Natural aquatic systems are abundant with particles of various origin, such as minerals, dead microorganisms, microplastics, and their aggregates in the form of porous marine snow. The majority of particles settle due to gravity in the depths of the ocean and lakes taking part in physical, chemical and biological processes. Settling particles play a number of significant roles: they transport carbon from the surface to the seafloor, they are hotspots for microorganisms, which take part in the remineralisation of organic matter, while microplastics pose a hazard to organisms becoming part of food-webs. The sedimentation rate has a significant impact on large-scale processes, such as biogeochemical transport including transport of carbon dioxide from the atmosphere to the ocean depths, ocean productivity, and climate, which affect the entire planet. Consequently, understanding particle settling dynamics is significant not only for learning more about Earth processes, but also in a social context.

Complex physical conditions occuring in the ocean and lakes affect the dynamics of single particle settling and interactions between partices, and consequently, the sedimentation rates in natural aquatic systems. These complex conditions include density stratification and rheological properties of natural waters.

Density stratification is triggered by vertical variability of salinity and/or temperature. Research has demonstrated that sharp density gradients (pycnoclines) significantly reduce settling velocity, induce reorientation of non-spherical particles, and enhance aggregation of particles. Microorganisms accumulate in the pycnocline region, where substantial concentrations of extracellular polymeric substances (exopolymers) secreted by these microorganisms are observed.

Exopolymers modify the rheological properties of natural waters. Rheology considers the deformation and flow of materials under external forces and studies materials exhibiting attributes of liquids and solids characterized by viscosity and elasticity, respectively. Water is a Newtonian liquid, that is, its viscosity is constant under certain temperature and pressure. Water with exopolymers becomes a non-Newtonian liquid, that is, has combined characteristics of liquid and solid and its viscosity changes with the rate of deformation.

It is well-known from the research on non-Newtonian liquids that particle settling dynamics in such substances are far from the settling behaviour observed in water. However, there is no specific research on aqueous solutions of salts with dissolved exopolymers occurring in nature. This project aims to advance our knowledge necessary to gain insight into the settling dynamics of particles in complex physical conditions occurring in natural aquatic systems.

The goal of the project is to assess how exopolymers modify the rheological properties of ionic aqueous solutions, and how the exopolymer content and salinity affect the settling dynamics of individual porous and nonporous particles and interactions between particles in a density-stratified aquatic environment.

The project will involve hydrodynamic laboratory experiments and rheological measurements. The impact of salts occurring in natural aquatic systems on rheological properties of ionic aqueous solutions of exopolymers will be evaluated. Next, the impact of salinity and exopolymer concentration on the rheological properties of artificial seawater with exopolymers will be examined. A series of small-scale laboratory experiments will be conducted to address the fundamental processes of variously shaped particles settling in complex ambient conditions occurring in the ocean and lakes. Spherical and non-spherical nonporous particles and porous spheres will settle in specially designed tanks filled with ionic aqueous solutions, including artificial seawater, with addition of exopolymers. Particles settling in homogeneous liquid and passing through the transition of density and rheological properties will be examined. Settling of particles will be filmed and the recorded images will be analysed to measure the settling velocity of particles, variations in non-spherical particle orientation, interactions between particles and the flow pattern around particles. All solutions used in experiments will be measured for their rheological properties and the hydrodynamics of settling particles will be interpreted along with the rheological properties of the solution.

The results of the project will extend our fundamental knowledge on the impact of exopolymers present in ionic aqueous solutions on the settling dynamics of particles. Mathematical relations for drag and rheological models, as well as experimental data provided in the project could be next used to develop numerical models simulating particle settling in stratified conditions with modified rheology including particulate organic matter fluxes in the ocean. The knowledge gained as the effect of the project can play an essential role in the future in light of recent research reports indicating that stratification of the ocean, as well as algal blooms will increase as a result of climate change. The results of the project may not only contribute to Earth and Environmental Sciences, but also to other disciplines dealing with processes in non-Newtonian fluids.