

## 1. Introduction

The settling behaviour of suspensions is crucial to the stability of consumer products (e.g. fabric conditioners). The suspended particles must not settle noticeably during the product's shelf-life for it to remain effective and convey quality.

This work focuses on colloidal suspensions, which are mixtures containing very fine insoluble particles which are dispersed throughout a continuous fluid phase. Both experiments and modelling are used to investigate their phase separation.

A novel model is proposed which takes into account additional rheological and chemical influences. The numerical results are compared against highly controlled experiments.

## 2. Modelling

The proposed model avoids the hard-sphere assumption, taking into account the influence of the ionic double layer on the particle's surface. This is implemented via a viscosity equation using the effective maximum volume fraction,  $\phi_{\text{eff}}^{\text{max}}$ . In this work, the Quemada mixture viscosity relationship

$$\mu = \mu_c \left(1 - \frac{\phi}{\phi_{\text{eff}}^{\text{max}}}\right)^{-2}$$

is used, where  $\phi$  is the volume fraction,  $\mu_c$  the continuous phase viscosity and  $\mu$  the mixture viscosity.

Settling in suspensions is hindered by other particles. This is incorporated in the model through the mixture viscosity and the initial volume fraction, [1].

The model is the convection-diffusion equation

$$\frac{\partial \phi}{\partial t} + \frac{\partial(\phi u)}{\partial x} = \frac{\partial}{\partial x} \left( D \frac{\partial \phi}{\partial x} \right)$$

where  $x$  is height,  $t$  time,  $u(\phi)$  the particle velocity and  $D(\phi)$  diffusion due to Brownian motion, [2].

The settling model has been implemented numerically, using a finite difference solver with adaptive meshes.

## 3. Aggregation

Aggregation of particles significantly effects settling behaviour. The proposed model includes the experimentally obtained aggregation rate,  $k$ ,

$$d(t) = \frac{d_{eq}}{\left[ \left( \frac{d_{eq}^2}{d_0^2} - 1 \right) \exp(-kt d_{eq}^2) + 1 \right]^{\frac{1}{2}}}$$

$$d_{eq} = 2r\phi_0^{1/(f-3)}$$

where  $d_{eq}$  is the equilibrium diameter and  $f$  is the fractal dimension of the aggregate, [3]. Figure 3 shows 0.01M KCl does not result in aggregation, so was used for the settling experiments.

## Acknowledgements

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## 4. Settling Results

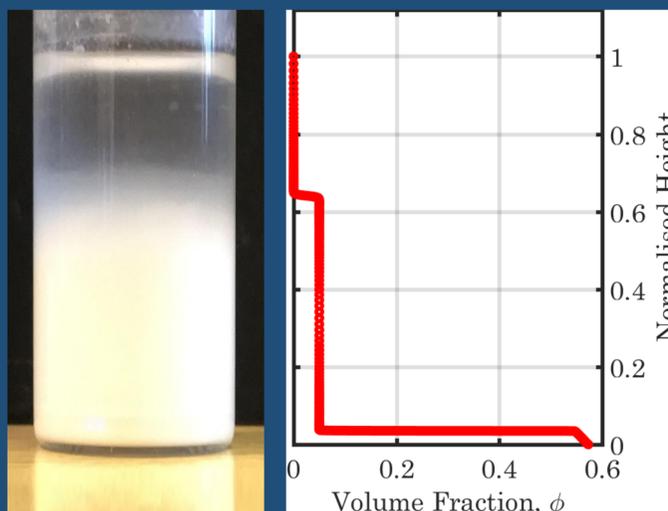


Figure 1: Variation of volume fraction with height.

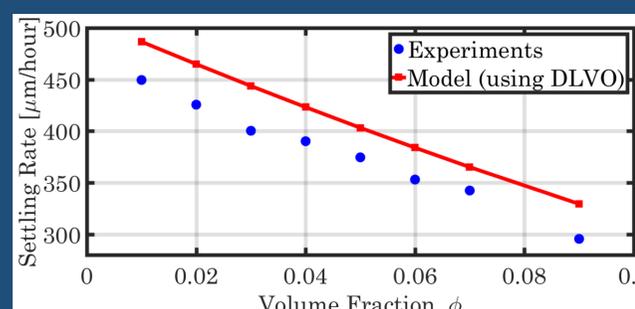


Figure 2: Settling rate against volume fraction for experiments and model, 0.01M electrolyte.

Figure 1 shows the volume fraction dependence with height at a fixed time. An interface develops where the rapid change in volume fraction exists.

Settling experiments using colloidal silica were conducted at enhanced gravity and converted to Earth gravity rates for fixed salt concentrations.

Figure 2 shows the experimental and model settling rate predictions for various initial volume fractions. The proposed model correctly predicts the settling gradient; however, there is a fixed offset between the corresponding rates.

## 5. Conclusions

Enhanced gravity in the experiments appears to affect the physics of the settling, which may lead to the offset between the experimental and modelling rates. The proposed model appears to predict the settling rate well. The numerical implementation captures the effect of enhanced gravity. Further, the aggregation model correctly predicts a well-dispersed suspension up to a given electrolyte concentration.



## 6. Further Work

Further experiments, including at Earth gravity, could help to understand the effects of enhanced gravity. Additionally, we suggest a time dependent implementation of aggregation into the settling model to extend it to aggregated systems.

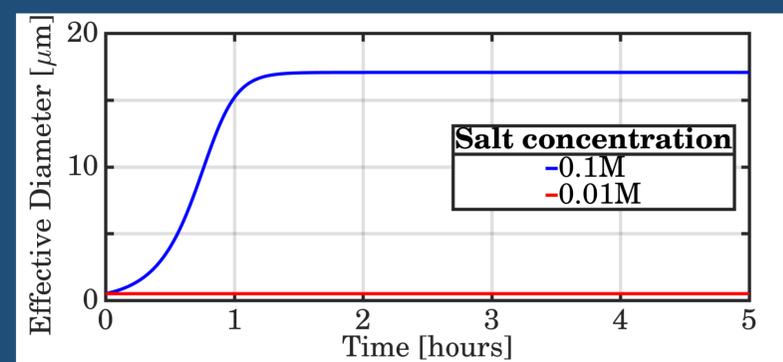


Figure 3: Time evolution of aggregate diameter for different salt concentrations.

## References

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- [3] Metin, C.O. et al. J Nanopart Res (2011), 13(2): 839. doi: 10.1007/s11051-010-0085-1