Evaluation of the ppm·h concept for end-of-life RO membrane into recycled NF and UF membranes

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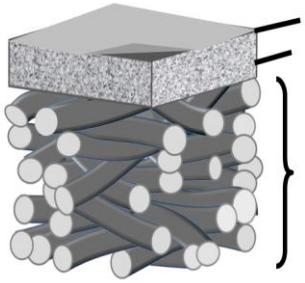
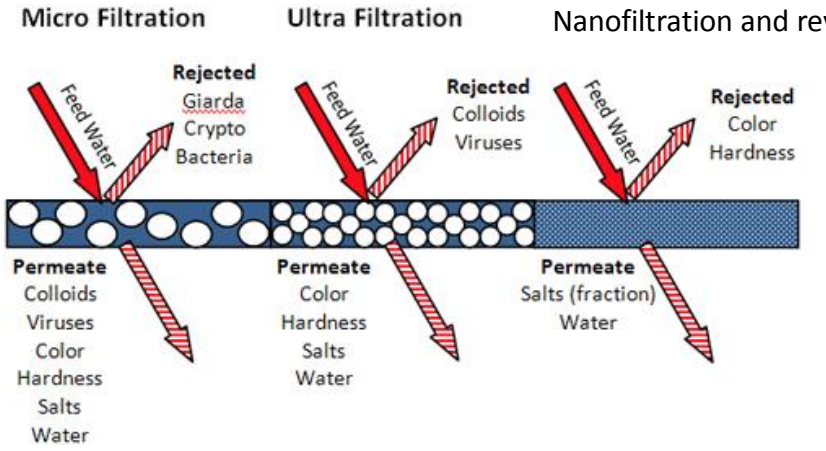
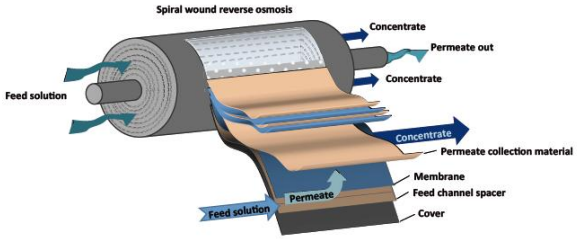
What is a reverse osmosis membrane?



Capa superficial ultrafina (0.1 - 0.5 µm)
Capa porosa (20 - 60 µm)

Tejido soporte (100 µm)





Commercial spiral wound modules.
Selective polymer: **Thin film composite of polyamide** → for over **95%** of existing RO desalination plants

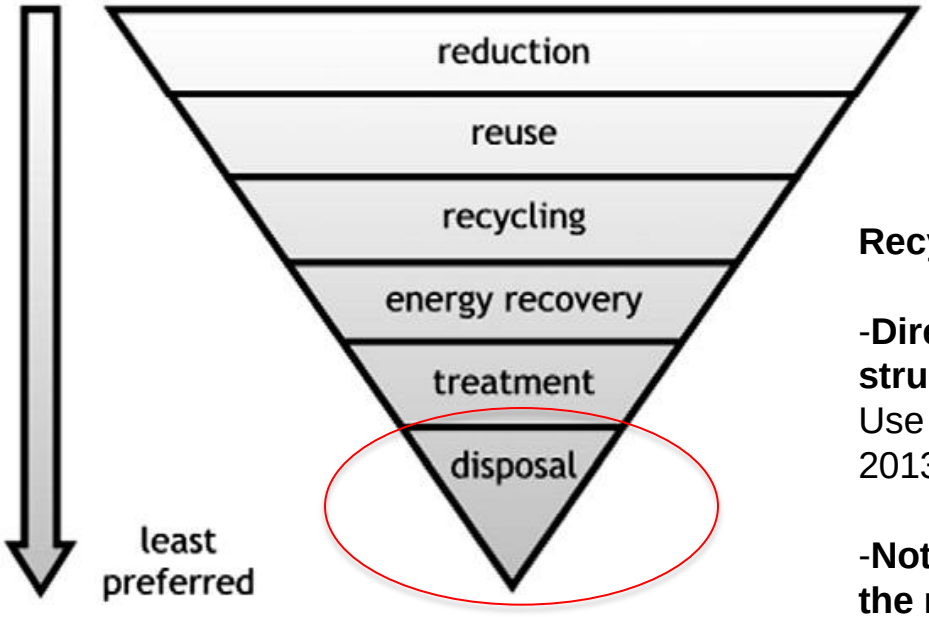
Some numbers regarding Reverse Osmosis Membrane

	Worldwide >150 countries (data from IDA 2013)	Spain (data from AEDYR)	
Total number of desalination plants	>17,000	>700	≈ 4% of total plants
Global capacity of commissioned desalination plants (as of 2013)	> 80 Hm^3/day	> 5.4 Hm^3/day	≈ 6.75% of global capacity
Estimated end-of-life membrane per year	**960,000**	**64,800**	Considering 100 modules to produce 1000 m^3 and a 12% annual membranes replacement rate
Tonnes of end-of-life membranes per year	>12.900	> 800	

Could be recycling membranes an alternative solution?

Reverse osmosis membranes recycling and reuse experiences

DIRECTIVE 2008/98/EC on waste



Waste management hierarchy from most to least preferred options.

Reuse: do not damage the polyamide layer

- Desalination plant experiences, used membrane in the same desalination plant (changing positiion

- Life Remembrane (cleaning and prepearing for reuse)

Recycling: polyamide oxidation

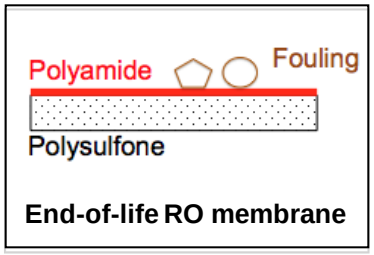
-**Direct recycling: do not interfere in the module structure**.
Use K7MnO4 , NaOCl: Veza et al., 2002; Lawler et al., 2013

-**Not direct recycling: involve the deconstruction of the module**
Geotextile, fabric and decoration for clothing

Aim of LIFE-TRANSFOMEM european project

End-of-life membranes used in high pressure filtration process: reverse osmosis

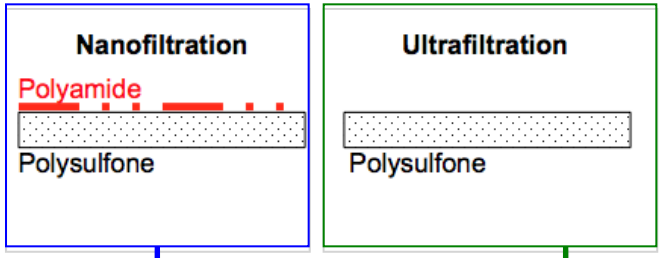
Selective polymer 0.1% of membrane thickness



Transformation

It suffers sodium hypochlorite chemical attack

Recycled membranes to be used at low pressure filtration process



Reuse of the recycled NF membranes
- Brackish water
- Sacrifice membranes in RO process

Reuse of the recycled UF membranes
- Pretreatment of RO process
- Reclaim wastewater as tertiary treatment.

Up to date results of the Life Transfomem

-It was identify the transformation condition at passive method to achieve nanofiltration and ultrafiltration performances.

-It was identified that concentration of NaOCl and exposure time are the main factor (at basic pH) affecting the transformation process.

-**Optimal ppm·h exposure level were identified**

6,200 ppm·h to achieve NF performances

30,000 ppm·h to achieve UF performances

Main Objective of this work

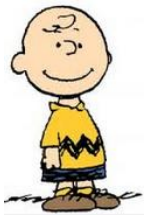
-To transform end-of-life membranes into **NF** and **UF recycled membranes** at lab scale.

-To optimize the concentration and exposure time of the transformation process to further scale it up to pilot systems.

Specific Objective

-Evaluation of the exposure level ppm· h (concentration x time) for end-of-life RO transformation

Does the ppm·h exposure level remain optimal when concentration and exposure time change?



When **transformed membranes** achieve UF performance, do the membranes **surfaces have identical properties**?

Is exposure level (ppm·h) **reproducible** in **different** end-of-life **membranes brands** to achieve NF range and UF range?

Membrane transformation protocol and filtration test

Coupons **Extration**

Membrane **performance** Mix solution

Passive method

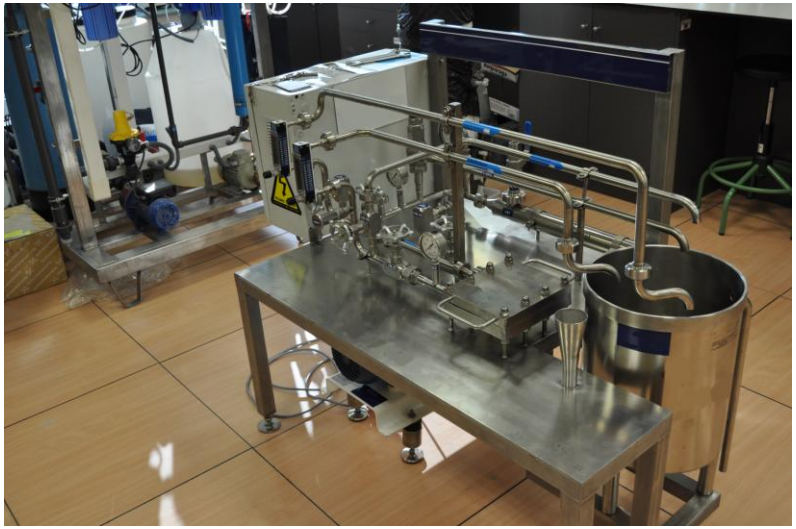
Membrane **performance** Mix solution

In case of UF performance. **Surface characterizat**ion

End-of-life membrane | **Transformation solution** | **Recycled membrane** → Time

Two exposure level were evaluated

- **6,200 ppm · h** → To transform into **NF** recycled membrane
- **30,000 ppm·h** → To transform into **UF** recycled membrane



Using a total recycling system and a mix solution (MgSO4, NaCl and dextrose) membranes performances were evaluated by

-Permeability L / (h·m2·bar)

-% Rejection [(C0-Cp)/C0*100]

Cases studies of concentration and exposure time were evaluated

A	X Concentration	Y Exposure time
B	10X Concentration	Y/10 Exposure time
C	50X Concentration	Y/50 Exposure time
D	100X Concentration	100Y Exposure time

✔ Ideal for pilot scale

- **6,200 ppm · h → NF**
- **30,000 ppm·h → UF**

4 membrane coupons for 4 different brands (BW, SW) employed to conduct the 2 exposure level

A Total of 32 experiments

Surface characterization in case of UF recycled membrane

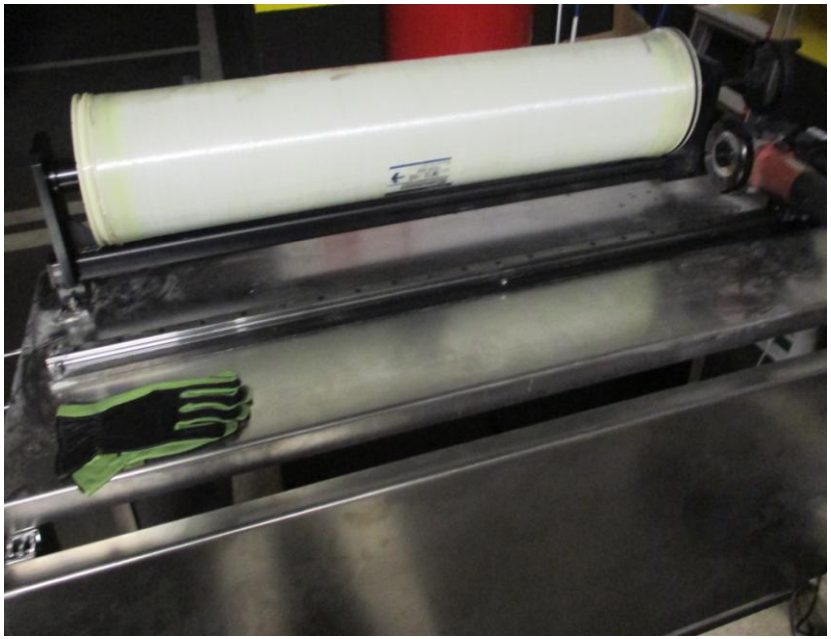
-Scanning electron microscopy (SEM) using S-800 MODEL (HITACHI)

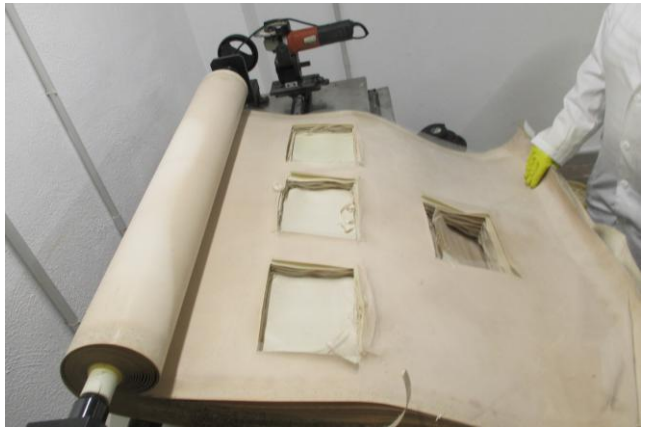
-Attenuated total reflectance –Fourier transform infrared (ATR-FTIR)

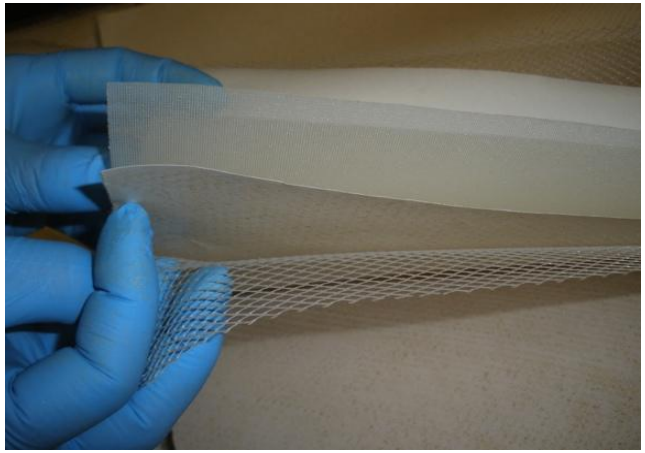
Does the ppm·h exposure level remain optimal when concentration and exposure time change?

Lets see an individual case of end-of-life membrane

TM 720-400 BRACKISH WATER

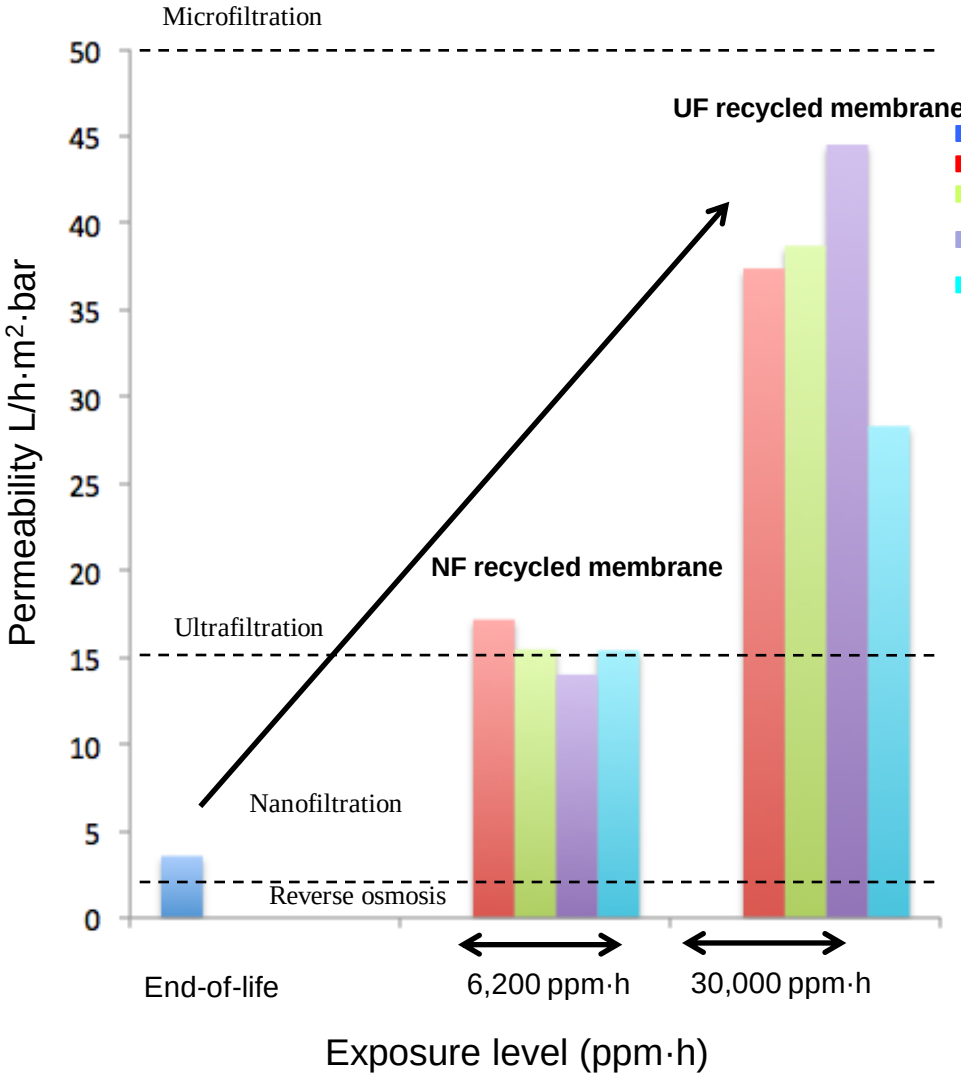






Filtering test: evaluation of membrane permeability

TM 720-400 BRACKISH WATER



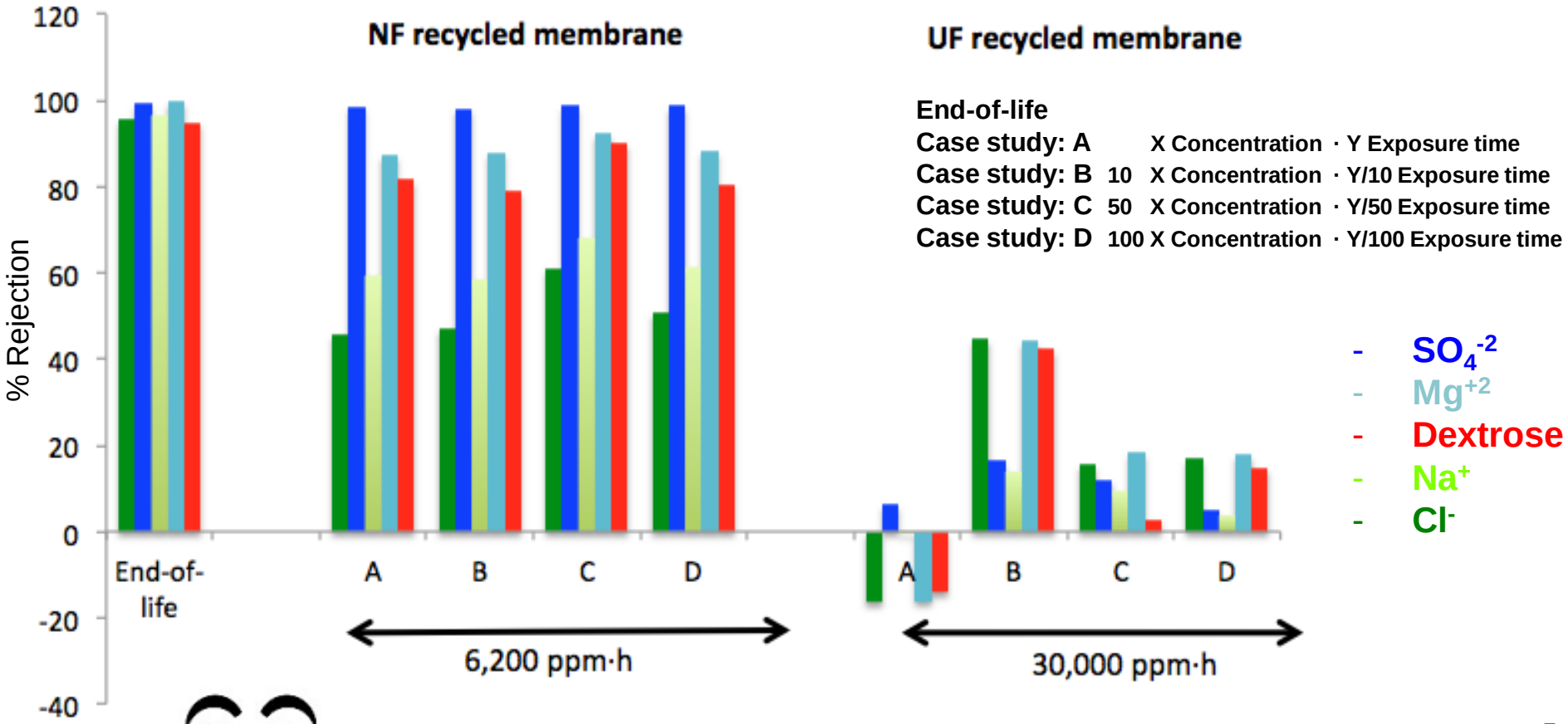
End-of-life		
Case study: A		X Concentration · Y Exposure time
Case study: B	10	X Concentration · Y/10 Exposure time
Case study: C	50	X Concentration · Y/50 Exposure time
Case study: D	100	X Concentration · Y/100 Exposure time

Membranes rejection are reproducible for transformation in **NF** recycled membrane. **Permeability achieve is similar**

For transformation into **UF** recycled membrane permeability is variable

Filtering test: evaluation of ionic and dextrose rejection

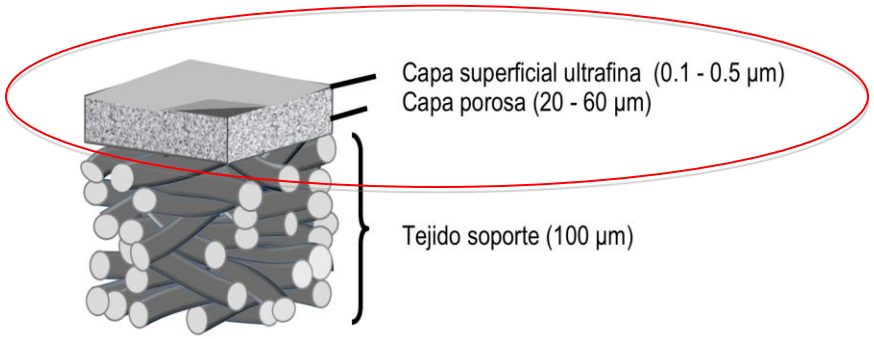
TM 720-400 BRACKISH WATER



Membranes rejection are reproducible !

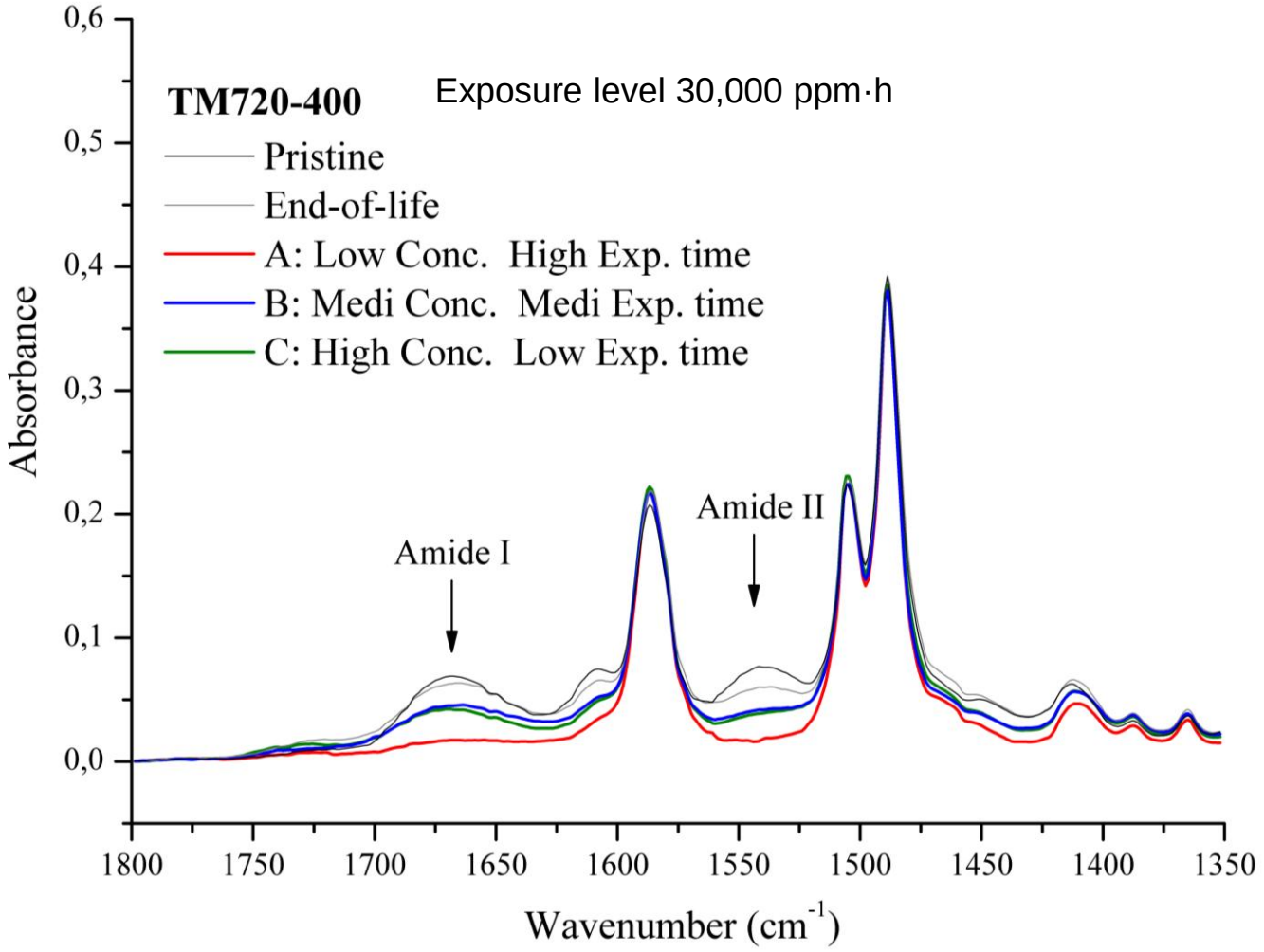
Transformation into UF recycled membrane is dependent from concentration and exposure time to NaOCl !

When **transformed membranes** achieve UF performance, do the membranes **surfaces have identical properties**?

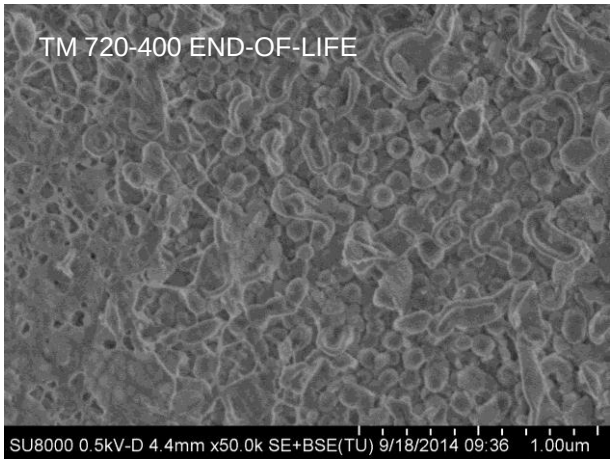


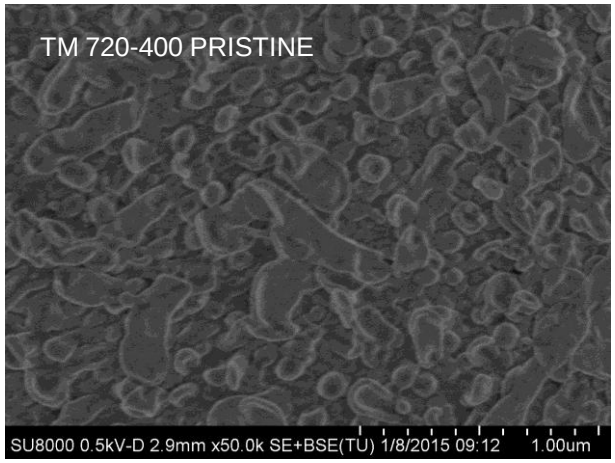
Surface characterization in case of UF recycled membrane:

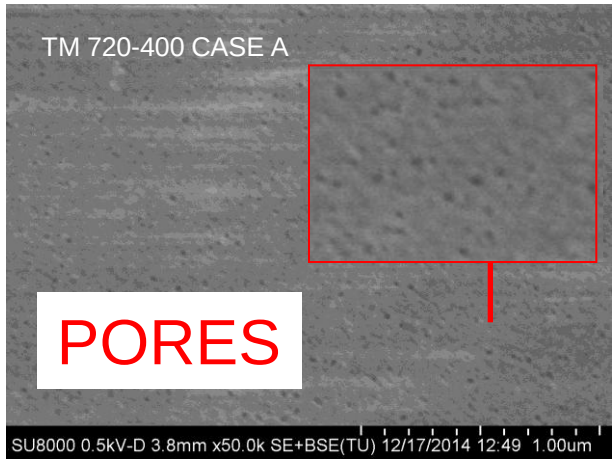
Attenuated total reflectance –Fourier transform infrared (ATR-FTIR)



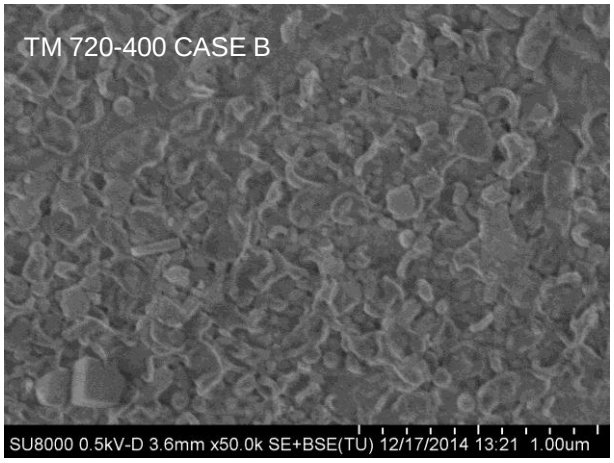
-Scanning electron microscopy (SEM) using S-800 MODEL (HITACHI)

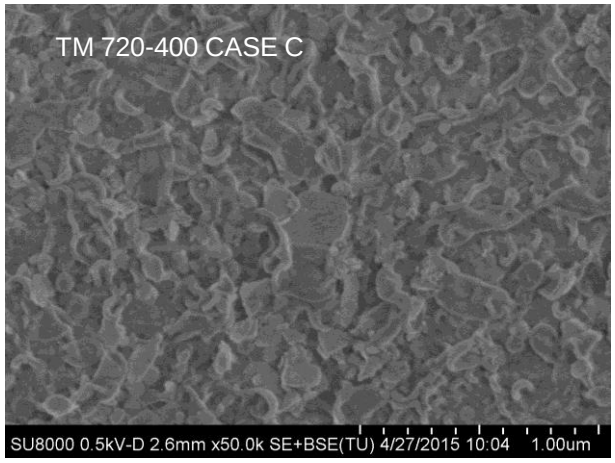


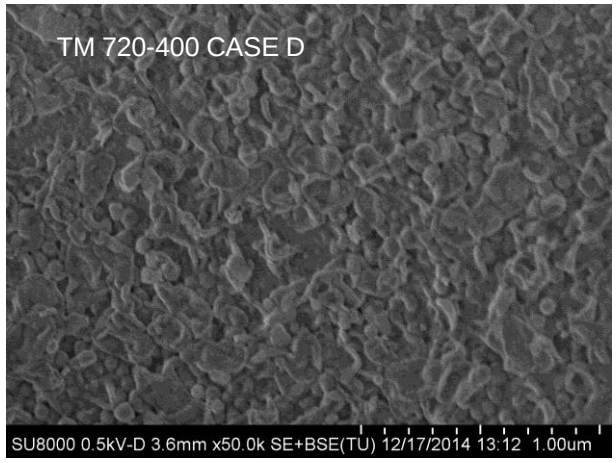




In all cases excepting “A” exist polyamide

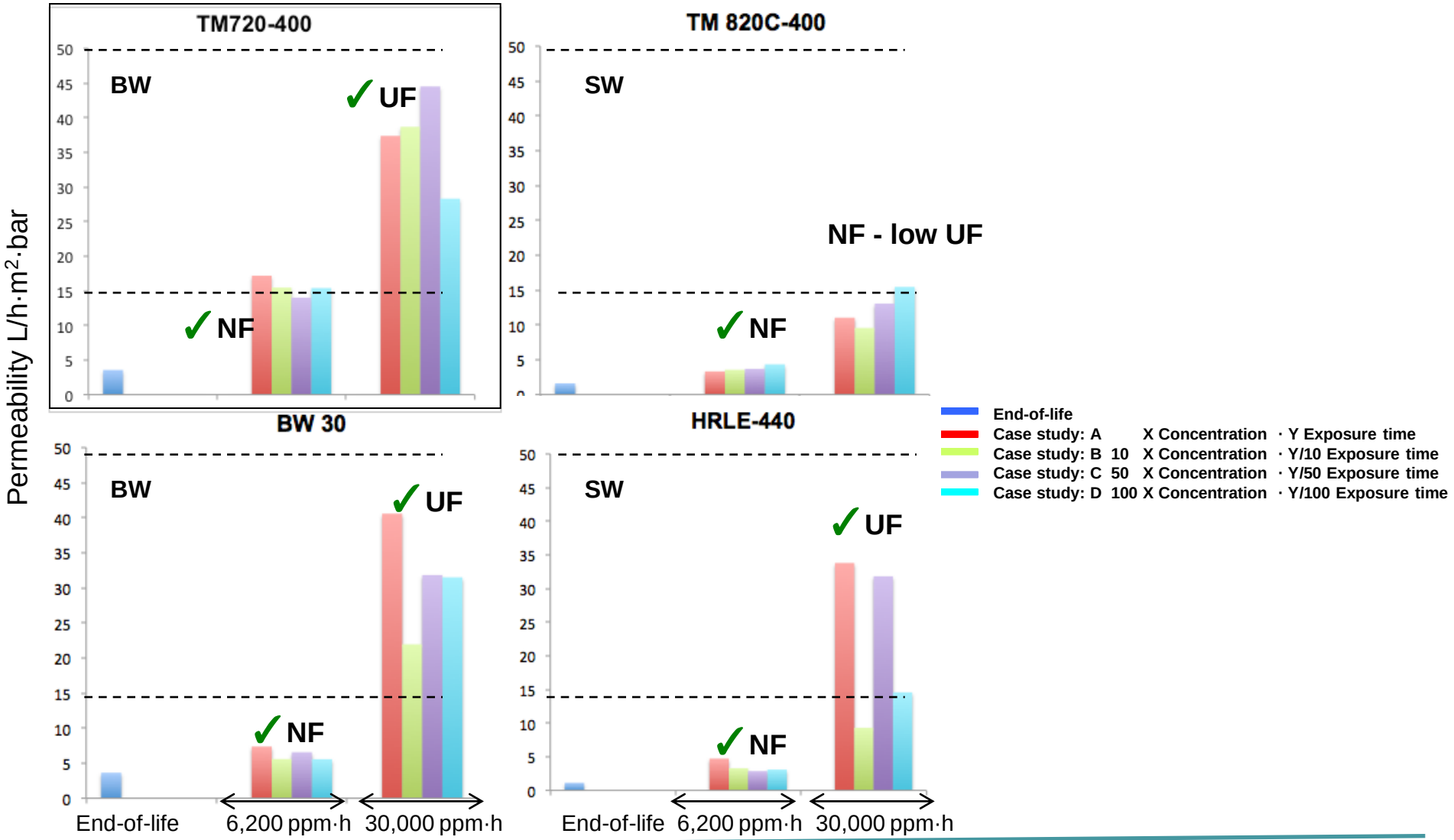






Is Exposure level (ppm·h) **reproducible** in **different** end-of-life **membranes brands** to achieve NF range and UF range?

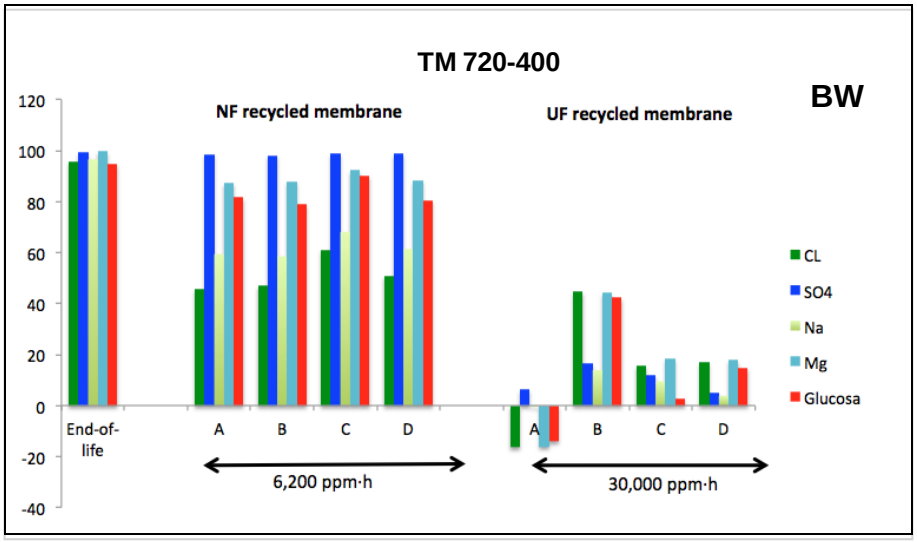
Filtering test: evaluation of membrane permeability

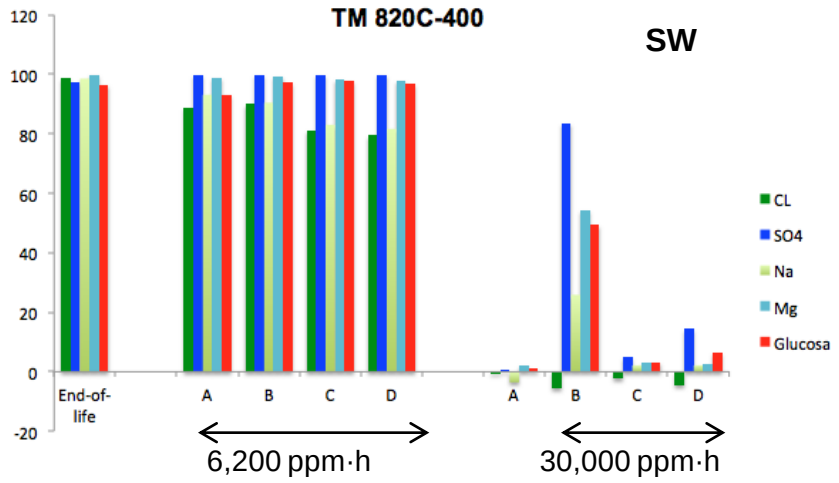


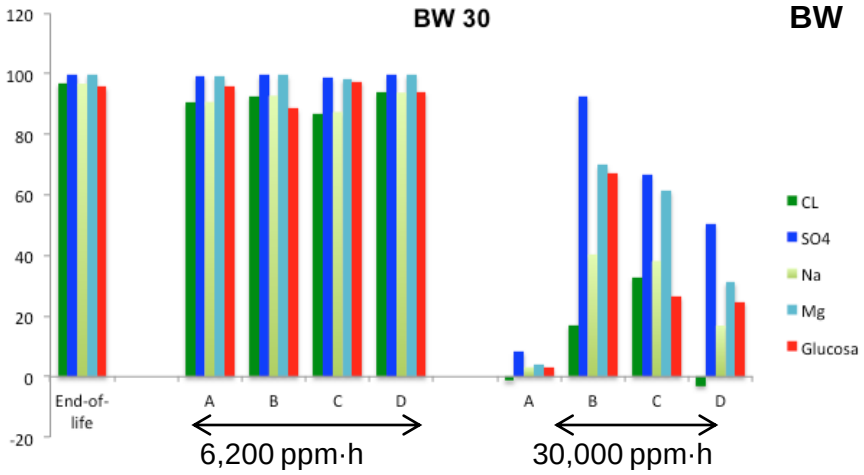
Filtering test: evaluation of ionic and dextrose rejection

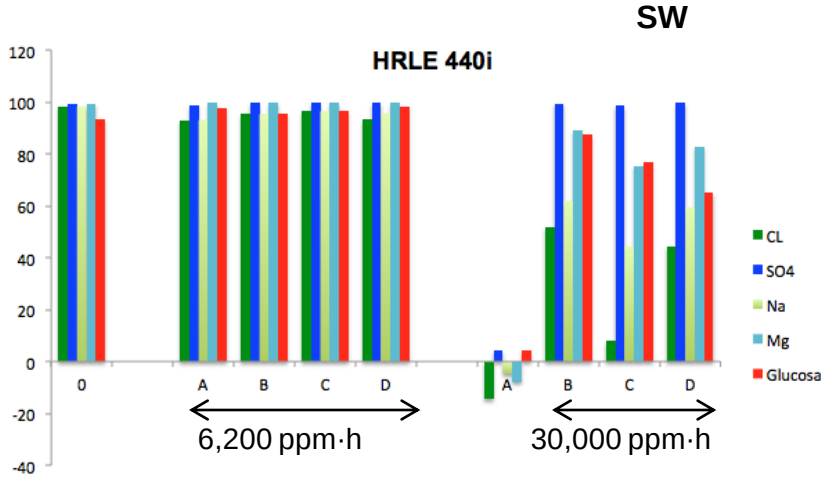
End-of-life

Case study: A		**X Concentration · Y Exposure time**
Case study: B	**10**	**X Concentration · Y/10 Exposure time**
Case study: C	**50**	**X Concentration · Y/50 Exposure time**
Case study: D	**100**	**X Concentration · Y/100 Exposure time**









End-of-life RO membranes were efficiently transformed into NF and UF membranes by exposing to NaOCl solution (passive inmersion)

¿Is there **any difference on the transformation process if concentration** of NaOCl and the **exposure time are variable** but the **product of them is constant**?

- **NF Transformed** membranes achieved **same permeability and rejection.**

- **UF Transformed** membranes performances are **significant differences**.
  The most similar results were found in case A (lowest concentration, highest time) and case C (50X concentration and Y/50 exposure time)

When **transformed membranes** achieve NF and UF performances, do the membranes **surfaces have identic properties**?

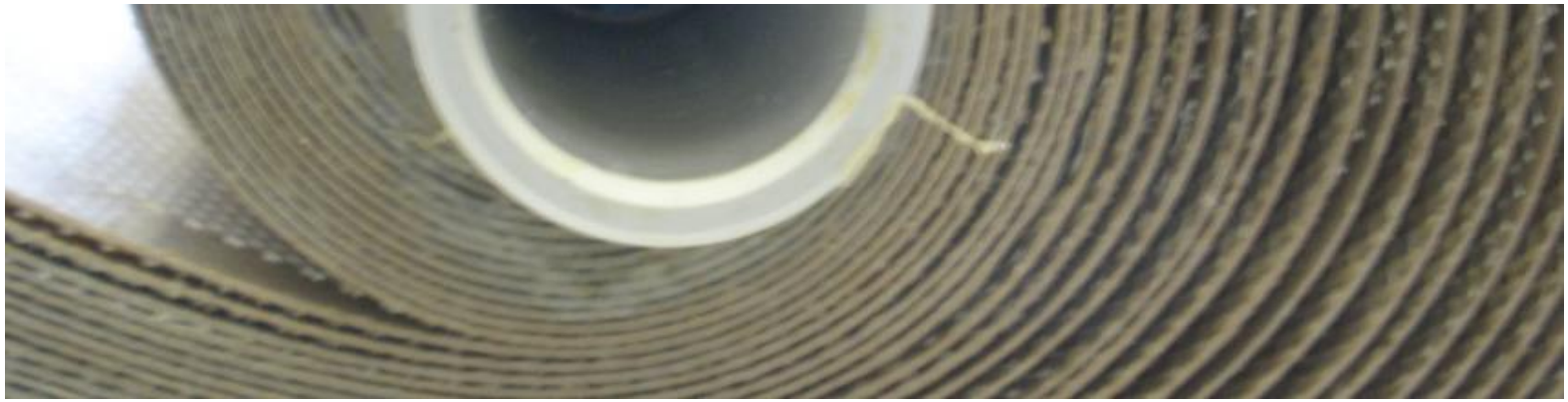
- **No, UF Transformed** surface have **significant differences**.

Polysulfone pores were only found in case A (lowest concentration, highest time), in the rest of cases rest of polyamide polymer are still present. Same occurred with ATR-FTIR analysis. Only in case A exist polyamide polymer.

Is Exposure level (ppm·h) **reproducible** in **different** end-of-life **membranes brands** to achieve NF range and UF range?

- **All membrane achieve NF and UF range performances**
- **The main factor for a sucsseful transformation is previous membrane fouling**

Thank you so much for your attention



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