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

The arctic region is a potential area of exploration for natural resources. To be sustainable, this exploration should be carried out with minimal disruption to the arctic environment. 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. As such, the proper handling and treatment of wastewater is critical. WINICE investigated an energy efficient variation of freeze wastewater treatment, which uses available cold arctic air to cool the wastewater enough for ice crystallization. In natural freezing method, the cooling is based on seasonal variation only – no additional energy for ice formation is required. When wastewater begins to freeze, more pure layer of ice forms on its surface. This upper layer of ice is separated from the unfrozen liquid below, now with a higher contaminant concentration, and subsequently melted to obtain pure water. Because the method will rely on natural cold climate freezing, energy need only be consumed to break, separate, and transport the purified ice from the wastewater pond area to melting ponds. WINICE consists of research groups at Lappeenranta University of Technology (LUT) and Aalto University (AU) focusing on natural freezing, mathematical modeling and mechanical processes, such as breaking, collection and transportation of ice.

Ice crystallization research has been carried out with the winter simulator to investigate natural freezing in controlled conditions in terms of temperature and flow rate of cooling air. The investigations with synthetic aqueous solutions and real wastewaters have focused on measurement of freezing point depression, freezing kinetics, obtained ice purities and ice structure studies. Ice purity is highly dependent on growth rate: the lower the growth rate, the higher the ice purity. The wastewaters from mining industry, municipal wastewater treatment plant and with leachates from peat bog areas and landfills have been used in natural freezing studies. Furthermore, the recovery of a salt by eutectic freeze crystallization from wastewater of silica industry was investigated. Mathematical modelling of natural freezing has focused on ice growth kinetics and CFD simulations to investigate the influence of flow patterns of cooling air in the winter simulator and temperature distributions in a jacketed stirred tank crystallizer. International research collaboration on eutectic freeze crystallization has been carried out with the University of Cape Town.

The ice-breaking process requires more detailed information on the extraction and transportation method for the wastewater ice. In order to determine the strength of wastewater ice, extensive testing of mechanical properties for the ice samples obtained in controlled laboratory conditions as well as for the natural ice on the various wastewater basins in Finland in winter conditions was carried out. The results from the tests have been used to determine the effect of impurities in ice on the mechanical properties of ice samples, such as bending and compression strength and natural frequency. Based on the obtained results, the approach for breaking and collecting the ice using a systematic methodology is under development.

More information:
Prof. Marjatta Louhi-Kultanen (marjatta.louhi-kultanen@aalto.fi, Marjatta.Louhi-Kultanen@lut.fi)
Prof. Aki Mikkola (Aki.Mikkola@lut.fi)
Prof. Pentti Kujala (pentti.kujala@aalto.fi)