of the flow velocity field can be studied as well as the motion of the mechanical scrappers and their influence on the system.

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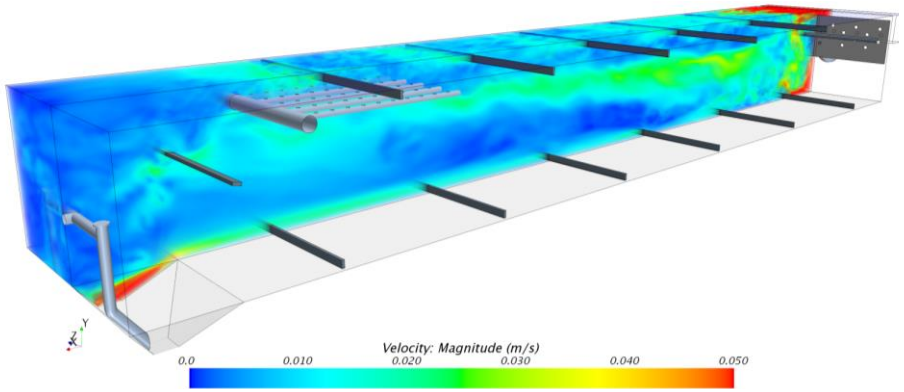
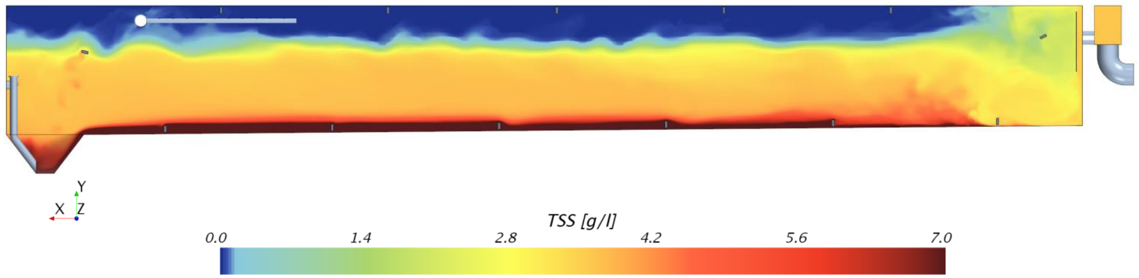
Simulation of Rectangular Clarifiers

Study of velocity and solid concentration field in real time.

CFD animation in YouTube





In many plants around the world, rectangular clarifiers can be found. They offer many advantages such as the need for less land and construction costs in multiple unit design, and there are less chance for short-circuiting. On the other hand they have the disadvantage of longer detention time for settled sludge.

With real-time CFD simulation the operation of the basin and the degree of solids removal can be studied, issues can be identified and non-optimal designs can be optimized.

Modeling of Clarifiers

A new way of studying process operation

A new way of design and optimization

Numerical simulations are the perfect environment for identification of problems, parameter studies and optimization work

- Accurate modeling of sludge and their settling characteristics based on experimental data
- Real time simulation of the process
- Simulation and analysis of the motion of mechanical parts (scrappers) and their effects on the reactor behavior
- Full description of velocity and concentration field over entire reactor space and physical time

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Technical Competence

Company Video in YouTube

THINK Fluid Dynamix offers support and assistance with the design, optimization, and modernization of hydraulic structures in water and wastewater treatment plants.

More than 25 years of experience innovating and developing revolutionary solutions allow us to provide unique and in-depth analysis and solutions. We have a comprehensive functional and industrial expertise, and are passionate about taking on challenges that matter to our clients and to the environment.

The design of optimized process applications and hydraulic structures for the water and wastewater treatment industry requires a high level of multidisciplinary scientific and engineering skills. An optimal solution should show energy efficiency while maintaining a robust and reliable system approach

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Sources:
Metcalf & Eddy (2014), Wastewater Engineering, 5th ed.
T. E. Wilson (2005), Clarifier Design, 2nd Edition