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

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- **Arctic climate of Finland can contribute to treat wastewater by means of natural freezing.**
- **Ice layer formed by simulating natural freezing is found to be of high purity.**
- **Inclusion / purity level within the ice layer determines its strength.**
- **Verification of mathematical models and strength analysis through on site experiments.**
- **Energy efficient ice breaking and transportation system is required to make the integrated ice separation as a cost-effective process.**

Freezing of Waste Water

- When waste water freezes, it is purified.
- Lower freezing rate provides almost pure ice.
- Freezing suitable natural conditions prevail in Finland.

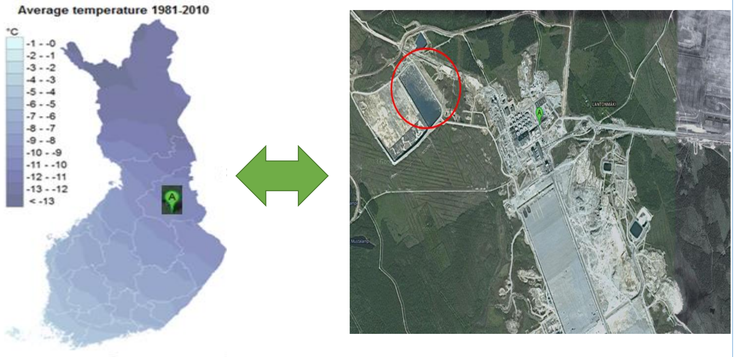


Fig.1: Adaptability of Natural freezing in mining industries*.

- Natural freezing performance tests are done by winter simulator

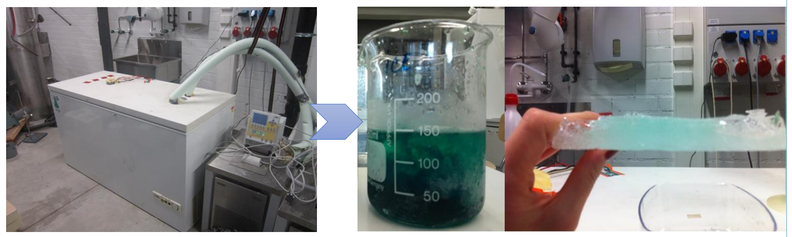


Fig.2: Freezing of $NiSO_4$ (aq) solution in winter simulator (LUT) and collected ice layer.

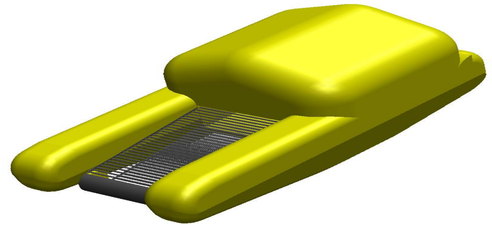
*Temperature contour in Fig.1 was collected from Finnish Meteorological Institute.

Modelling and optimization of natural ice growth

- A growth rate model of ice layer from waters containing soluble salt by natural cooling will be developed.
- The model predicts dependences of heat and mass transfer on solute concentration.
- Crystal growth rates from various salts containing wastewaters will be modeled and verified empirically.
- There is an optimal moment to collect ice depending on different physical, economical, and environmental aspects.
- The process is optimized by developing a numerical tool based on a mathematical model of the growth of the ice layer.
- Evolutionary computation will be utilized in the optimization.
- As there are multiple criteria in the model, this will typically lead to multi-objective optimization.

Ice breaking and transportation

- Identification of low energy consuming and environmentally sound structural or non-structural methods to break the ice.
- New devices for icebreaking and ice collection by utilizing already established arctic technologies, e.g. icebreakers and mining conveyor systems.
- New transportation system that allows to extract the purified ice efficiently from wastewater



Autonomous ice-skimmer

Ice strength and ice property study

- Physical testing of ice properties at a frozen waste water site.
- The tests are conducted at the optimum ice thickness defined in the mathematical growth model. Furthermore, the ice properties are investigated in terms of inclusion to validate the growth model
- The physical property tests will give insight on the required ice breaking forces and ice cusp sizes. This is an essential input for the design of ice-breaking and transportation equipment

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