Membrane technology in valuables and water recovery from wastewaters of food industry

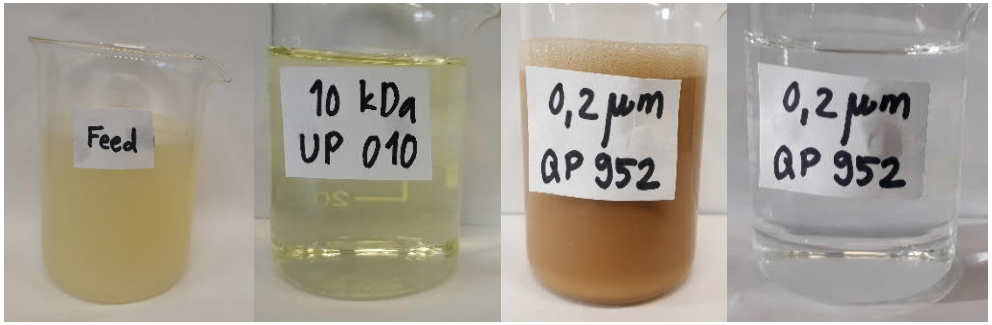
RESEARCH WORK DONE IN WP1 MAINLY BY VTT, CTC, AND LUREDERRA

AFTERLIFE STAKEHOLDER WORKSHOP, OCTOBER 9TH, 2020, ANTTI GRÖNROOS AND HANNA KYLLÖNEN

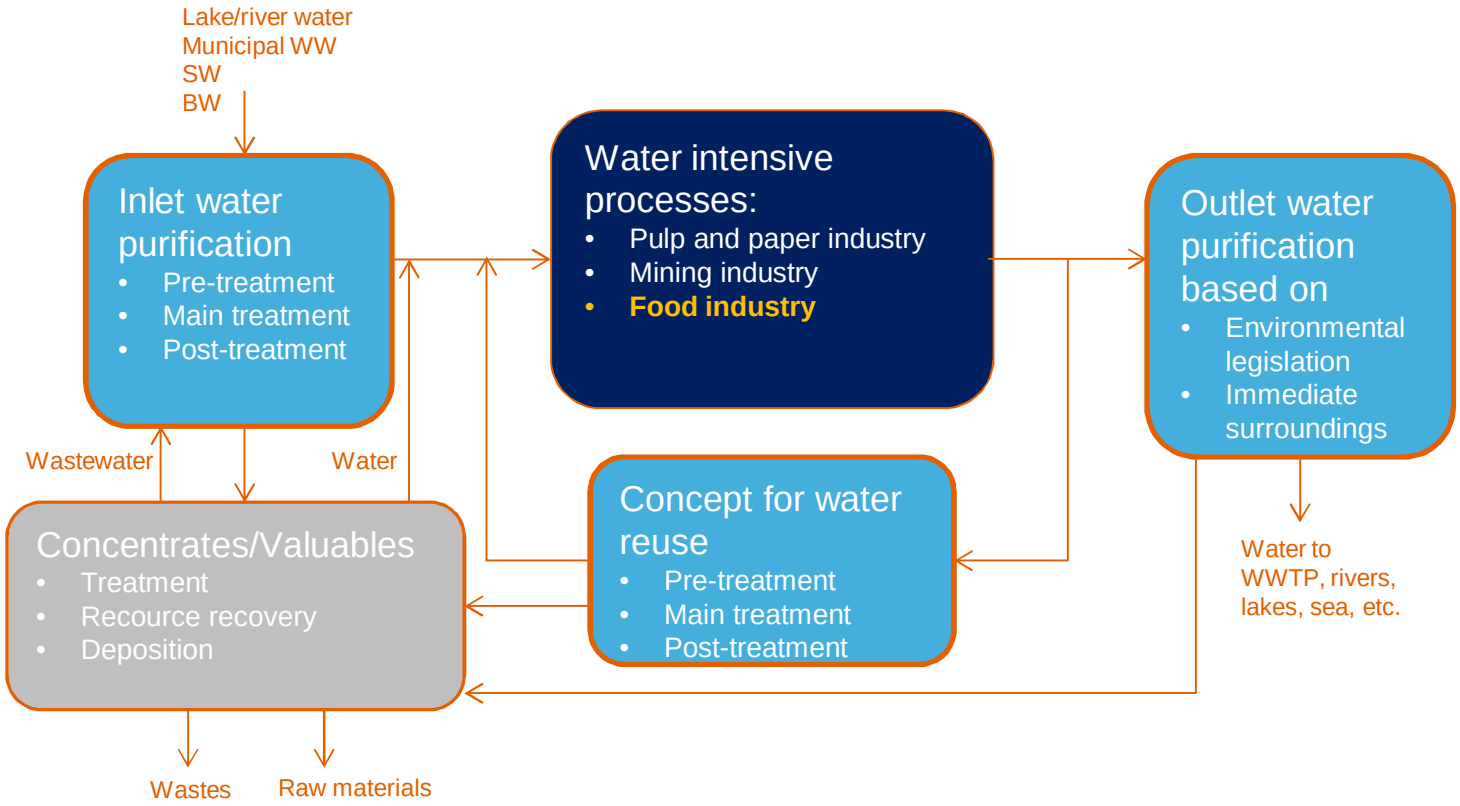
AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737 .

Content of the presentation

- ✓ Water treatment in general
- ✓ Supplying wastewater from industries representative of different food processing sectors with disparate characteristics
- ✓ Characterization of the wastewaters
- ✓ Designing the unitary operations for wastewater pretreatment according to the required characteristics for the subsequent filtration steps
- ✓ Maximizing separation for valuables and water from suspended and soluble solids, i.e. flux, water recovery (WR), concentration factor (CF), and rejection,
- ✓ Producing pure water for reuse using “fit for purpose” principle
- ✓ Conclusions

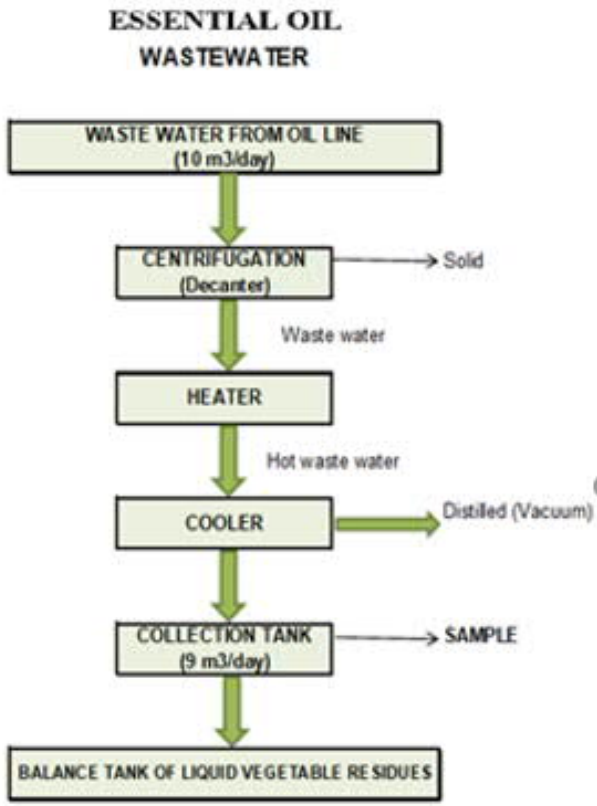


Water treatment in general



Supplying wastewater

- Wastewaters were collected from the industries representative of different food processing sectors with disparate characteristics
  - Jake wastewater (Jake-WW) from candy production, constant wastewater production
  - Citromil wastewaters from citric fruits processing, periodic production
    - Juice line wastewater (Cit-JL)
    - Essential oil line wastewater (Cit-EO)
  - Heritage wastewaters from cheese production
    - Wastewater, flocculated at site (Her-WW)
    - Whey (Her-W) simulating the highest concentrations to be recovered
- Variation of the concentrations were studied with six samples during three weeks
  - Concentrations of all wastewaters varied



Water characterisations

- Jake-WW contained high concentrations of SS and sugars, also pectin like organic matter. Content of vitamin C was not relevant in general but could appear sometimes in notable concentrations.
- Cit-JL and Cit-EO contained notable concentrations of compounds of interest in SS, such as hesperidin and essential oil, Cit-EO also in liquor
- Phytosanitary treatments applied to citric fruits are responsible for the presence of pesticide residues in Cit-JL and Cit-EO. Pesticides and pathogens could appear somewhat.
- Her-WW contained low amounts of valuables to be economically recovered
- Her-W was rich of proteins and lactose. Pure whey was studied to consider the most “extreme” scenario for wastewater.
- None of the wastewaters contained notable amounts of heavy metals with exceptions for boron, iron and zinc.


Jake-WW

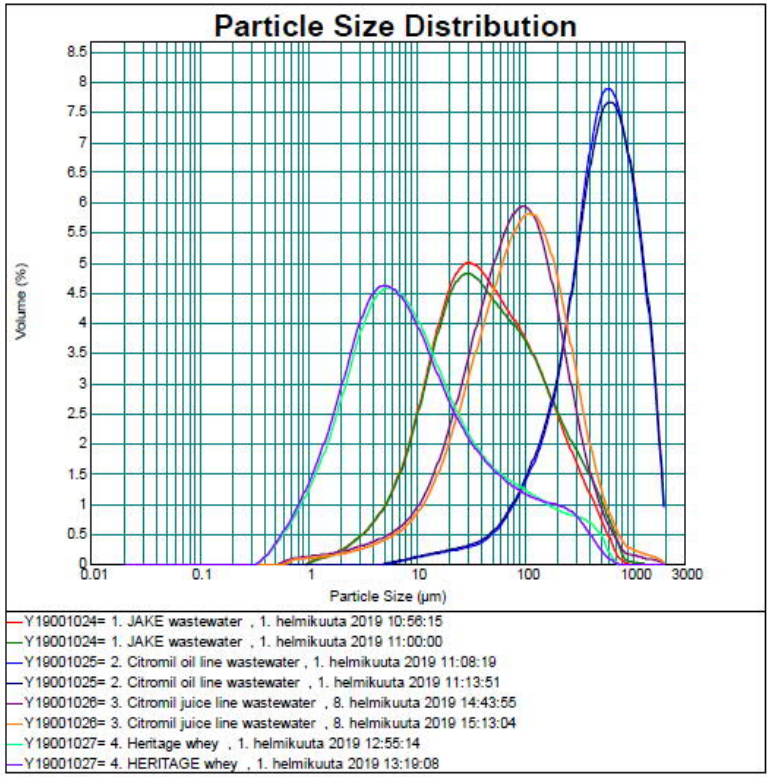
Citromil-EO

Citromil-JL

Heritage-W

Reuse ideas based on characteristics

- Jake-WW:
  - High sugar concentration enables it to be used at fermentation in WP3 as such or after SS removal
  - Pure water production is possible after fermentation
  - Recovery of sugars can be carried out from wastewater as such
- Cit-EO:
  - Suitable for the recovery of valuables from SS or liquid phase to be valorised in WP2
- Cit-JL:
  - Suitable for reuse water production directing SS and concentrates to WP2
- Her-WW:
  - Pure water production can be carried out after flocculation and separation at site
  - Her-W suitable for proteins and lactose recovery after FOG removal



Design of pretreatment

- There were two main issues addressed: relatively high viscosity and potential membrane fouling owing to the very high content of total SS
  - Viscosity decrease was enabled by the use of different surfactants.
  - MF was selected as the pretreatment option to tackle the removal of SS. It was expected to yield also significant viscosity decrease. The potentially beneficial combination of surfactant and MF pretreatments was also explored.
  - Coagulation and flocculation procedures was found an option to help MF of some wastewaters
- No reduced microbial activity from imazalil for polyhydroxyalkanoates (PHA) production was found in WP3.
- The removal of fat, oil, and grease (FOG) by elastomeric materials with sponge-mimicking behavior was proposed for pretreatment

Flocculation and MF

Pretreatment in lab

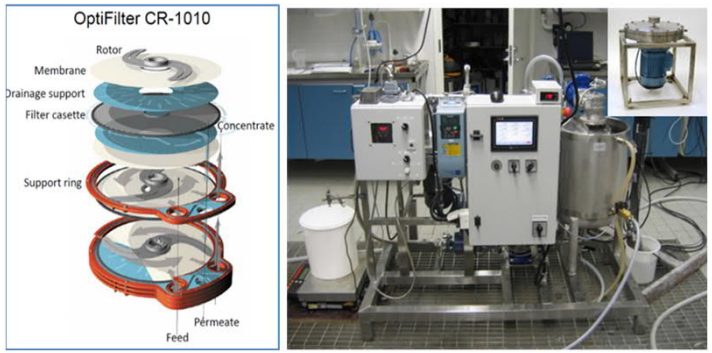
- MF was part of the proposed workflow along with the use of surfactants to address viscosity of wastewaters.
- Viscosity decrease enabled by sodium dodecylbenzenesulfonate (SDBS, 0.4 mM) was successfully achieved with Jake-WW after MF
- Streams of valorizable material were obtained from Cit-EO wastewater. Pretreatment operations for this wastewater was proposed: filtration with 150 µm sieve, followed by fat-oil-grease (FOG) adsorption, and then coagulation/flocculation to further removal of suspended solids.
- FOG removal with a 50% reduction was carried out with Cit-EO, and also with Her-W

FOG removal

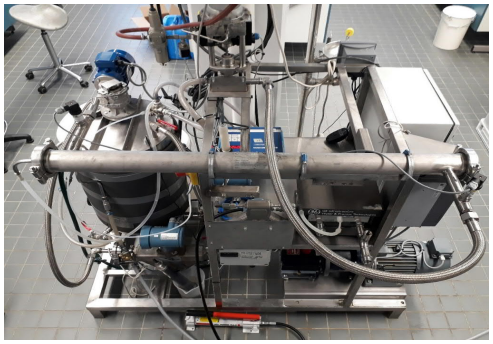
Developing of filtration steps

- SS removal was studied using flocculation, belt filtration and press filtering
- Suitability of MF using bag or cartridge filtration were tested as a clarification filtration for RO
  - Low fouling ultrasound aided MF was also an option. However, commercially available ultrasound aided MF was found unsuitable for organics containing wastewaters.
  - Cartridge filter was capable to remove FOG but it was not suitable for recovering
- UF using spiral wound and low fouling cross-rotational options were tested
- RO, either brackish or sea water membranes, or membrane distillation (MD) were found good as a last filtration step. MD especially was found good for samples having high osmotic pressure.

Cross-rotational UF



Spiral wound UF

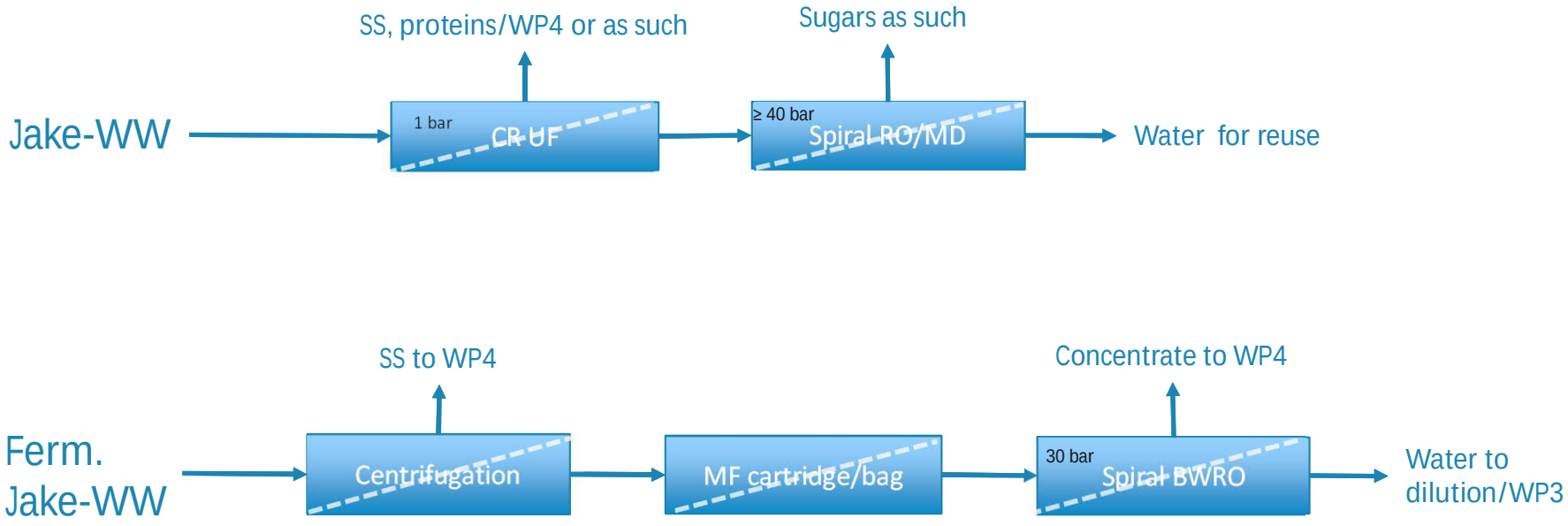


Performance of filtration

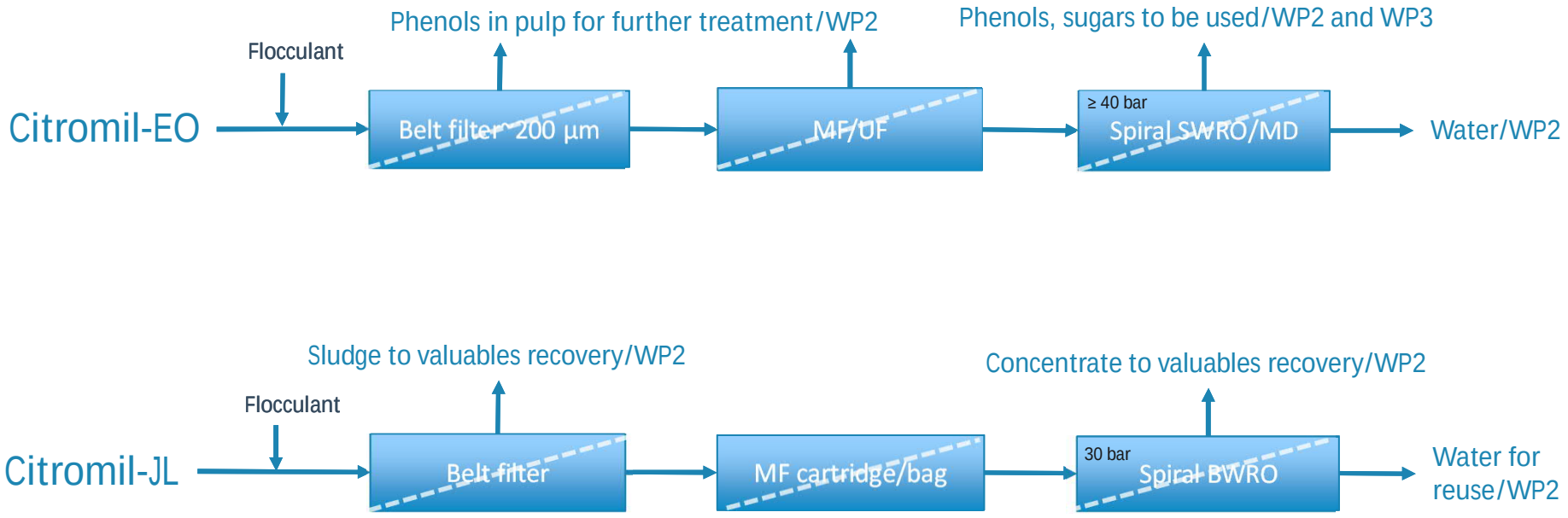
Technique	Jake-WW	Ferm. Jake-WW	Cit-JL	Cit-EO	Her-WW	Her-W
Coagulation and flocculation	✓		✓	✓	✓	-
Belt filter	✓		✓	✓		-
FOG removal	-	-	-	✓	-	✓
Clarification MF	-	✓	✓	✓	✓	✓
Spiral wound UF	✓	✓	-	✓	✓	✓
Cross-rotational UF	✓	-	-	-	-	-
Reverse osmosis	✓	✓	✓	✓	✓	✓
Membrane distillation	✓	-	-	-	-	✓

✓ Workable technique ✓ Not workable technique – Technique not relevant

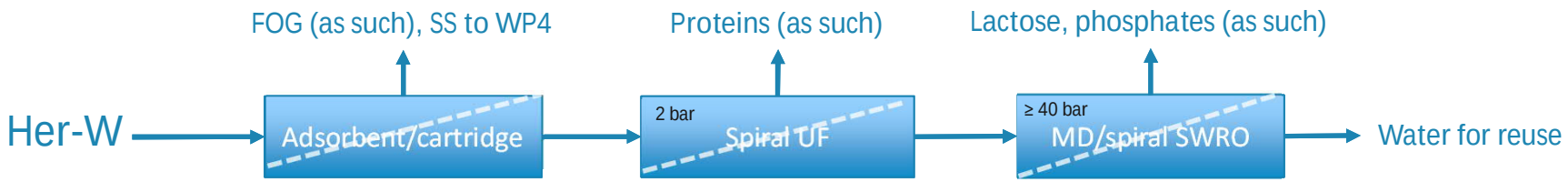
Concepts, Jake



Concepts, Citromil



Concepts, Heritage



RO-water quality

Sample	Jake-WW	PHA ferm Jake-WW	Cit-EO	Cit-JL	Her-WW	Her-W
pH	3.3	7.7	3.2	4.8	7.0	3.5
Conductivity, mS/cm	0.17	0.47	0.3	0.04	0.35	0.20
COD, mg/l	180	890	100	340	33	290
P total, mg/l	<1	<1	<1	<1	<1	<1
N total, mg/l	<1	<1	5.7	<1	<1	3.1
Cr, mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0013
Cu, mg/l	0.28	0.022	0.021	0.0041	0.0034	0.0088
Ni, mg/l	<0.0005	0.00051	<0.0005	<0.0005	0.0012	<0.0005
Zn, mg/l	0.016	0.024	0.008	0.005	0.004	0.004
Pb, mg/l	0.0031	0.00038	0.00034	0.00021	<0.0001	0.00023
As, µg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cd, µg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb, µg/l	0.49	0.29	0.19	<0.1	<0.1	0.22
Hg, µg/l	0.4	<0.02	<0.02	<0.02	<0.02	<0.02
Fe, mg/l	0.010	0.006	0.048	0	0.61	0.014
B, mg/l	0.036	1.08	0.026	0.064	0.15	0.010

Conclusions

- Planned key exploitable results
  - Development of a cost-effective cascade of membrane filtration units for the separation and concentration of wastewater
- Realized results
  - Filtration concepts made for valuables recovery and water reuse with 70% water recovery, considering
    - Availability in large scale
    - Low-fouling technologies
    - Maximum cost-efficiency: high flux, high water recovery, concentration factor
    - Good quality water for reuse with “fit for purpose” principle

Thank you!

Antti.Gronroos@vtt.fi
Hanna.Kyllonen@vtt.fi