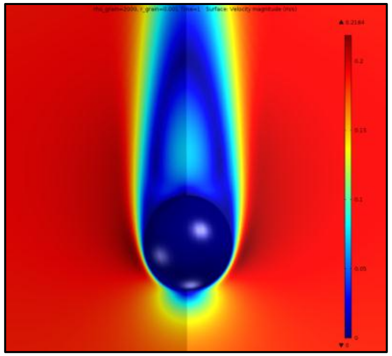
COMSOL CONFERENCE INDIA 2012



Multiphysics Simulations of Granular Sludge on the Optimization of Effluent Treatment Plant

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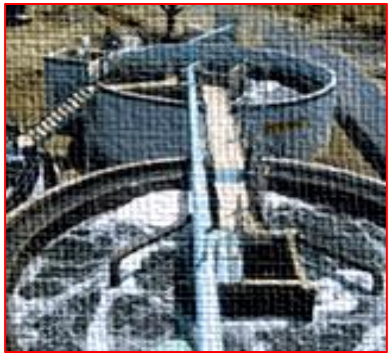


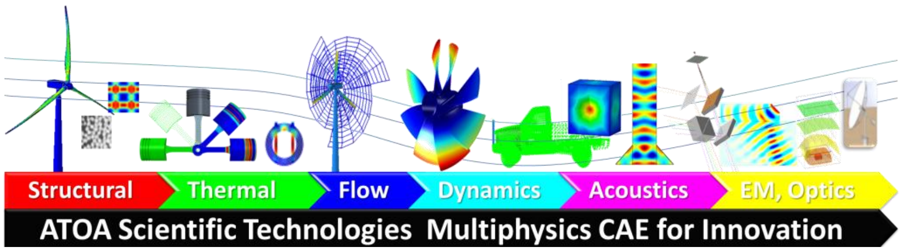
Excerpt from the Proceedings of the 2012 COMSOL Conference in Bangalore

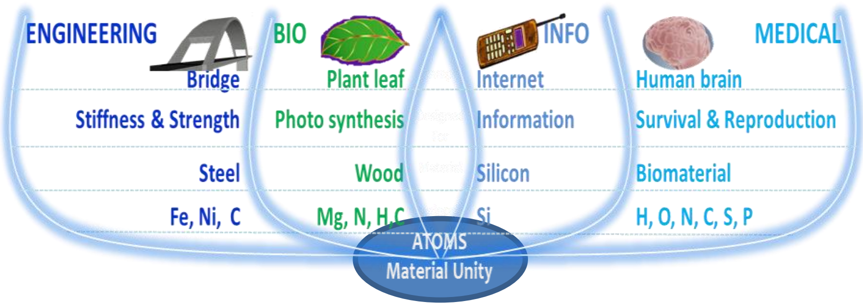
ATOA Scientific Technologies

Multiphysics CAE for Innovation ™

ATOA Scientific Technologies (ATOAST)

- Engineering Simulation Solution Provider for First Time Right Design.
- Bridge Atom to Application to Proliferate Simulation (Multiphysics, Multiscale & multimaterial) for cost effective Innovation.
- ATOAST's Technical Vision is Driven by Material Unity
- ATOAST Global with HQ's in Bangalore
- India's First COMSOL Certified Consultant
- ATOAST JYOTHI Foundation empowers our social mission.





COMSOL certified consultant

Introduction

Effluent Treatment Plant (ETP)

Most challenging: Stringent environmental norms-

Focus Area: Activated Sludge Process (ASP)

Benefits:

- ✓ Optimized Design
- ✓ Reduced costs
- ✓ Reduced BOD &COD

Tool: COMSOL Multiphysics

Chemical Reactions depleting O_2

Organic matters ('C') in effluent deplete dissolved O_2.

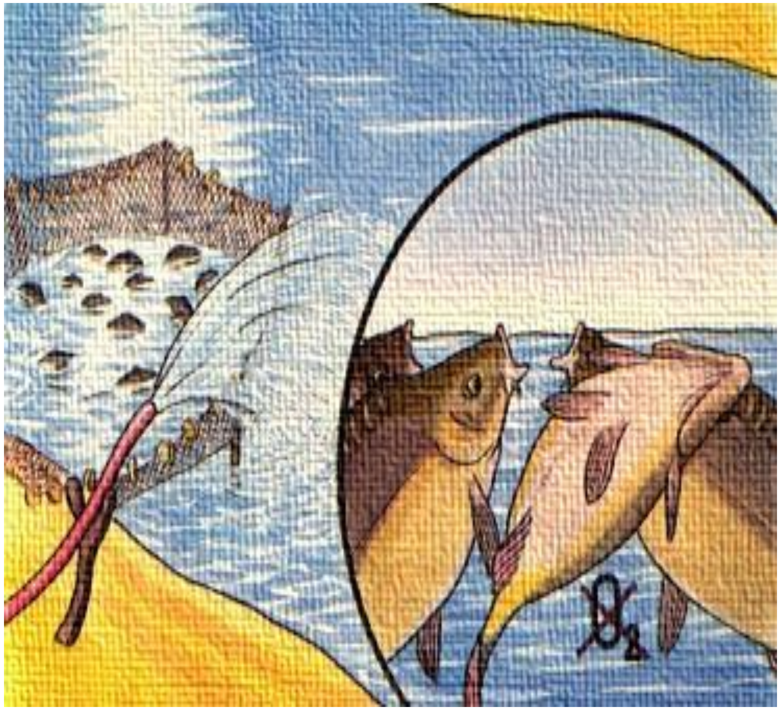
Nutrients (N_2, P) lead to algae growth, causing O_2 depletion.

'C' + Bacteria + Nutrient + $O_2 \rightarrow$

CO_2 + H_2O + Biomass (Sludge)

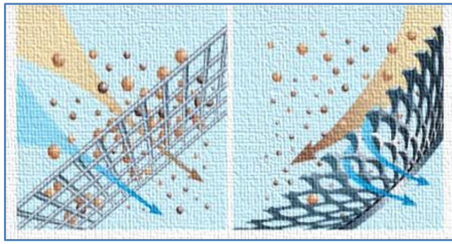
O_2 is also consumed by reducing chemicals in waste water:

- $S^{-2} + 2\,O_2 \rightarrow SO_4^{-2}$
- $NO_2^{-} + \frac{1}{2}\,O_2 \rightarrow NO_3^{-}$



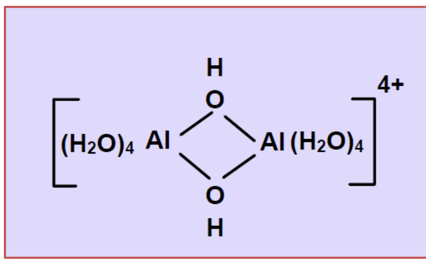
Harmful for Aquatic Environment

ETP Processes



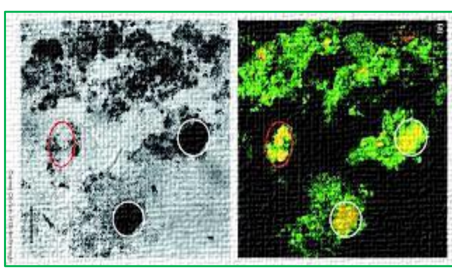
Physical

- Screening
- Flow Equalization
- Sedimentation
- Floatation
- Granular Separation



Chemical

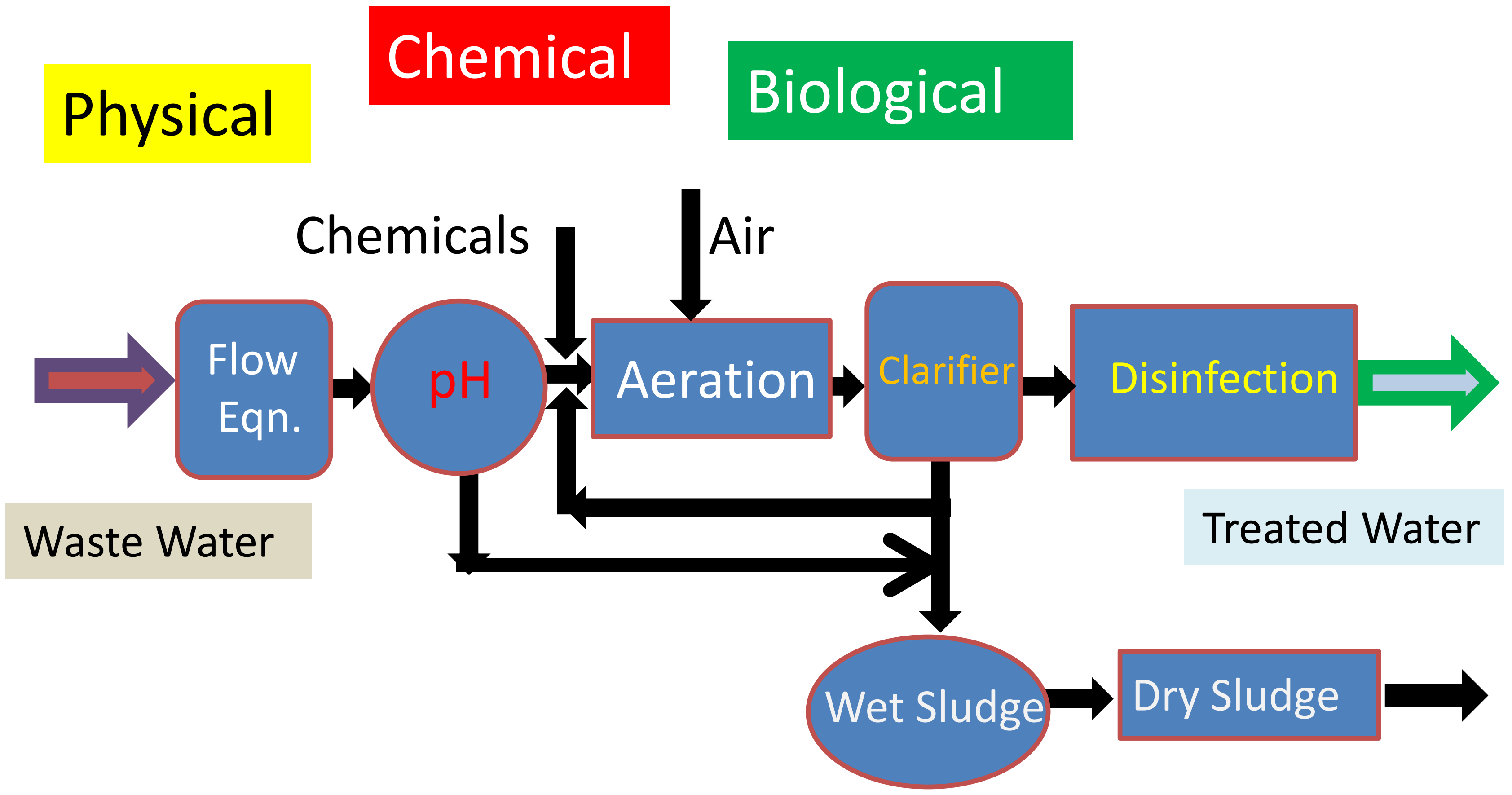
- Precipitation
- Adsorption
- Disinfection
- Dechlorination
- Other Chemical Means



Biological

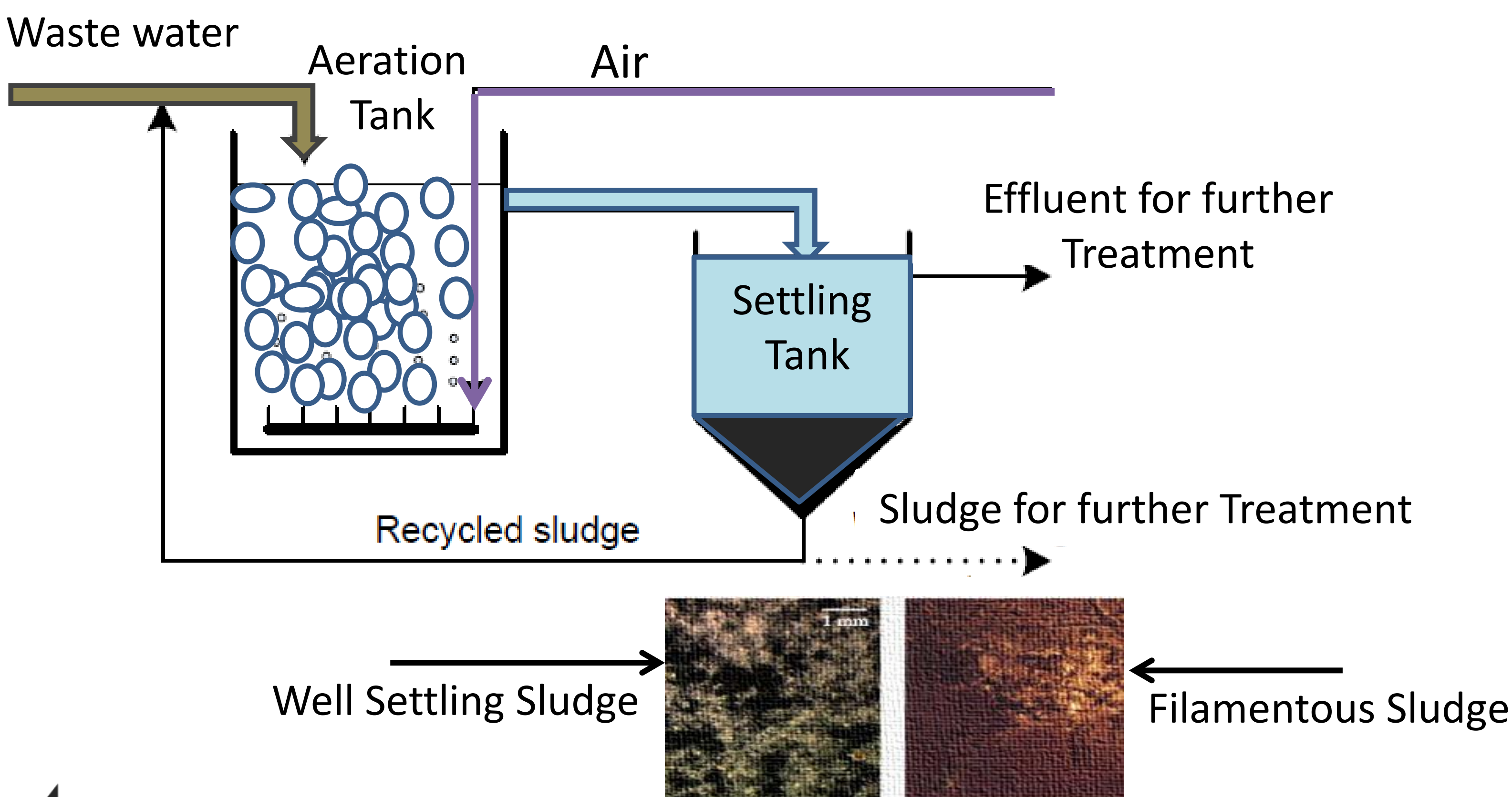
- **Activated Sludge Process**
- Aerated Lagoons
- Trickling Filters
- Anaerobic Digestion
- Nutrient Removal

ETP Flow Chart



Activated Sludge Process (ASP)

Under aerated conditions, microorganisms thrive, forming an active suspension of bio-solids (mostly bacteria) called an "*activated sludge*."



Settling in ASP is critical - Better settling - Better reduction in COD

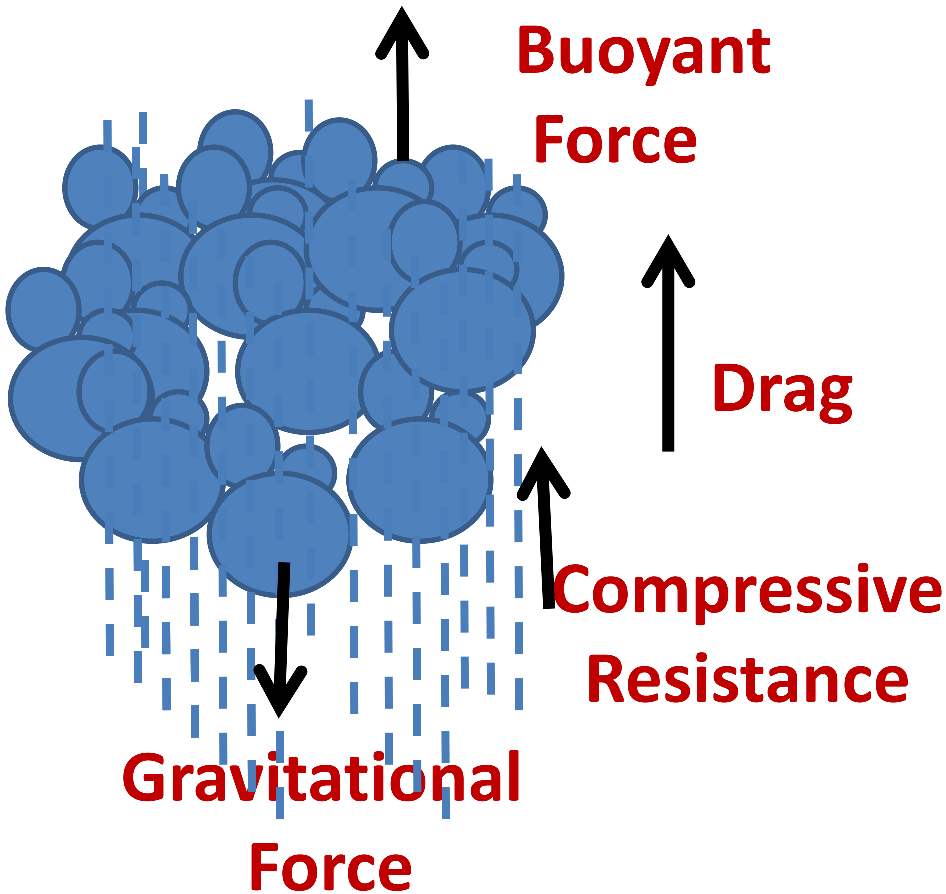
Optimized Sludge Settling

Stokes Law –Particle Settling Velocity: $v = 2r^2g(d\text{-}D)/9N$

It shows, efficient way is to **increase radius**.

In reality, flocs are not spheres.

Spherical granular Sludge in ASP, presents optimum cross sectional area to volume ratio, for optimized settling.



Numerical Simulation

Gravity Settling in ASP is economical 

But, complex to study & optimize due to bio- nature 

A numerical model is best suited by coupling fluid flow to particle motion with ODE. The single-phase fluid-flow governed by Navier-Stokes Eqn. helps us to model settling behavior.

Continuity Eqn.1 represents conservation of mass; Vector Eqn.2 rep. Conservation of Momentum, Conservation of Energy Eqn.3 and Constitutive relation for Newtonian fluid eqn.4 are :

1. $\frac{\partial \rho}{\partial t} + \nabla.(\rho u) = 0$
2. $\rho \frac{\partial u}{\partial t} + \rho(u.\nabla)u = \nabla.(-pI + \tau) + F$
3. $\rho C_p \left\{\frac{\partial T}{\partial t} + (u.\nabla)T\right\} = -(\nabla.q) + \tau : S - \frac{T}{\rho}\frac{\partial \rho}{\partial T}|_p \left\{\frac{\partial \rho}{\partial T} + (u.\nabla)p\right\} + Q$
4. $\tau = 2\mu S - \frac{2}{3}\mu(\nabla.u)I$

Results and Discussions

The sludge particle accelerates from a standstill position and rapidly reaches its terminal velocity.

Effects of sludge density, sludge particle size, density of aqueous medium are investigated as function of velocity of sludge granules. Figure 1 shows the contour plots for a typical sludge size, sludge density and effluent density.

Simulations data help us to identify flow pattern for optimal design of biological treatment in advanced ETP.

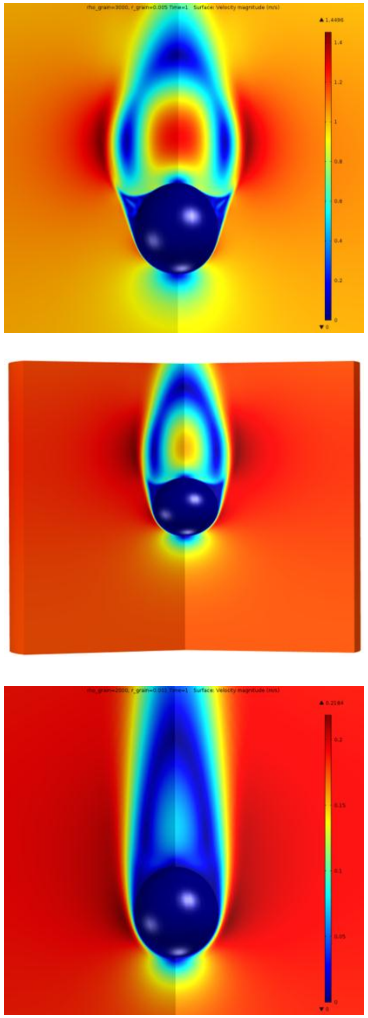


Figure 1

Results and Discussions

Simulation data indicate sludge settling depends mainly on physical characteristics of effluent and granules.

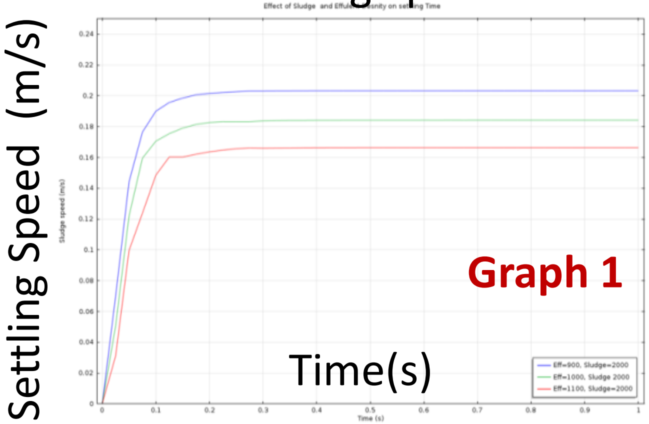
Reduction in effluent density increases the settling speed of the sludge granule.

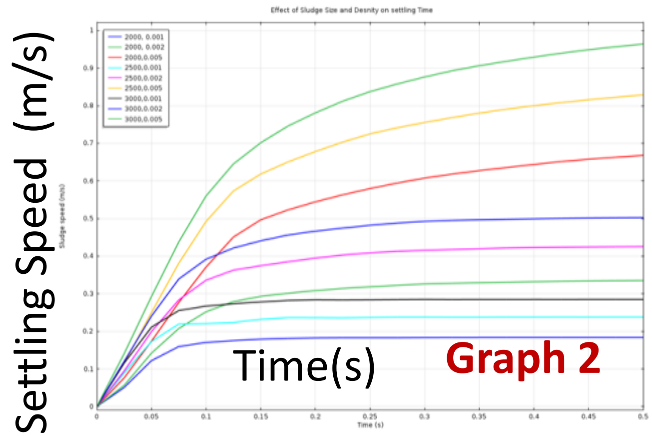
(Graph 1).

Increase of both density and size of sludge particle increases settling speed (Graph 2).

Results show settling behavior can be estimated and used for design of biological ETP. Simulation data compare experimental observation & published results.

Effect of Effluent Density on Settling Speed



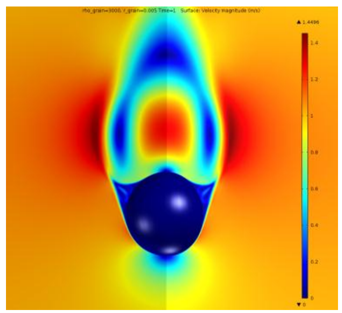


Effect of Sludge Size &Density on Settling Speed

Conclusion

Problem

Analyze



Optimize

Solution