17th Minisymposium Verfahrenstechnik and 8th Partikelforum, BOKU

Modelling of Multi-Stage Internal Loop Air Lift Bioreactor Utilizing Computational Fluid Dynamics

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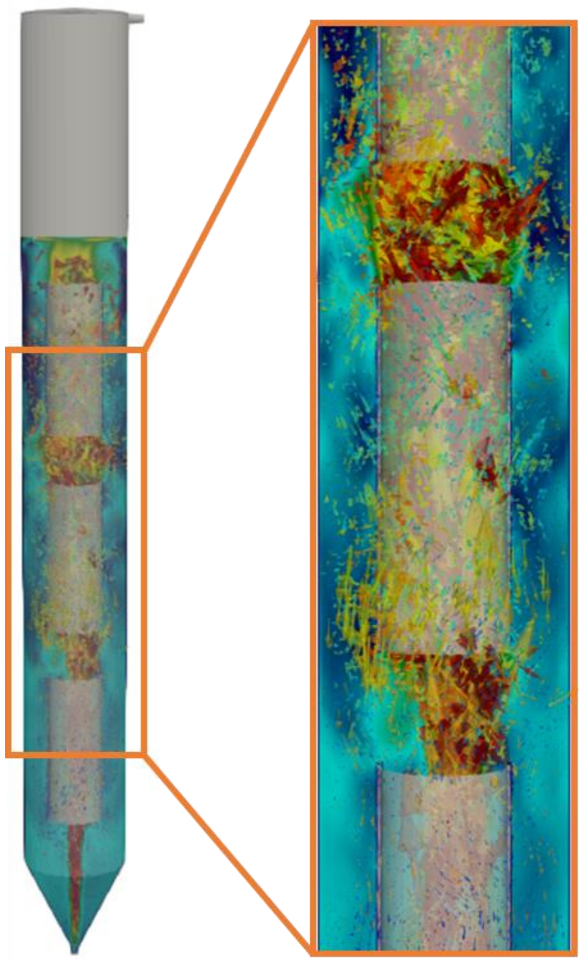
13 April 2023. Vienna, Austria.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 860477

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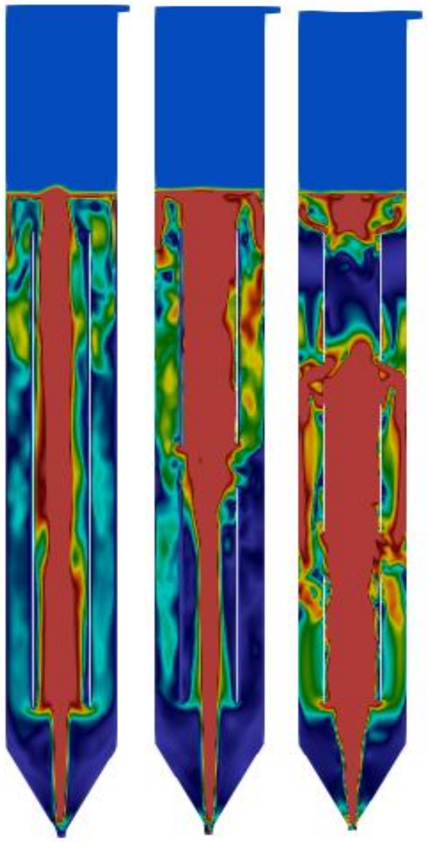

About AgRefine – European Training Network

- Green biorefineries
- 15 PhD students, interdisciplinary projects
- 3 work packages


Technology


System-level analysis


Value chains

UCD Dublin
DTU Technical University of Denmark
TU Wien Technische Universität Wien
Ghent University
Wageningen University & Research
BMRS Bantry Marine Research Station
ces Clean Energy Solutions
Avecom Bioproducts & Apps
BIOG Solutions for Green Energy
Comhairle Contae Thiobraid Árann
Tipperary County Council
CERTH Centre for Research & Technology Hellas
EBA European Biogas Association
Innolab
enviroeye

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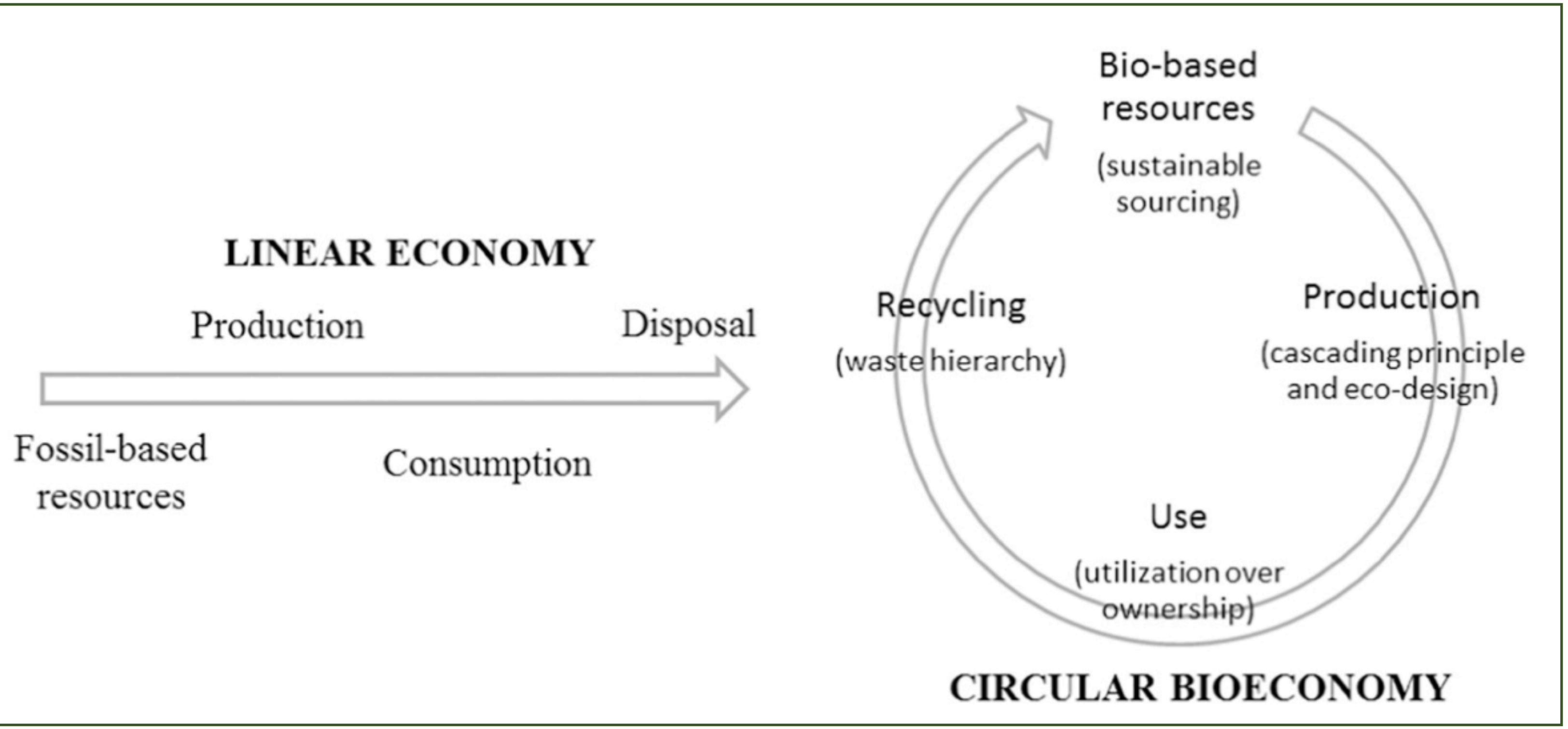
Transition to the circular bioeconomy

(Figure from D'Amato, Veijonaho, and Toppinen (2020))



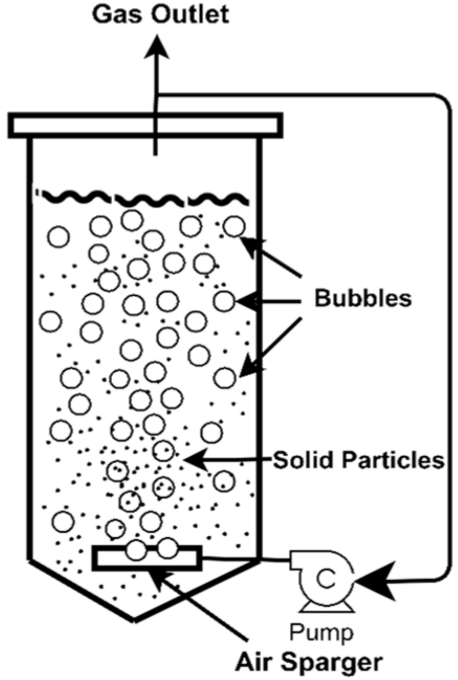
(Figure from biorefinerygroup.com)

Reactor types

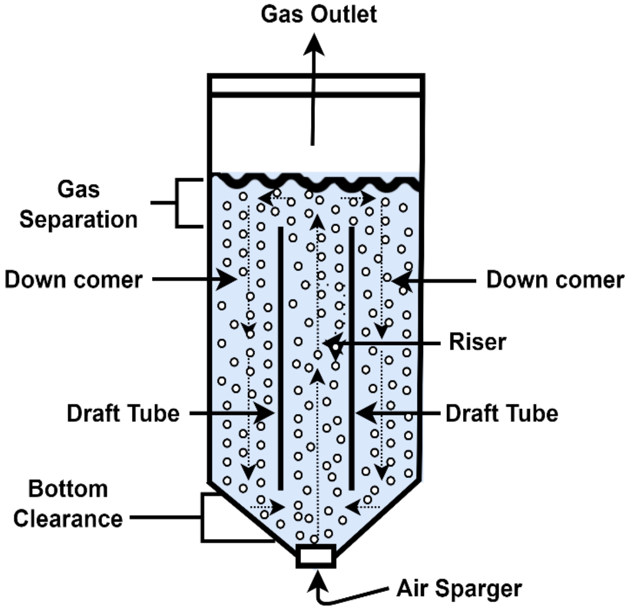
Mechanically stirred

Continuously stirred tank reactor

Pneumatically stirred



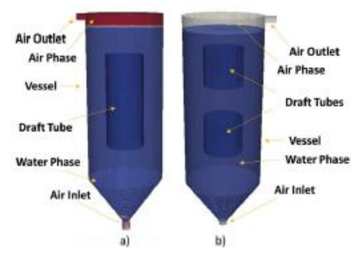
Bubble column



Air lift reactor

My works on ALRs

2021 – EU Project Report



CFD optimisation and analysis of existing Anaerobic Digestion and Biorefineries Report

2021 – Poster Vienna SS

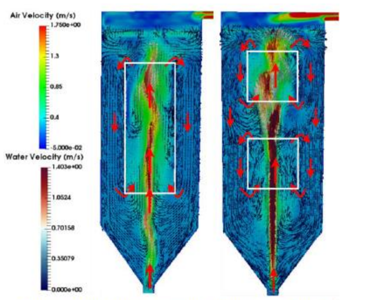
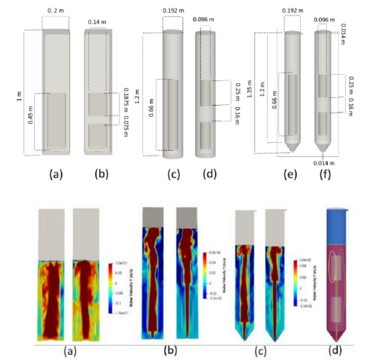


Figure 2. Flow pattern generated by both geometries.

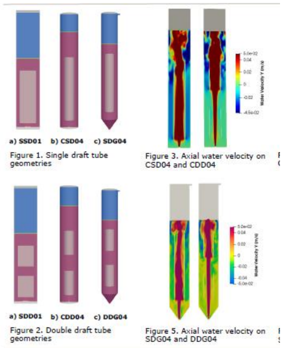
CFD simulation of flow inside air lift bioreactors

2022 – PRES22 Conference



Modelling and Design of Optimal Internal Loop Air-Lift Reactor Configurations Through CFD

2022 – Poster Gent



Modelling And Characterization Of Internal Loop Air Lift Bioreactor Configurations Through CFD

2023 – EU Project Report

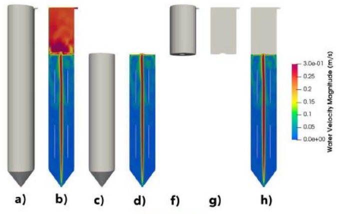


Figure 74. Threshold utility

Geometry and CFD results for Anaerobic Digestion retrofit and Three Phase Bioreactor up-scaling Report

2023 – Energies MDPI

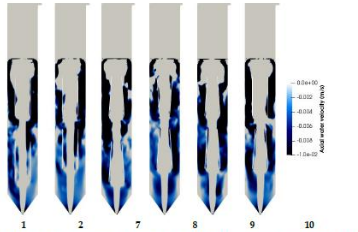
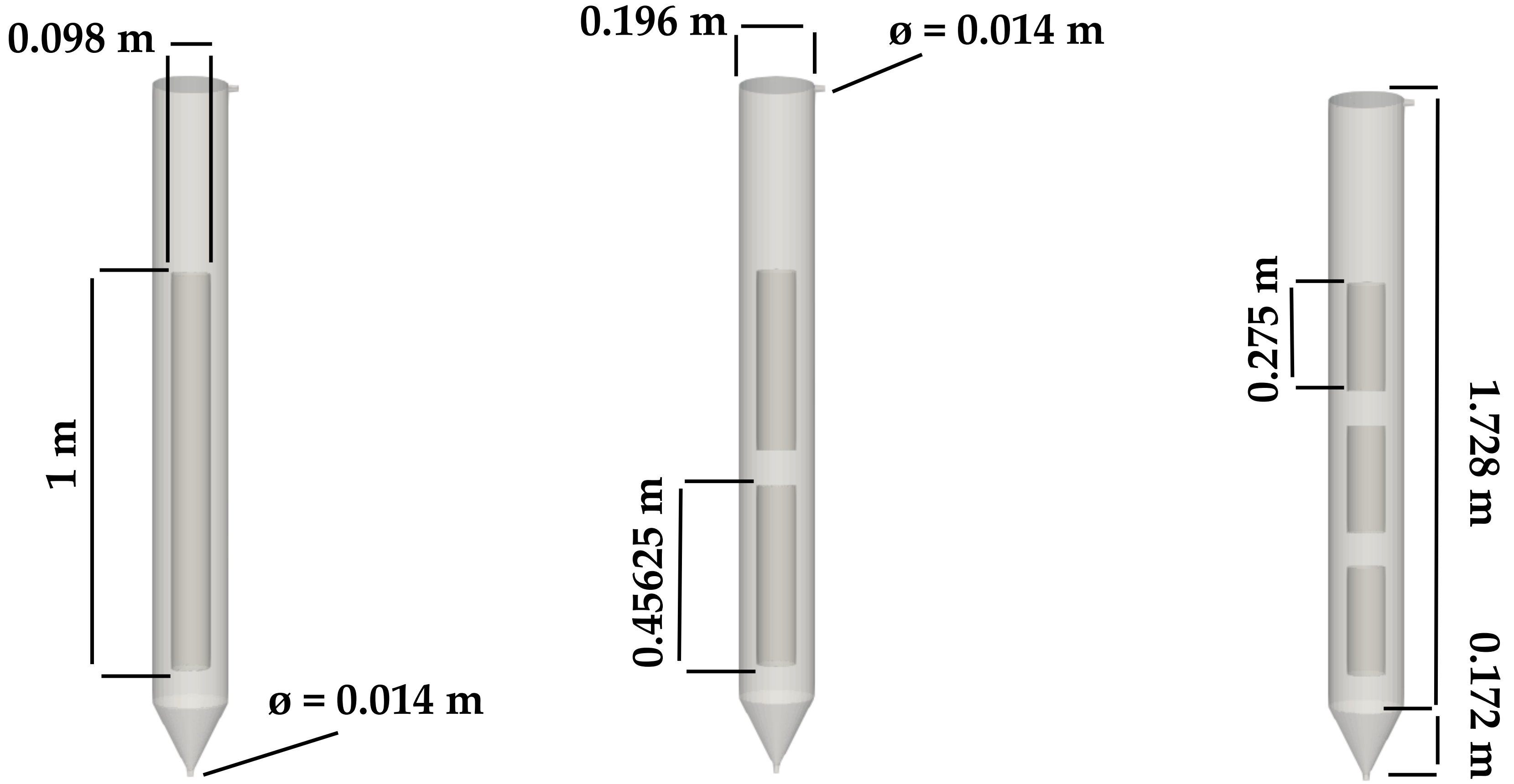


Figure 12. Filtered downcomer velocity neglecting the riser flow of geometries 1, 2, 7, 8, 9 and 10.

Optimal Design of Double Stage Internal Loop Air-Lift Bioreactor

Bioreactor geometries in this study



Single draft tube

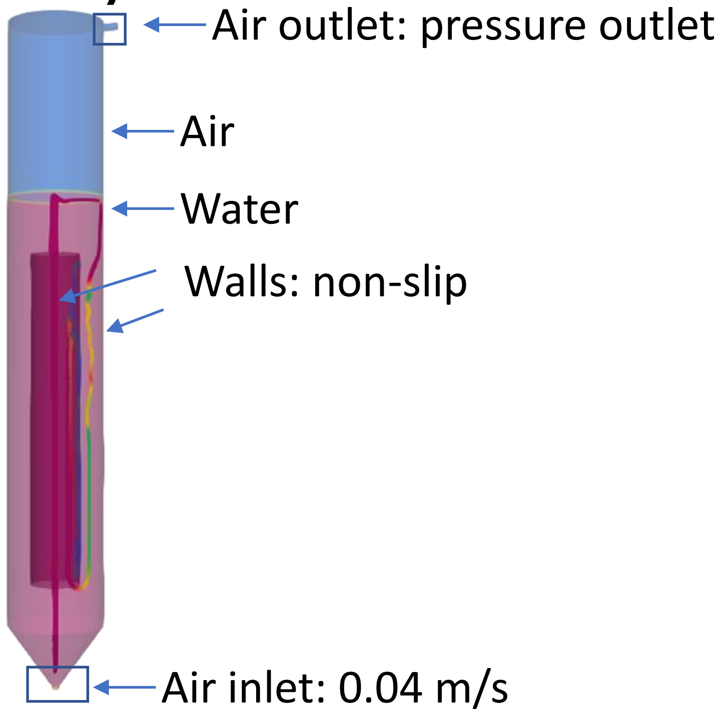
Double draft tube

Triple draft tube

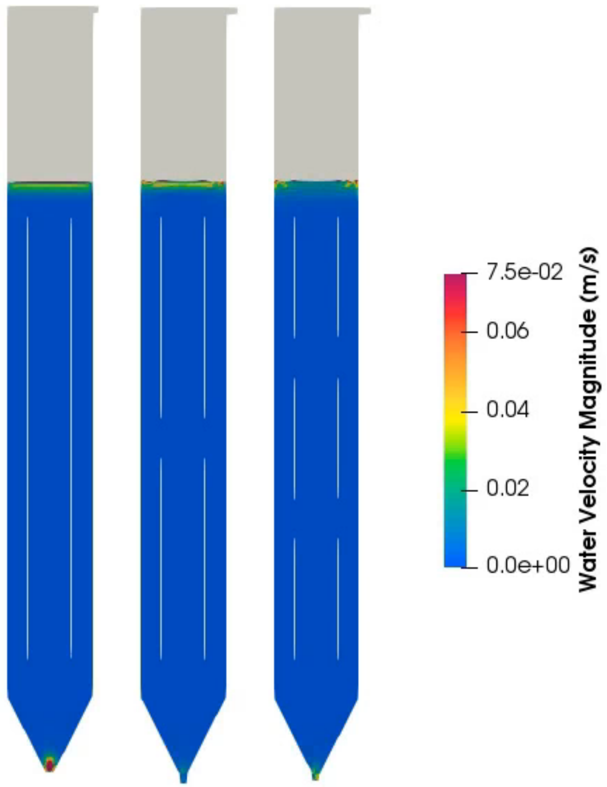
Simulation set up

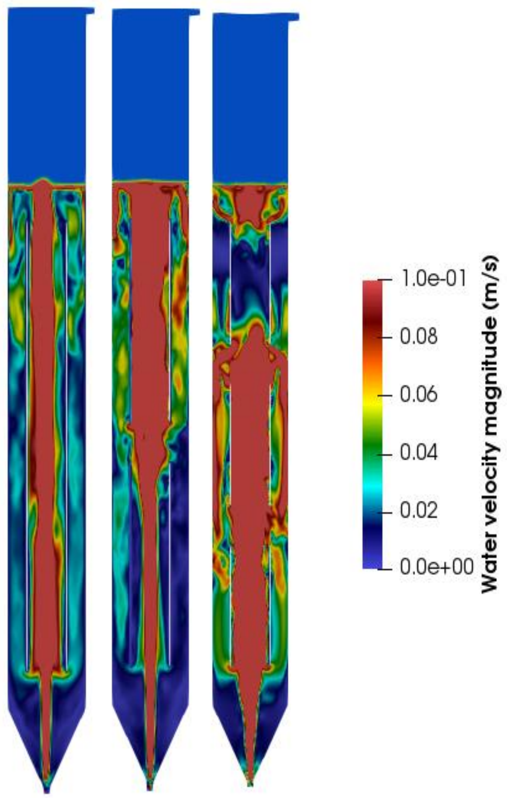
- Software: OpenFOAM version 9
- Solver: multiphaseEulerFoam
- Mesh:
  - ✓ Cells: ~370,000, ~900,000, ~1,200,000
- Eulerian phase size distribution:
  - Water: 1 mm
  - Air: 4.5 mm

- Boundary conditions:

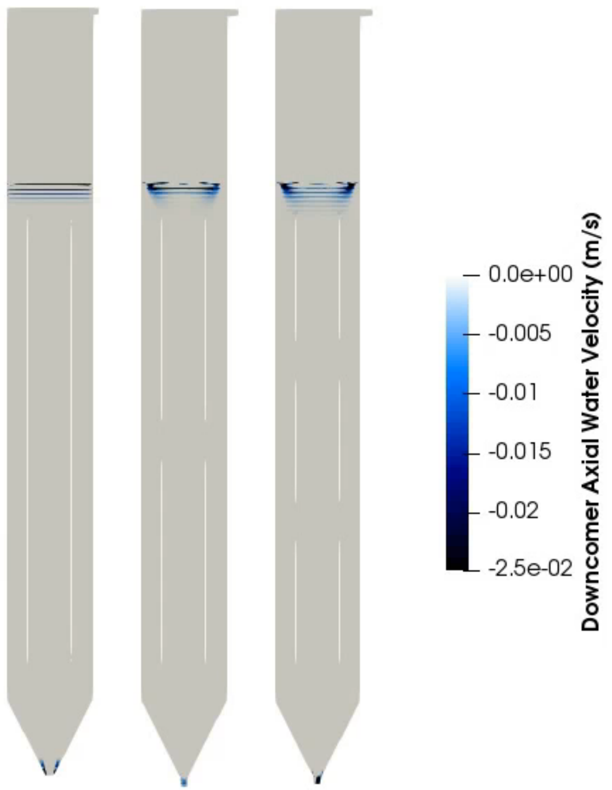


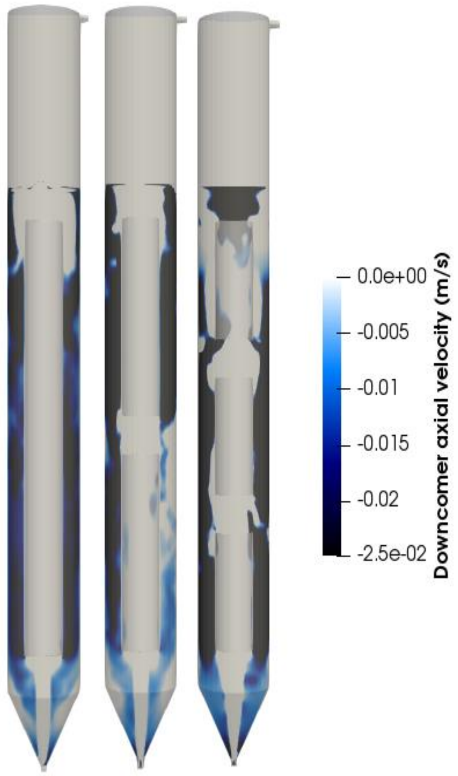
Water velocity comparison





Animation
Video speed: 5x



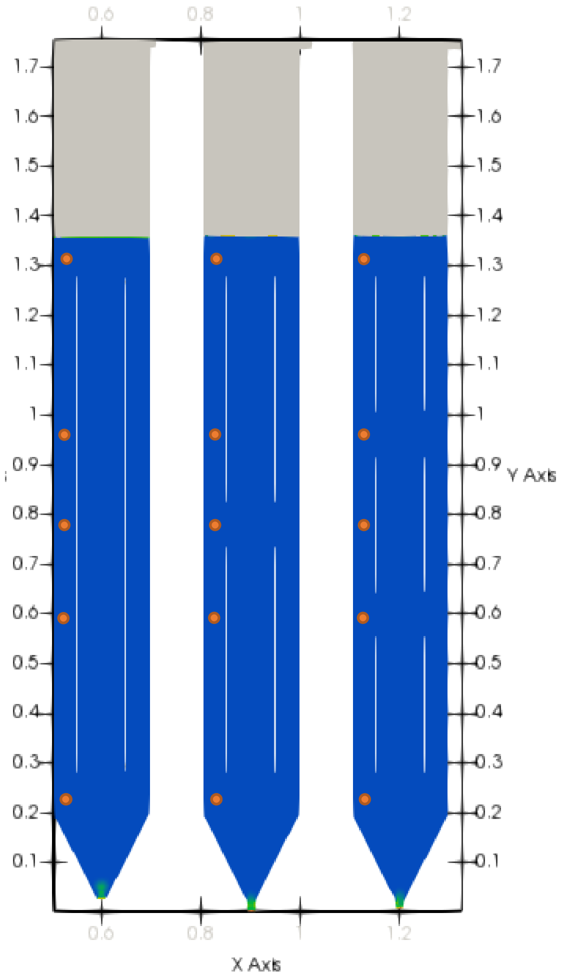


Animation
Video speed: 5x

Simulation time: 234, 267, 358 hours

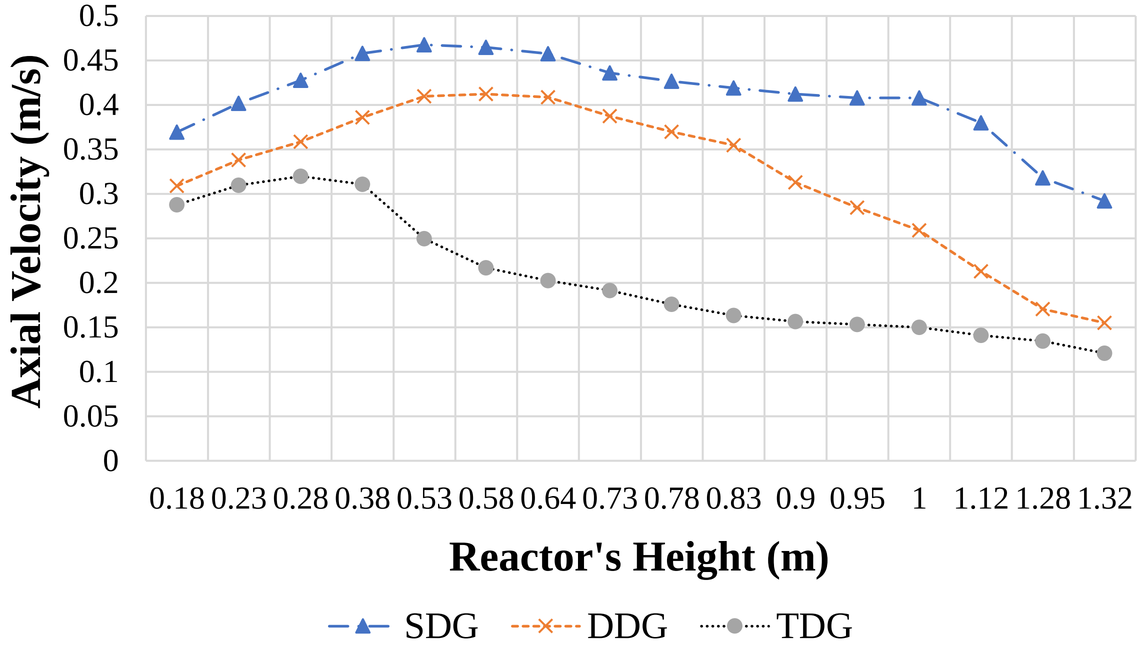
Obtained results

	Pressure (Pa)			Turbulent kinetic energy in fluid phase ($x10^{-6}$ m^2/s^2)			Fluid velocity on Y-axis ($x10^{-2}$ m/s)		
Height	**SDG**	**DDG**	**TDG**	**SDG**	**DDG**	**TDG**	**SDG**	**DDG**	**TDG**
0.23	111,044	111,048	111,098	3.949	0.999	1.468	0.858	0.121	0.342
0.58	107,623	107,626	107,676	2.792	5.019	9.666	3.497	1.475	1.874
0.78	105,668	105,671	105,721	4.382	16.568	11.175	3.217	2.463	4.086
0.95	104,006	104,009	104,058	7.774	9.551	71.622	3.015	3.987	4.552
1.32	100,386	100,389	100,440	108.579	109.766	113.069	2.647	2.638	2.580

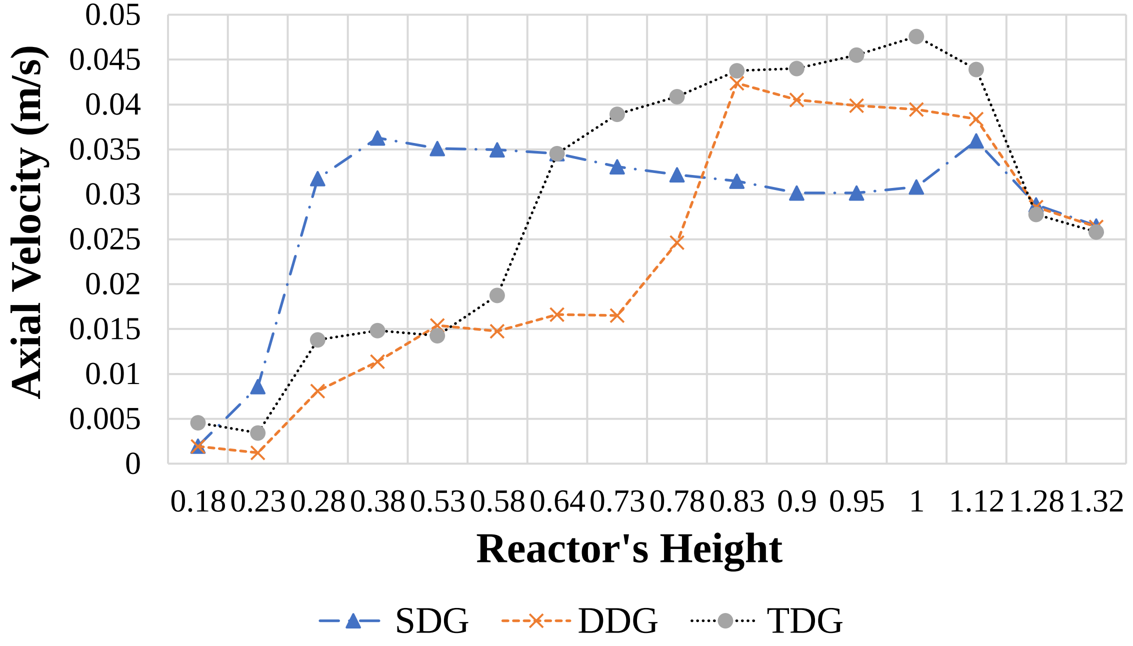


Bioreactors velocity comparison

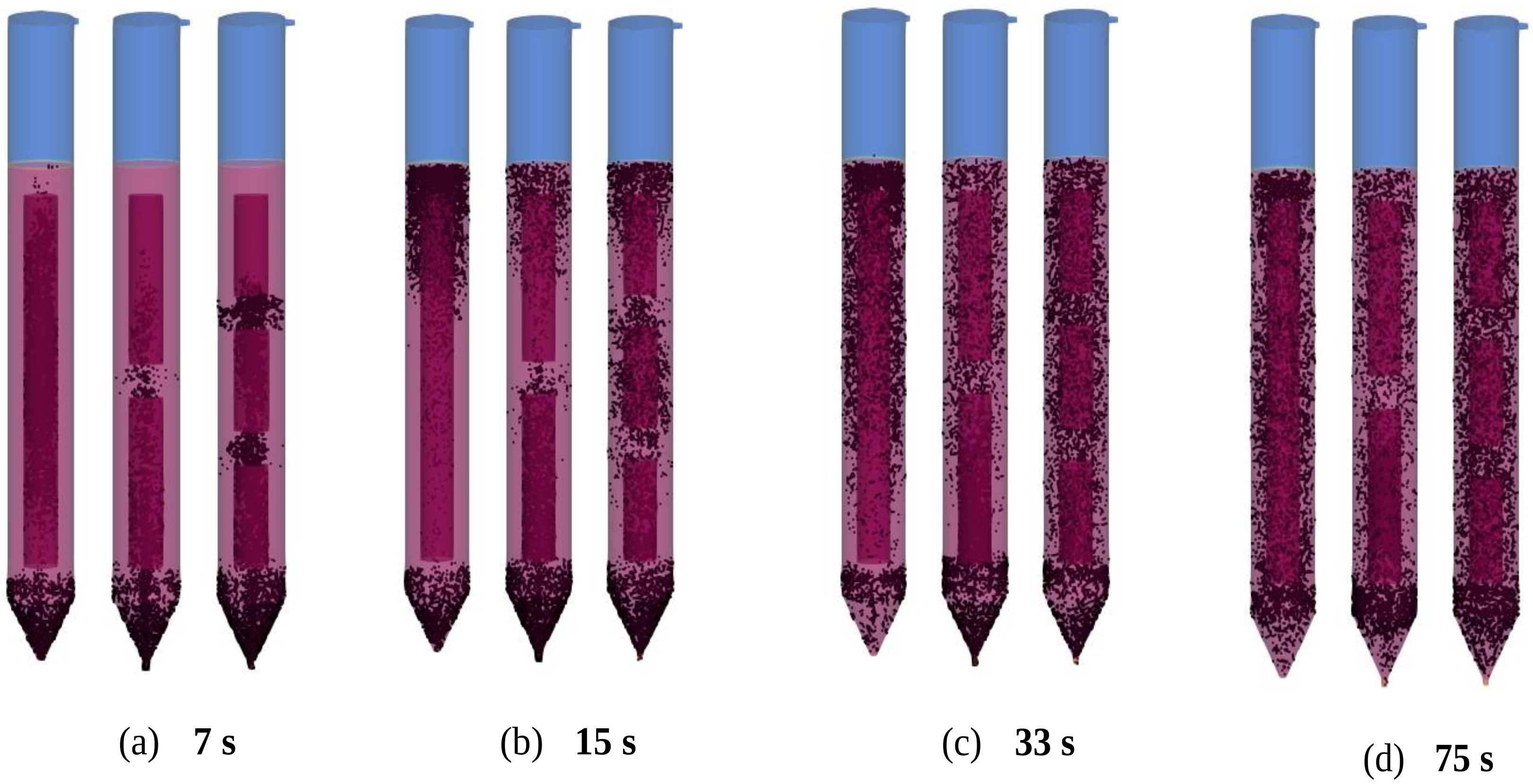
Riser velocity

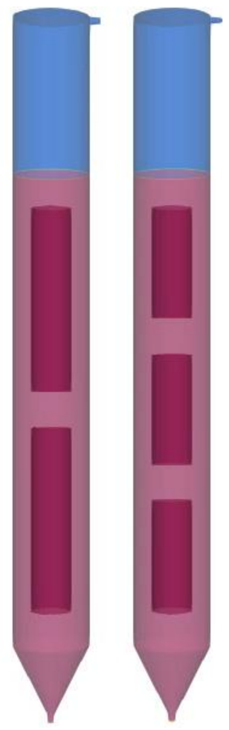


Downcomer velocity



Lagrangian Particles Coupling

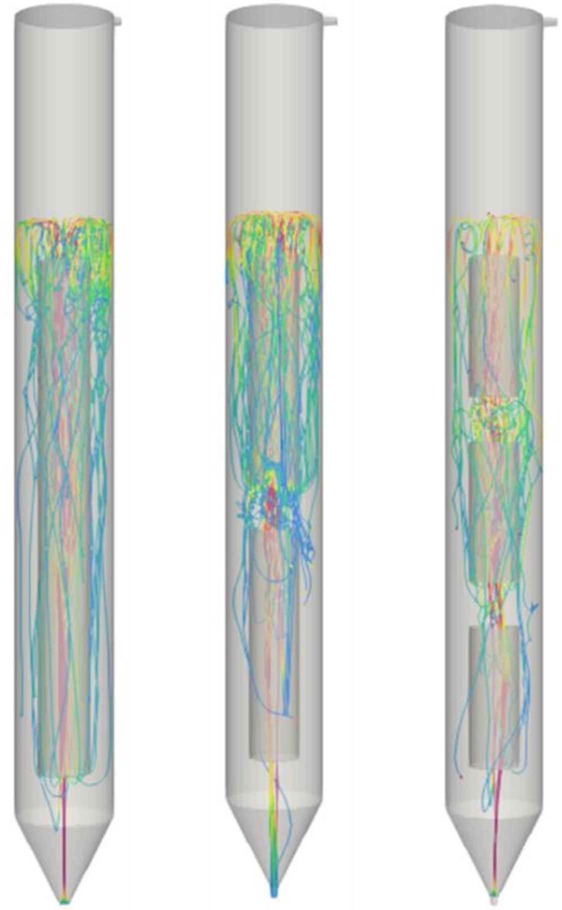




Animation
Video speed: 5x

Conclusions

- This study compared the hydrodynamics of three different internal loop reactors including multi-stage geometries using CFD simulations.
- The single draft tube geometry maintained a constant downcomer velocity, while the double-stage and triple-stage geometries showed higher downcomer velocities on the top section and a more stable downcomer velocity.
- Particle tracking simulations revealed that the conical bottom is a low fluid circulation zone that can cause the accumulation of solids.
- Coupling Lagrangian particles to the continuous phase of an Euler-Euler simulation allowed for better flow visualization, showing flow and circulation loops.



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THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

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