A concept of wastewater purification by natural freezing

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1. Wastewater purification by freezing
   - Purified ice layer is formed on liquid surface

2. Ice from air-cooled winter simulator
   - Ice growth rates are determined with various temperatures and velocities of cooling air
   - Chemical oxygen demand (COD), turbidity, color, conductivity and natural frequencies are studied

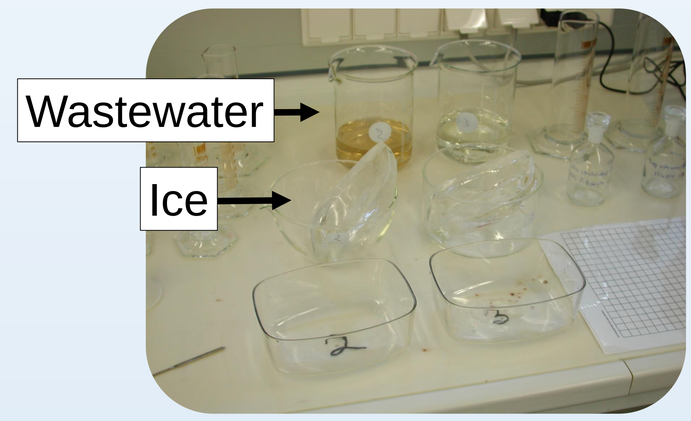

Fig. 1: Ice grown from wastewaters

Fig. 2: Winter simulator

3. Results

A) Municipal and landfill wastewaters
   - Analysis results of initial wastewater samples and ice samples
     - Municipal wastewater: Figs. 3 to 6
     - Landfill wastewater: Fig. 7

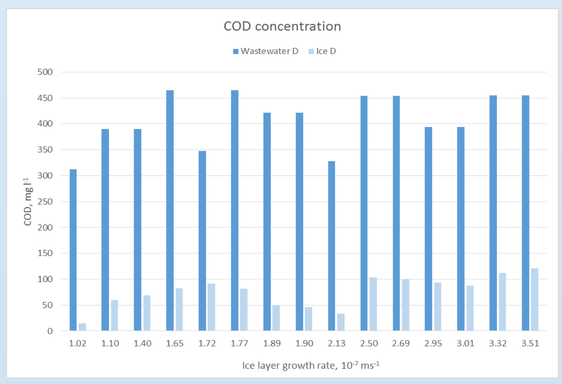

Fig. 3: COD separation

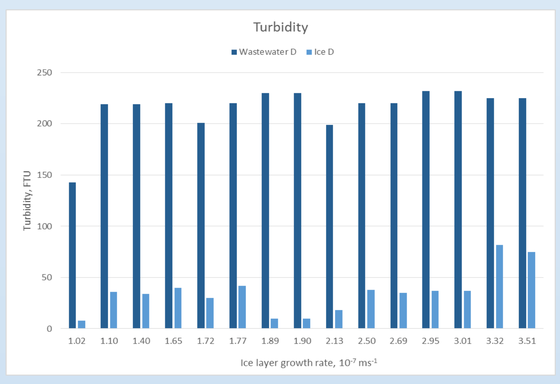

Fig. 4: Turbidity

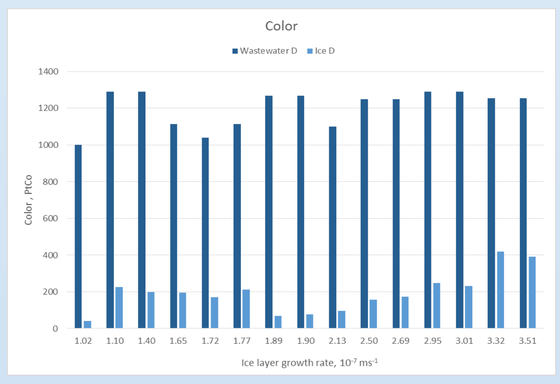

Fig. 5: Color

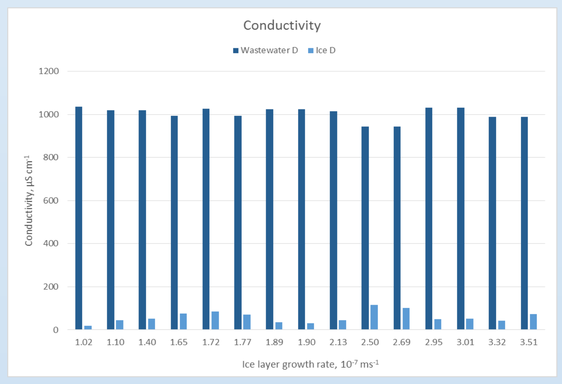

Fig. 6: Conductivity

B) Bending and compressive strength of natural ice

Table 1: Bending and compressive strength of ice from ponds and lakes.

Location	Description	Bending strength (MPa)	Compressive strength (MPa)
Lappeenranta	Saimaa lake	1469	1491
Taipalsaari	Peat bog (Vapo Oy)	636	1037
Lappeenranta	Peat bog (Vapo Oy)	518	1487
Sotkamo	Mining area (Terrafame Oy)	367	756
Sotkamo	Settling pond (Terrafame Oy)	269	438
Sotkamo	Kortelampi (Terrafame Oy)	248	283

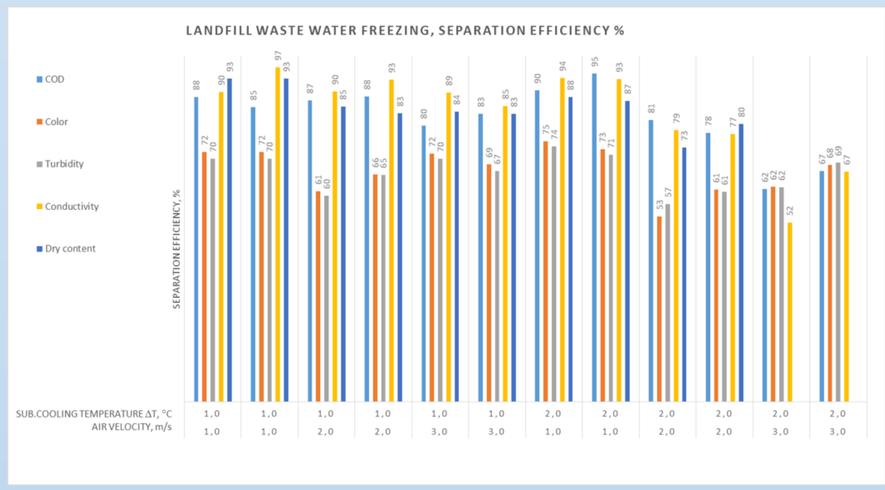

Fig. 7: Separation efficiency with various undercoolings and velocities of cooling air

C) Natural frequency of pure ice

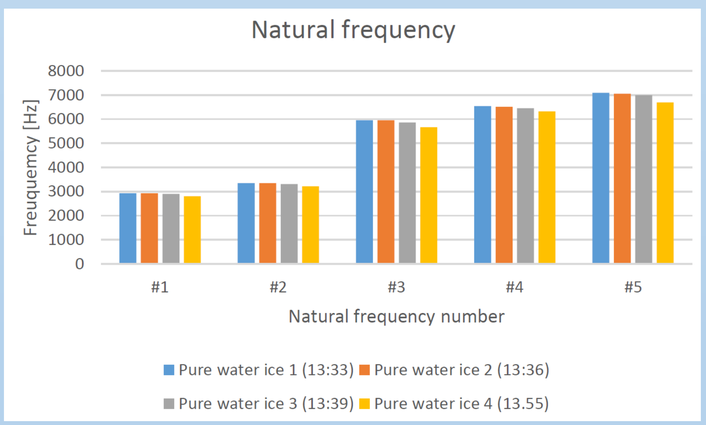

Fig. 8: Natural frequency of ice

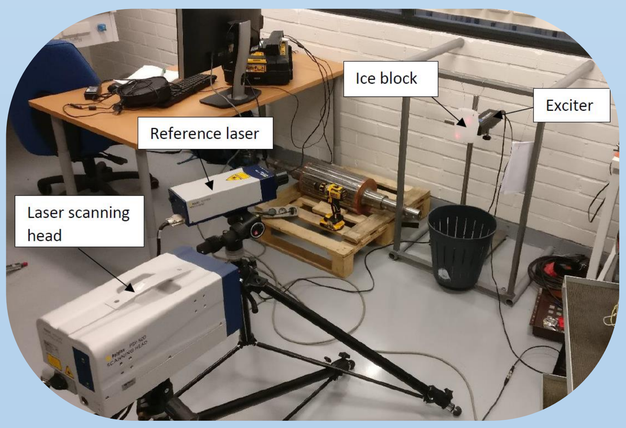

Fig. 9: Measuring natural frequency of ice

Fig. 10: Bending strength test

Fig. 11: Compressive strength test

4. Discussion and conclusion
   - Ice growth rate and impurities have clear influence on ice properties, impurities in ice weakens ice mechanical properties
   - Specific shape of ice can be excited at its natural frequency and break it
   - Controlling freezing gives possibility to optimize purification of waste waters

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Wastewater Treatment by Natural Freeze Crystallization and Ice Separation