Technische Universität Dresden

Settling or Spreading?

How Industrial Contaminants Affect Settling Dynamics

Master's Thesis by Franziska Lorz, Chair of Transport Processes in Hydro Systems

Introduction

Norwegian infrastructure projects, such as tunnel construction, generate vast quantities of fine-grained rock material that often require marine disposal. Predicting its settling behaviour necessitates understanding micro-scale dynamics, where sediments (≤ 63 µm) are driven by physico-chemical surface forces rather than gravity alone. In aquatic systems, natural surface charges govern the balance between long-range electrostatic repulsion and short-range van der Waals attraction (van Olphen, 1977). While dominant attraction promotes flocculation and accelerates settling, these interactions are influenced by natural factors such as salinity and hydrodynamics, and further complicated by industrial contaminants like cement.

Multi-scale Problem

Transferred to Lab-scale

Macro-scale [km-scale]

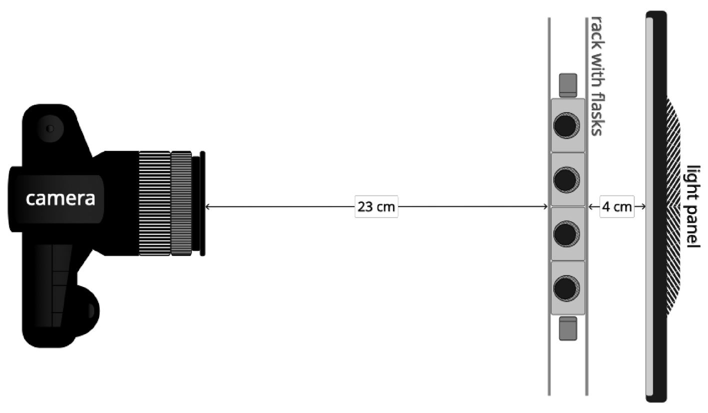
- Main Motivation - Behaviour of fine sediments in natural ecosystems?
  - ➢ Settle or Spread?
  - ➢ Influence of natural factors?
  - ➢ **Influence of contaminants - cement?**

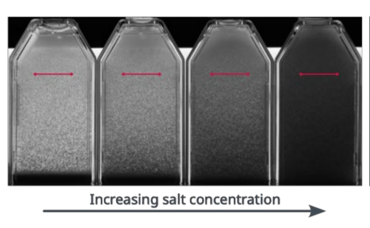
https://www.globalhighways.com/wh10/news/norway-mega-project-contract-fugro

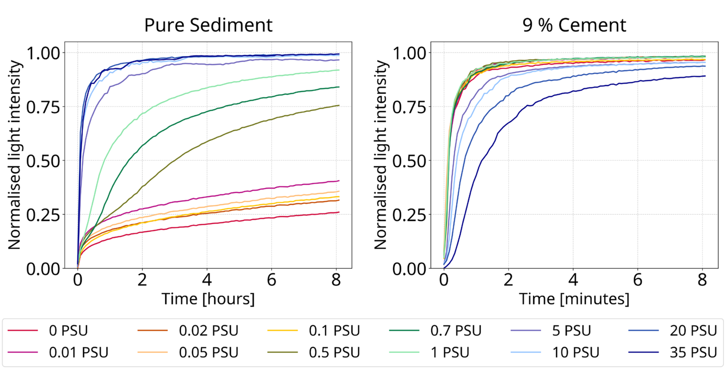
Planned route E39, including tunnels, along the Norwegian coast, requiring marine disposal.

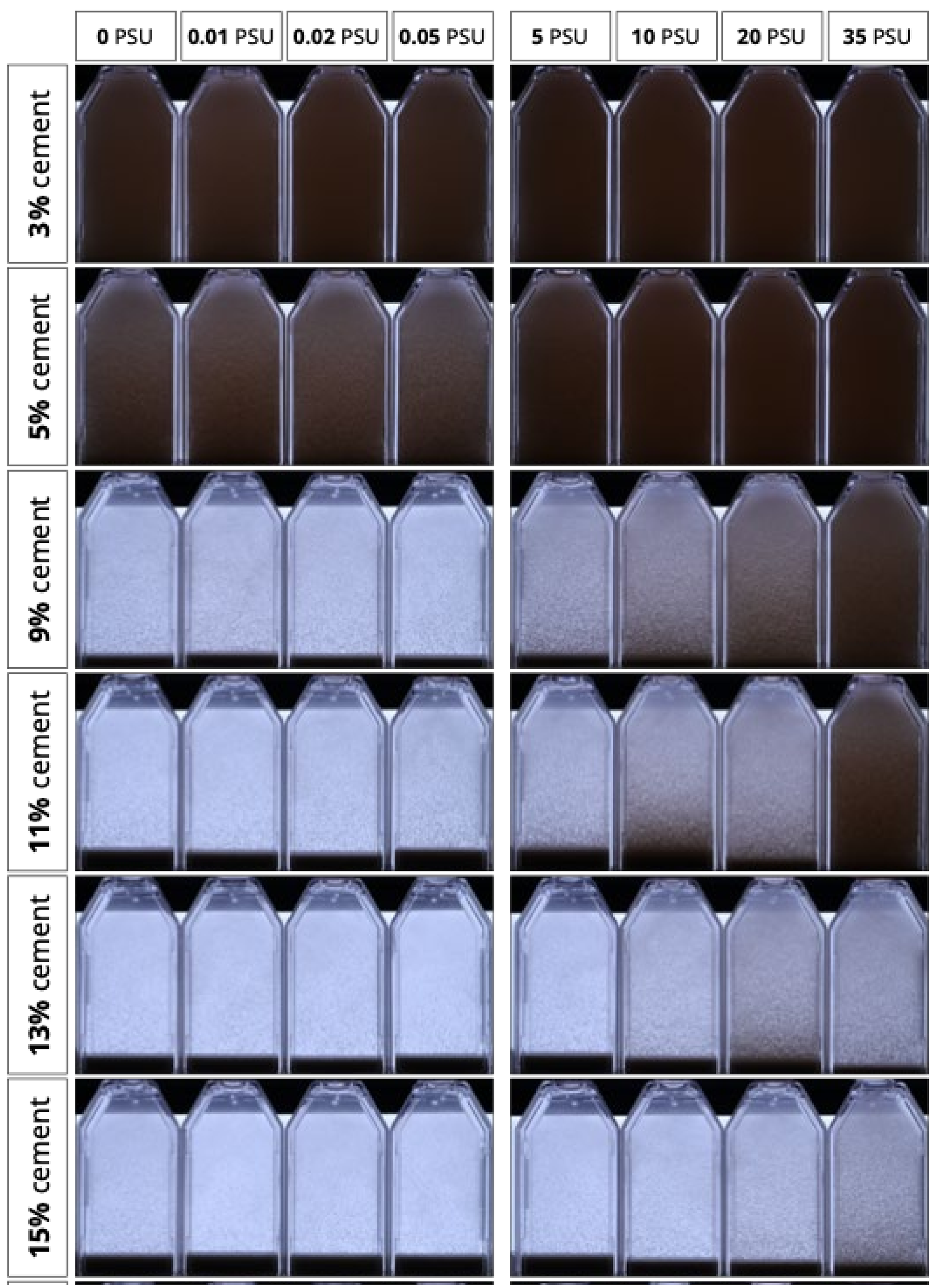
Meso-scale [cm-scale] — Bulk Settling Behaviour

- Investigation of mesoscopic sedimentation processes (Krahl et al., 2022)
  - ○ Constant sediment concentration (8 ppt*)
  - ○ 12 salinity levels (0 to 35 PSU*)
  - ○ 8 sediment-to-cement ratios (0 to 15%)
- Homogenised suspensions in flasks, illuminated and recorded at regular intervals → Image-based monitoring of the settling process
- Normalised transmitted light intensity serves as a proxy of particles in sus-pension → Evolution in time





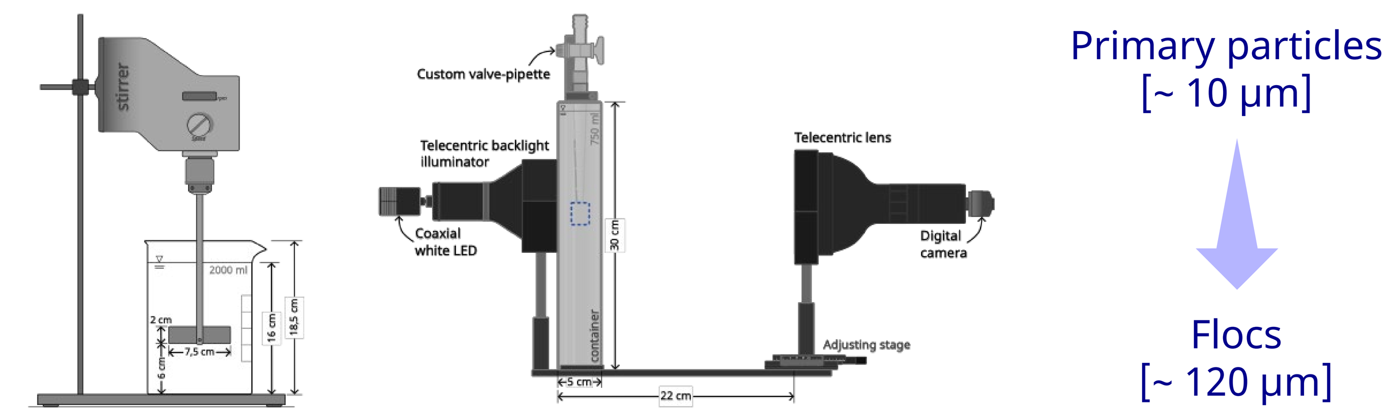


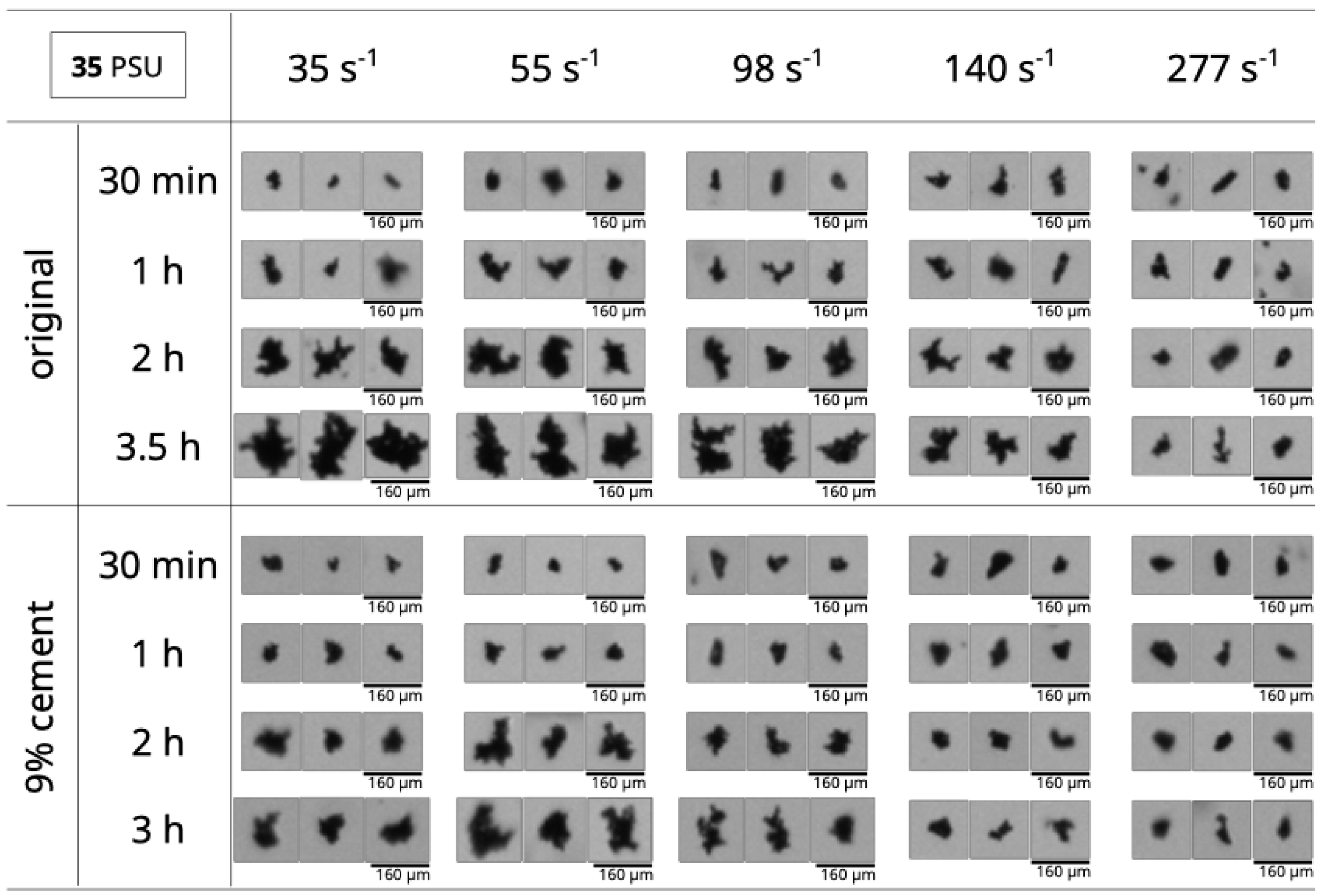


* 1 ppt = 1 PSU = 1 g/L

Micro-scale [µm-scale] — Floc Dynamics & Shear

- Microscopic observation of individual floc formation (Krahl et al., 2022)
  - ○ Reduced sediment concentration (0.5 ppt*) for optical clarity
  - ○ Boundary salinities (0 and 35 PSU*)
  - ○ Key sediment-to-cement ratios (0 and 9%)
- Suspensions exposed to controlled shear stress [s^{-1}] to promote or inhibit flocculation
- High-resolution imaging of sheared flocs to quantify morphology





Conclusion

- Salinity promotes flocculation and accelerates settling
- Cement further enhances sedimentation through chemical processes like hydration
- Low shear facilitates particle collisions and flocculation, while excessive shear causes floc breakage

Multiple factors drive flocculation, suggesting rapid deposition in natural ecosystems.

References:
- E. Krahl, B. Vowinckel, L. Ye, T.-J. Hsu, and A. J. Manning. Impact of the salt concentration and biophysical cohesion on the settling behavior of bentonites. *Frontiers in Earth Science*, 10: 886006, 2022.
- H. van Olphen. *An Introduction to Clay Colloid Chemistry: For Clay Technologists, Geologists, and Soil Scientists*. John Wiley & Sons, New York, 2nd edition, 1977. ISBN 0-471-01463-X.

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