Wastewater Treatment by Natural Freeze Crystallization and Ice Separation (WINICE)

The WINICE project investigates a concept that makes use of Finland’s cold climate to let nature assist in a green wastewater preparation solution. In this natural freezing method, the cooling is based on seasonal variation only – no additional energy for ice formation is required. The common challenges in water treatment are when wastewater volumes are huge, concentrations of various solutes are low and solutions are highly acidic or alkaline. The preparation and purification of wastewater presents challenges concerning processes, work and costs. WINICE consists of research groups at Lappeenranta University of Technology (LUT) and Aalto University (AU). The identified subprocesses are 1) natural freezing (LUT), 2) ice breaking and ice collection (AU) and 3) ice transportation (LUT).

Ice crystallization research at LUT has been carried out by Professor Marjatta Louhi-Kultanen, Doctoral Student Mehdi Hasan (doctoral thesis to be submitted to reviewers in summer 2016) and Doctoral Student Miia John. With LUT’s winter simulator, the investigations with aqueous electrolyte solutions have focused on freezing kinetics, obtained ice purities at various temperatures and velocities of cooling air and ice structure studies. Ice purity is quite directly dependent on growth rate: the lower the growth rate, the higher the ice purity. During 2016, this method has been investigated with wastewaters from a local wastewater treatment plant and with leachates from peat bog areas and landfills. Mathematical modelling has focused on ice growth kinetics. Furthermore, modelling based on CFD has been carried out to simulate airflow patterns in the winter simulator and temperature distributions in a jacketed stirred tank crystallizer. CEID’s Director Joonas Sorvari and Doctoral Student Roman Filimonov have been in charge of CFD modelling studies at LUT. International research collaboration on eutectic freeze crystallization has been carried out with the University of Cape Town.

The ice-breaking process has been investigated by the research group supervised by Professor Pentti Kujala at AU. The process requires more detailed information on the extraction and transportation method. In order to define the required ice-breaking forces, a series of mechanical experiments has been conducted by AU at LUT with ice samples grown at LUT in April 2016. An innovative idea and its feasibility for the ice collection process are being investigated in a Master's thesis project (Vaibhav Shah, expected May 2016). At the end of the project, a scaled prototype of the full process will be tested at the Aalto Ice Tank, which uses special model ice to scale the mechanical properties. The mechanical behaviour of this model scale ice is of key importance for the modelling of this process and has been investigated in the doctoral thesis of von Bock und Polach (currently under pre-examination).

The LUT team run by Professor Aki Mikkola, Dr Marko Matikainen and Eric Wildman is responsible for handling the collection of the ice. Once the ice has been broken, it needs to be collected and separated from the water. The method of collection and the mechanism(s) designed to perform this role will depend on the size of the broken ice pieces and the scale of the treatment operation. The first phase of the team’s work involved gaining a thorough theoretical understanding of movement and conveyor systems and their design aspects. This work focused on aspects particular to Arctic
conditions. The second phase of the work continues on from the first with a number of different concepts that fulfil the specific design requirements and follow standard engineering practices. In the third phase of the work, models of the viable conveyor designs will be computationally prototyped and analysed. This will be done using modern means such as finite element analysis and multibody system dynamics in order to develop better designs at a significantly reduced time and money expenses in comparison to more traditional prototyping methods. The final phase of the work will be the verification of the simulated results with the measured results of a scale model of the most viable ice collection option(s). This stage allows for not only confirmation of the concept but improvements to future designs and aids in reducing costs of manufacture and operation.