Issues and strategies for effluent stream valorization and water conservation in the Dairy Industry

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MEVGAL – Macedonian Dairy Industry

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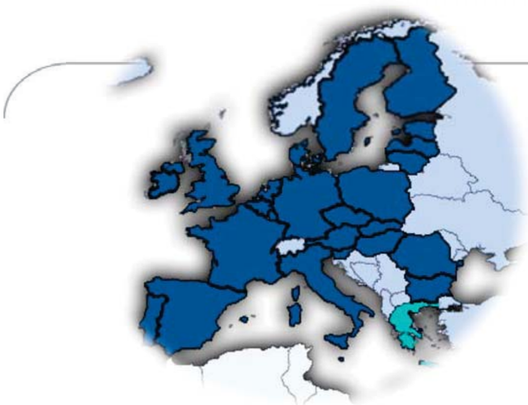

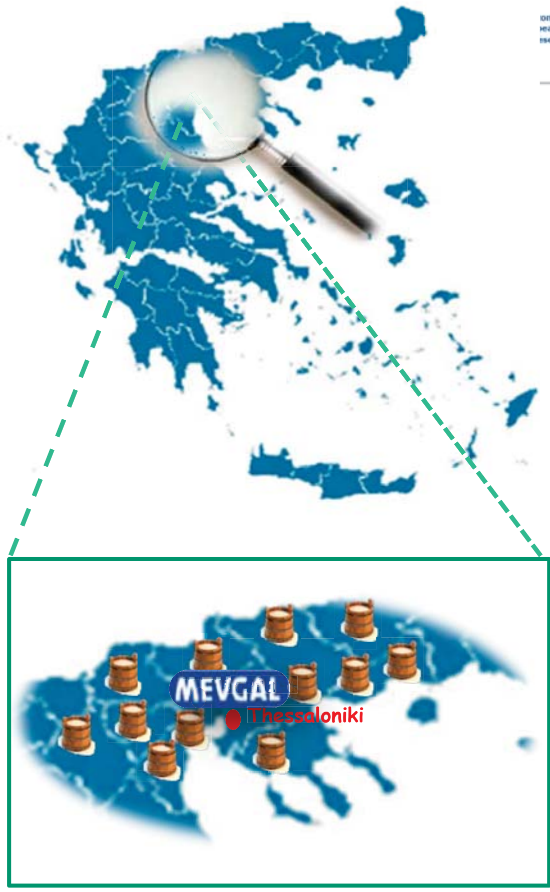

- is located in **Northern Greece**, in Koufalia, N/W of Thessaloniki in the historical area of **MACEDONIA.**

- was founded in **1950** and is family owned
- Employs **650** people
- Produces major dairy products of: **Milk, yogurt** and **cheese**

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MEVGAL ranks:

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- 4th among all the Greek Fresh Dairy producing companies
- 16th among all Greek Food producing companies
- 53rd among all Greek companies

- **Annual Net Turnover 2017: € 110 mil**

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MEVGAL today

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Incoming milk

- 80.000 tn/year cow
- 13.000 tn /year sheep-goat

Production

- 60.000 tn/year milk
- 22.000 tn/year yogurt
- 4.000 tn/year cheese

Plant in Koufalia

Distribution Center in Athens

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Issues & Strategies

- Effluent **stream valorization** and **water conservation** in dairy industry
- Various scenarios have been developed by CERTH and assessed in parallel with MEVGAL, aiming at
  - recovery of valuable compounds
  - minimizing freshwater consumption
  - reducing energy expenses for water and wastewater treatment
  - biogas production

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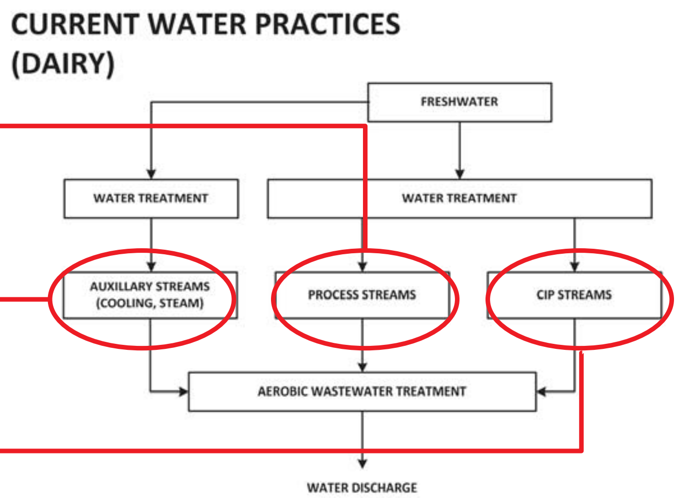
Present schemes for process and cooling water use in the dairy industry

- Water plays an important role to dairy industry; 2 - 10 m^3 freshwater per ton of milk processed, depending on the dairy product & industry
- Equal amount of wastewater needs to be treated prior to discharge
- Current process scheme concerning water uses in a small/medium size dairy industry

- Small volume but high organic loading
- Valuable milk compounds that can be recovered

- Freshwater is currently used as make-up cooling water
- Deionised water used for steam (strict quality param.)

- Strict regulations concerning quality (hygiene)
- Reuse as process water not permitted



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Strategy

- Possible technologies for valuable compounds recovery and water treatment and reuse:
  - Membranes
  - Hybrid membrane technologies
  - Anaerobic/Aerobic Bioreactors
  - Elevated pressure sonication
- A favorable combination of the examined technologies will be pursued for subsequent demonstration in the dairy industry.

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Main dairy water streams

- CIP water
- Process water (for flushing, in milk concentrate etc.)
- Cleaning water (external cleaning)
- Cooling water
  - Ambient temperature
  - "Ice" water (0-2 ^{o}C)
- Boiler feed water

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Main dairy wastewater streams

- CIP effluents
  - Yogurt
  - Milk
  - Cheese
- Flushing water effluents (Yogurt, Milk, Cheese)
- UF permeate
- Whey stream
- Fat-free whey stream
- WWTP inlet

Main process Streams in Dairy

- Flushing
  - The first seconds between products changes or the first step before a CIP cycle start. It is rich in proteins and fat
- Whey stream
  - By-product from the production of cheese (yellow or white cheese). It is used for the production of whey cheeses. It is rich in proteins
- Fat-free whey stream
  - By-product from the production of whey cheese. It has high content of salt.
- UF permeate
  - It is produced during the ultra-filtration of milk. It’s main substance is lactose

Process Streams in Dairy - Characteristics

- +++
  - Rich in substances (proteins, fat, lactose, etc.) that could be recycled
  - Volumes are low
- ---
  - There is a high number of low volume streams from different production processes
  - Some of them have high seasonality
  - They are not located in a place or in a department and thus they are difficult to be collected

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Complete CIP cycle (typical)

Step	Tank CIP (Typical)	
1	Water 20°C	120 sec
2	Soda (alkali) 80°C (closed loop)	660 sec
3	Water 20°C	180 sec
4	Acid 65° C (closed loop)	300 sec
5	Water 20°C	300 sec
6	Detergent	120 sec

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CIP Streams in Dairy - Characteristics

- +++
  - High volumes of water that potentially could be recycled
  - The content in substances is low
- ---
  - There is a large number of cycles from different production processes
  - They are rich in chemicals

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Main auxiliary streams

- Cooling water
  - Ice water (0-2 ^{o}C) in closed loop
  - Fresh water (ambient temperature)
  - Water for cooling of equipment (deionized water in some cases)
- Boiler feed-water
  - It is mainly water from RO, in a closed loop

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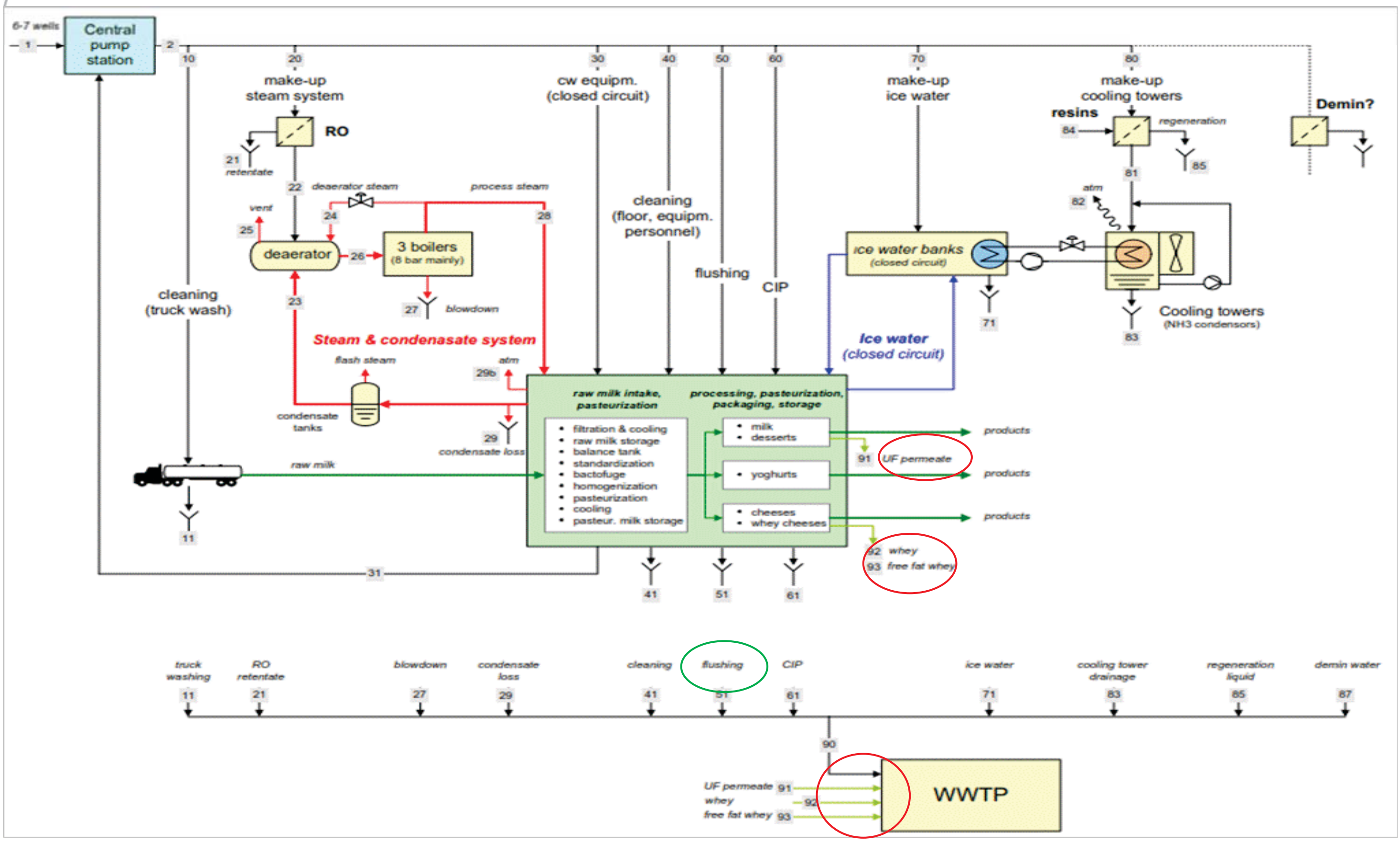
Complete mapping of water streams



Process and cooling water mapping in the dairy industry

Workplan

- Collection of different streams (CIP and flushing) and determination of their physicochemical characteristics
- Determination of CIP and flushing stream qualities and volumes
- Identification of the legislative and the technological constraints concerning water quality characteristics
- Set-up experimental equipment to study different process streams

Questions to be answered

- Which streams should be used for recovery of valuable compounds?
- How much biogas can be produced?
- Does MBR permeate meet specifications for make-up water?

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Strategy for process and cooling water reuse in dairy industry

- Main points of intervention:
  - Upgrade WWTP with an anerobic pre-treatment step for biogas production from whey and/or fat-free whey and/or UF permeate streams diluted with WWTP inlet and a MBR for high quality effluent etc.
  - Collection of water streams (mainly flushing milk and yogurt) for recovery of valuable compounds
  - Collection of separator and / bactofuge discharge for treatment with EPS technology and possible production of animal foods

- Benefits:
  - Recover proteins, lipids etc.
  - Reduce WWTP organic loading
  - Recover biogas (renewable energy source)
  - Substitute make-up water with treated WWTP effluent
  - Reduce freshwater consumption

Acknowledgement

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Innovative technologies for valuable substance recovery and water reuse in the Dairy industry

Aviles,Spain October 4th, 2018

Dimitrios Sioutopoulos, Anastasios Karabelas (CERTH), Narinder Bains (SERE-Tech), Konstantinos Georgakidis (MEVGAL)

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Presentation outline

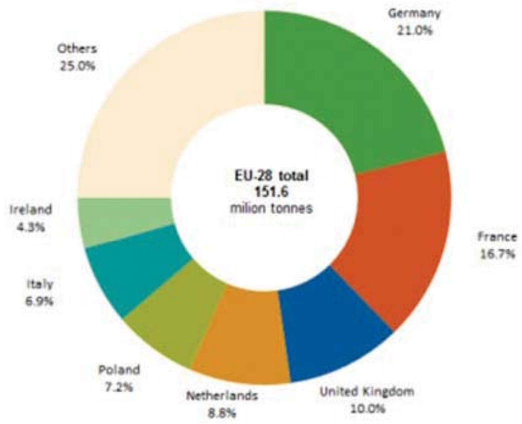
- Introduction-Dairy industry
- Technologies for valuable compounds recovery
  - Membrane technologies /Hybrid membrane technologies
  - Elevated pressure sonication
  - Results of laboratory tests
- Technologies for wastewater treatment
  - Aerobic treatment/ Anaerobic treatment
  - Membrane Bioreactor (MBR)
  - Results of anaerobic/aerobic MBR laboratory tests
- Final conclusions

Dairy industry in EU

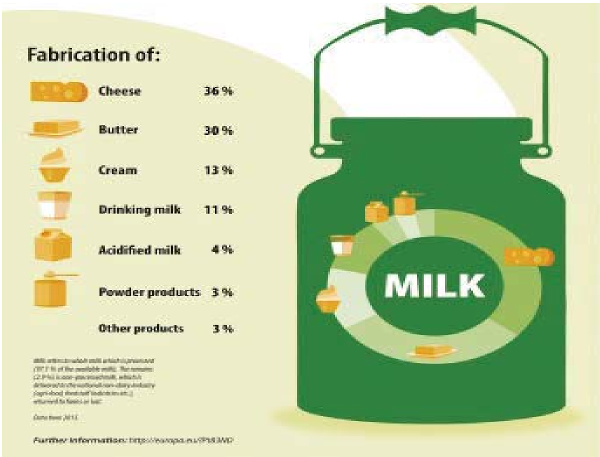
Total milk production in EU

150 million tons per year

Milk production %



Milk products



65 million tons per year

Water consumption in dairy industry

Annual milk production	Specific water consumption	Annual water consumption
147,000,000 m³	~4,0 m³/m³ milk	590,000,000 m³

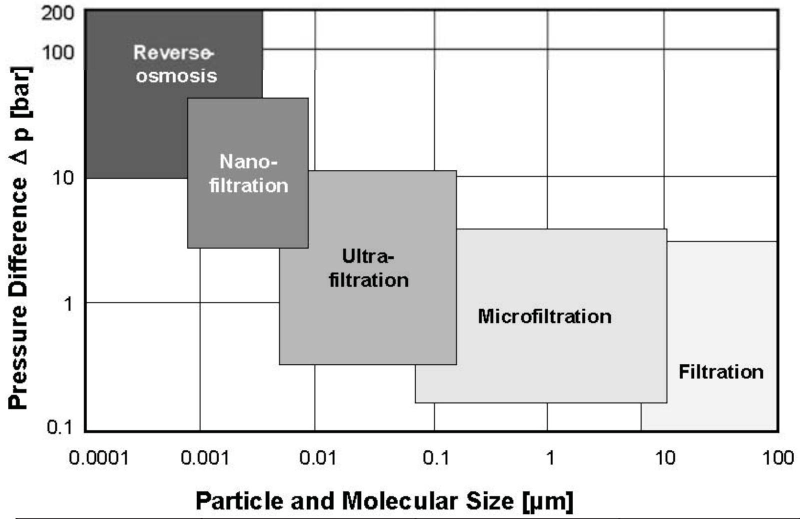
Separation Capabilities of Membranes

MF
- Suspended solids
- Colloidal matter
- Microorganisms

UF
- Organic macromolecules
- Pathogens

NF
- Multivalent ions
- Hardness removal
- Low molecular weight organic compounds

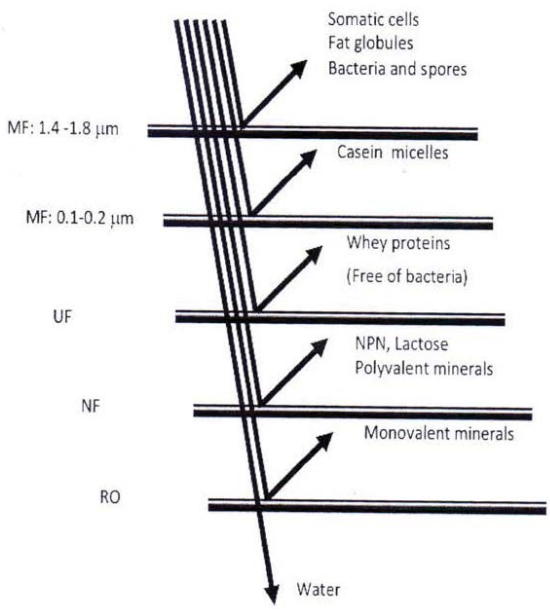
RO
- Dissolved salts
- Low molecular weight organics



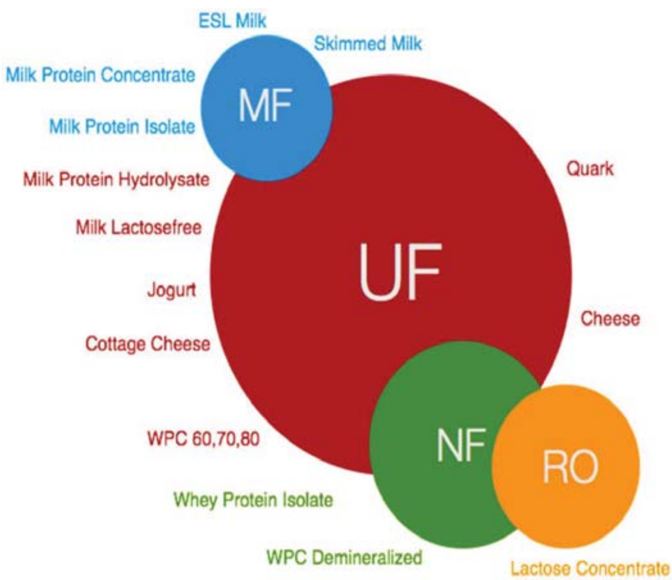
Membrane technology	Typical pore size range, µm	Typical operating pressure, bar	Rate of flux, L/m²·d
Microfiltration	0.1-10	0.07-1	405-1600
Ultrafiltration	0.01-0.1	0.7-7	405-815
Nanofiltration	0.001-0.01	5-10	200-815
Reverse osmosis	0.0001-0.001	8.5-70	320-490

Membranes in dairy industry

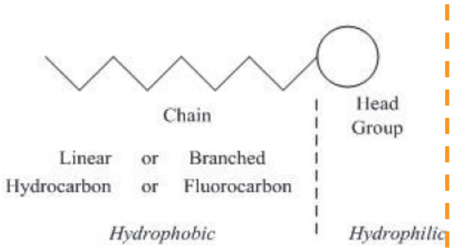
Rejection of milk components



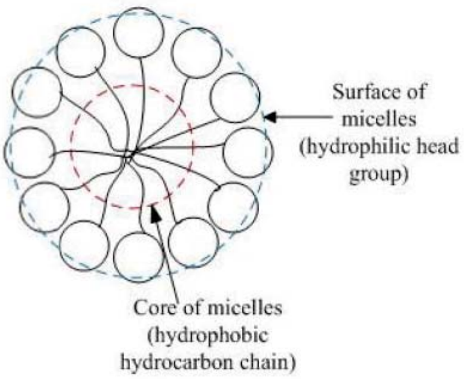
Membrane usage



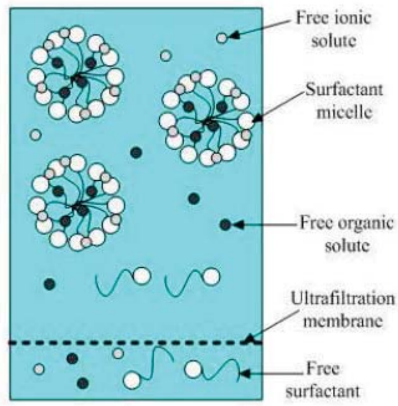
Micellar enhanced Ultrafiltration-MEUF



Surfactant



Micelle



MEUF concept

SURFACTANTS

Tween 80

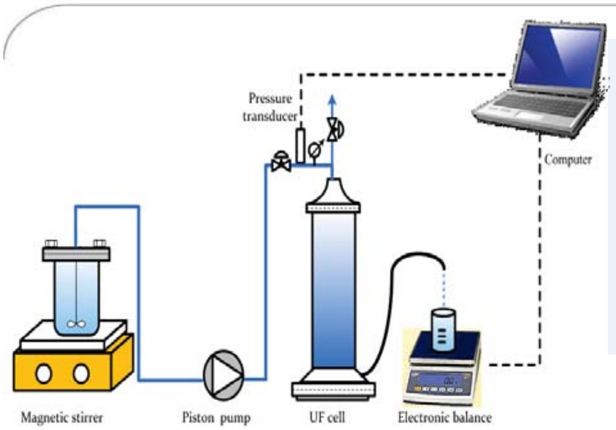
SDS

Selective separation technologies for the dairy industry - Lab tests

Pressurized membrane cell

UF/NF membrane Lab pilot

Experimental conditions

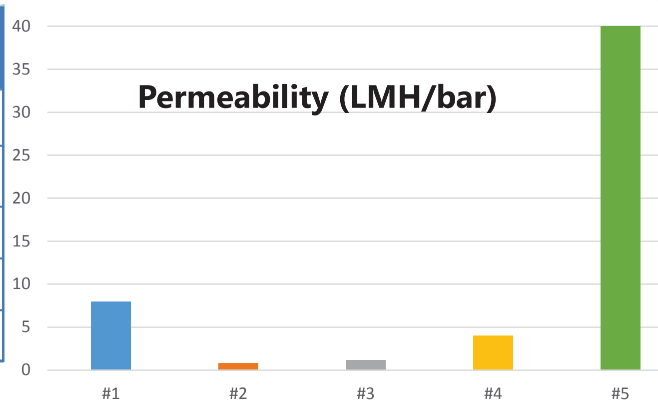


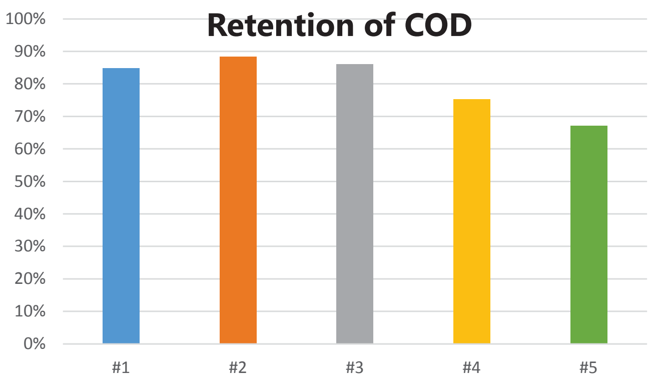
- **Treated sample**
  1. Flushing yogurt
  2. Flushing milk
- **Membrane type**
  1. UF PAN 20 kDa (AMI®)
  2. UF PES 20 kDa (ALVA LAVAL)
  3. MF 0.20 μm (MILLIPORE

Dead-end tests

Experimental results

#	Feedwater	Membrane	Applied pressure	Permeability Clean water (LMH/bar)	Permeability (LMH/bar)
1	Flushing milk	UF PAN 20 kDa	0.5 bar	550	8
2	Flushing milk	UF PES 20 kDa	3.0 bar	60	0.8
3	Flushing milk	UF PES 20 kDa	5.1 bar	80	1.2
4	Flushing yogurt	UF PES 20 kDa	3.0 bar	40	4
5	Flushing yogurt	MF 0.20 μm	0.14 bar	12,000	40





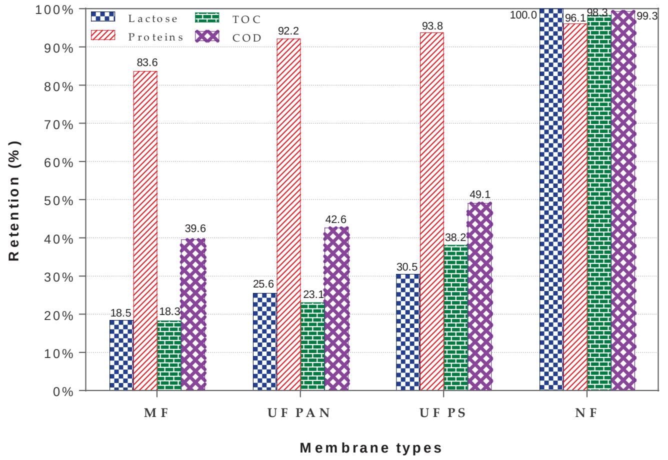
MF (#5) membrane exhibits the larger permeability, but the organic load retention is rather poor

UF membranes exhibit high COD retention (80%-90%)

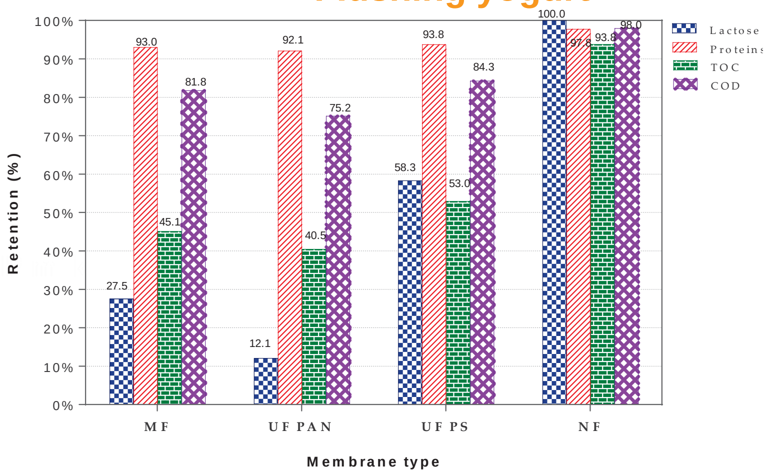
Retention characteristics

Dead-end tests

Flushing milk

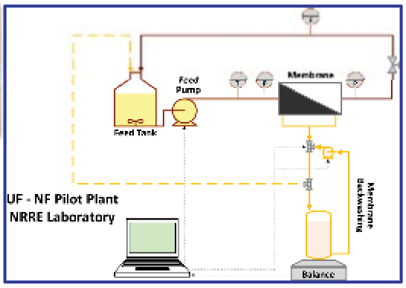


Flushing yogurt

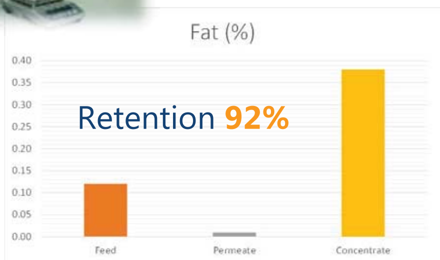


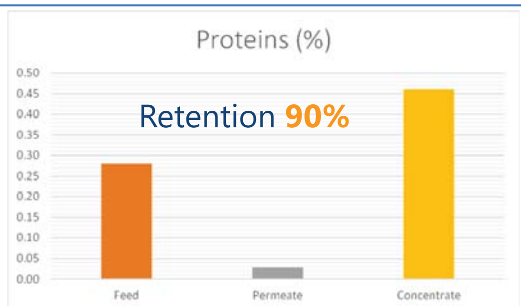
- Valuable compounds (proteins, fat) are effectively retained by UF membranes
- Lactose is totally rejected by NF, whereas UF membranes retain appr.20%-50% of lactose
- In general, higher recovery of valuable compounds using flushing yogurt compared to flushing milk

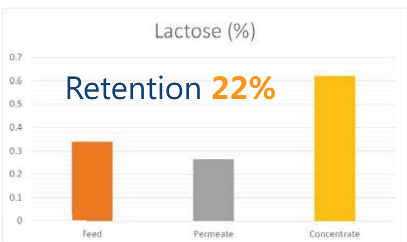
Crossflow tests - MEUF

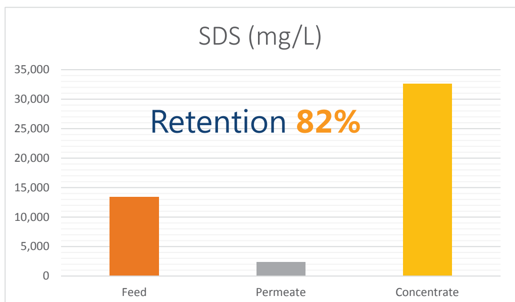


#	Feedwater	Surfactant	Membrane	Applied pressure
1	Flushing Milk 3.5%	SDS 5CMC	PCI FPA03, PVDF	3.5 bar
2	Flushing yogurt 10%	SDS 5CMC	PCI FPA03, PVDF	3.5 bar







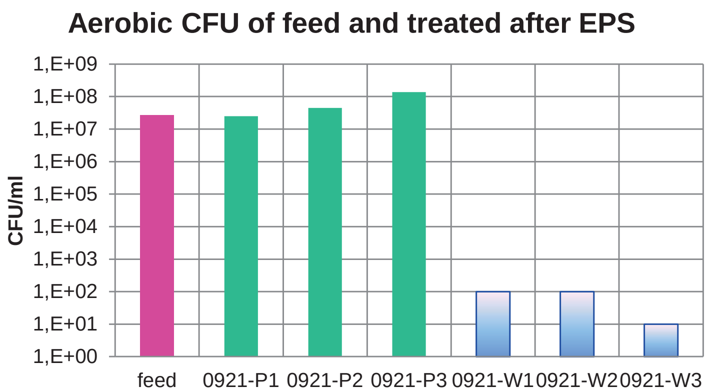


Recovery of useful compounds – Selection of particular UF membrane system

- **General results**
  - High protein (and fat) retention
  - For the retention of lactose, another membrane process (e.g. nanofiltration) would be required
  - Substantial concentration factor achieved for yoghurt
  - Very low membrane fouling tendency observed
  - Relatively small energy consumption (based on required pressure)

Elevated pressure sonication

- 75-100 bar Pressure, 40-55 °C Temperature
- Separator and Bactofuge sludge v. high in bacteria count 10^7-10^8 log counts
- Stabilize and separate for recovery
- EPS achieves 4-6 $\log_{10}$ reductions in bacteria at low energy treatment 10-30 kJ/litre



Biological wastewater treatment

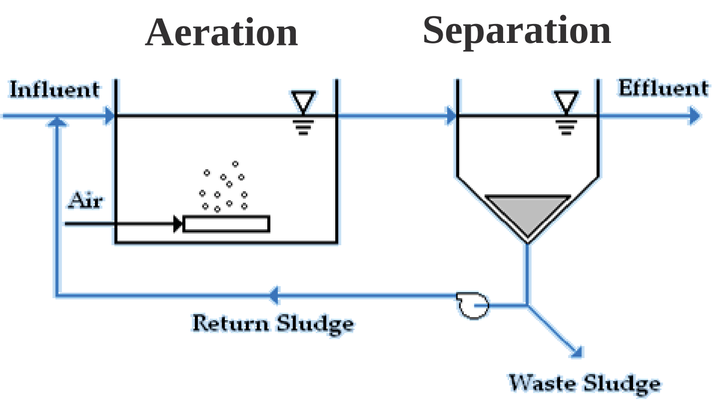
Biogas (CH_4 and CO_2) and sludge

- *H_2O, CO_2 and sludge*

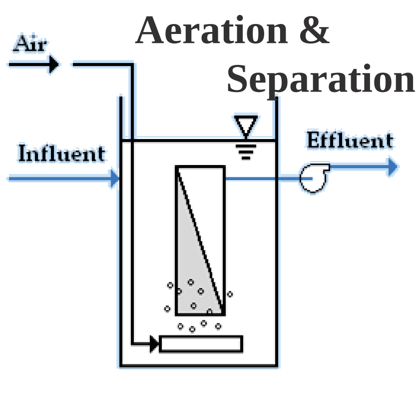
	Anaerobic	Aerobic
Space required	Small	Large
Energy input	Low	High
Energy production	Yes (biogas)	No
Sludge production	Low	Yes
Nutrient removal	No	Yes
Investment cost	High	Low
Operational cost	Low	High
CO2 emission	Low	High

Membrane Bioreactor (MBR)

- An attractive alternative of the Conventional Activated Sludge Process (Aerobic process) by combining biological processes and membrane filtration
- Sedimentation tanks and/or sand filters are replaced by membrane filtration (Microfiltration or Ultrafiltration)

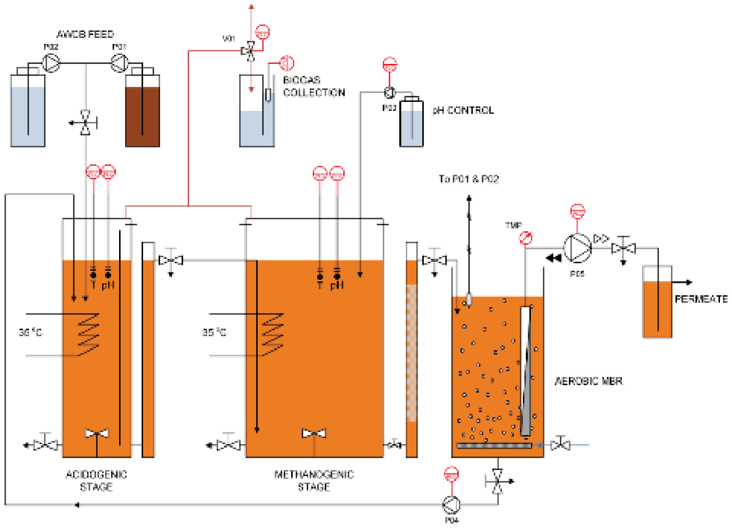


Conventional Activated Sludge Process (CASP)



Membrane Bioreactor (MBR)

Anaerobic/aerobic Membrane Bioreactor (MBR) - Lab tests



- Fully automatic, PLC controlled pilot plant
- Operation under different organic loading rates (i.e. 0.5 - 10 Kg COD/m^3·d) and COD values (i.e. 5 - 20 Kg/m^3)
- Automated pH correction, backwashing of MBR membranes.

Characteristics of activated sludge samples.

Parameter	Anaerobic sample	Aerobic sample
pH	6.92	7.48
MLSS (mg/L)	13,650	4,960
MLFSS (mg/L)	3,050	820
Volume (L)	25	20

Anaerobic/aerobic Membrane Bioreactor (MBR) - Lab tests

- Fully automatic, PLC controlled pilot plant
- Operation under different organic loading rates (i.e. 0.5 - 10 Kg COD/m^3·d) and COD values (i.e. 5 - 20 Kg/m^3)
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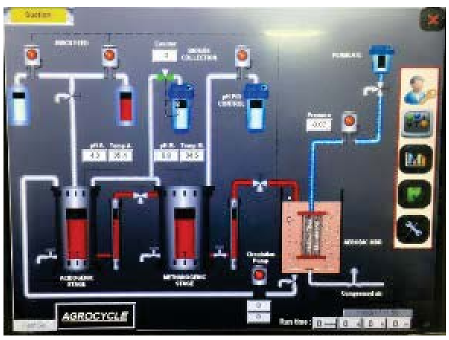
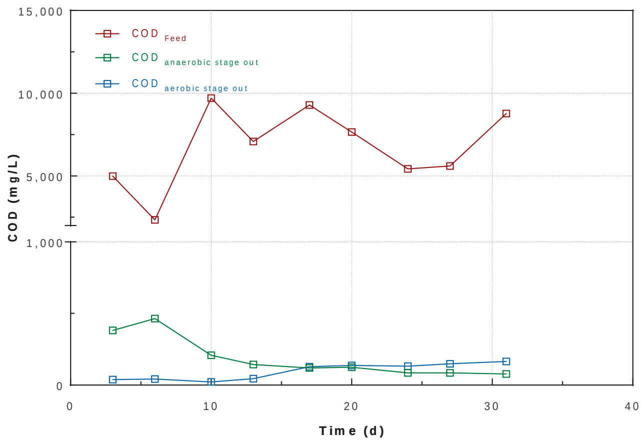
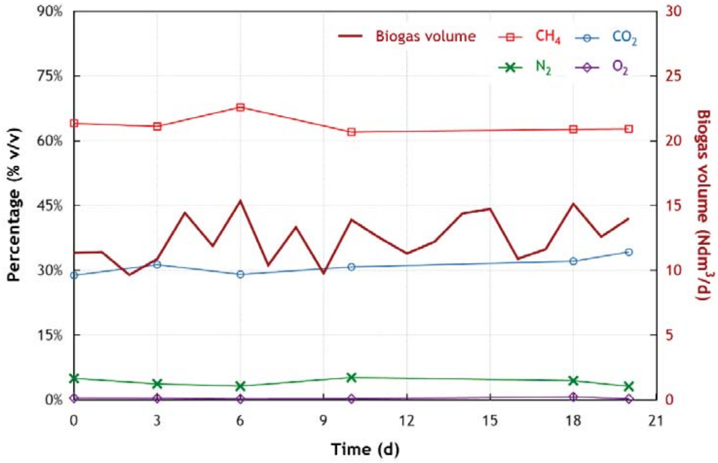


Anaerobic/aerobic Membrane Bioreactor (MBR) - Lab tests

COD removal



Biogas production



- Particularly high reduction of organic matter (COD) ~96% for the anaerobic stage.
- The quality of the aerobic MBR permeate is considered appropriate for cooling water.
- The quality of the produced biogas is considered satisfactory (approx. 65% CH_4)

Conclusions

- Microfiltration due to large pore size exhibits poor useful compounds retention. Nanofitration is characterized by the best retention/selectivity; however, due to increased feed-pressure requirements, energy consumption is significant.
- Ultrafiltration (UF) exhibits satisfactory selectivity and modest energy consumption.
- Micellar enhanced ultrafiltration (MEUF) does not lead to increased separation-process efficiency
- A particular Ultrafiltration (UF) system implementation was selected as the best option for further pilot testing.
- Elevated pressure sonication (EPS) process performance can produce higher value protein concentrate for the dairy and animal feed market.
- The anaerobic/aerobic MBR is considered quite satisfactory for the treatment and valorization of dairy effluents with significant organic load.

Aknowledgement

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