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INTEGRAL WATER MANAGEMENT IN THE PAPER INDUSTRY: A CASE STUDY

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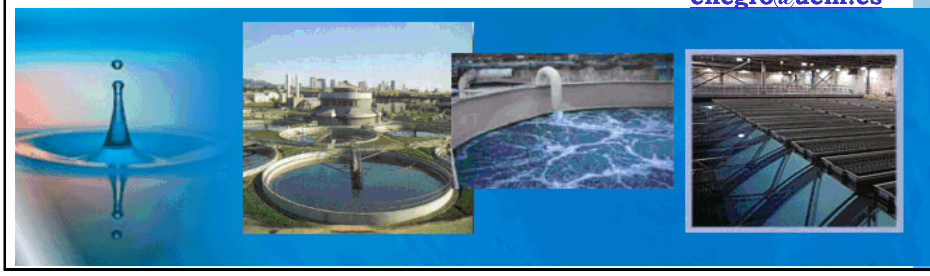
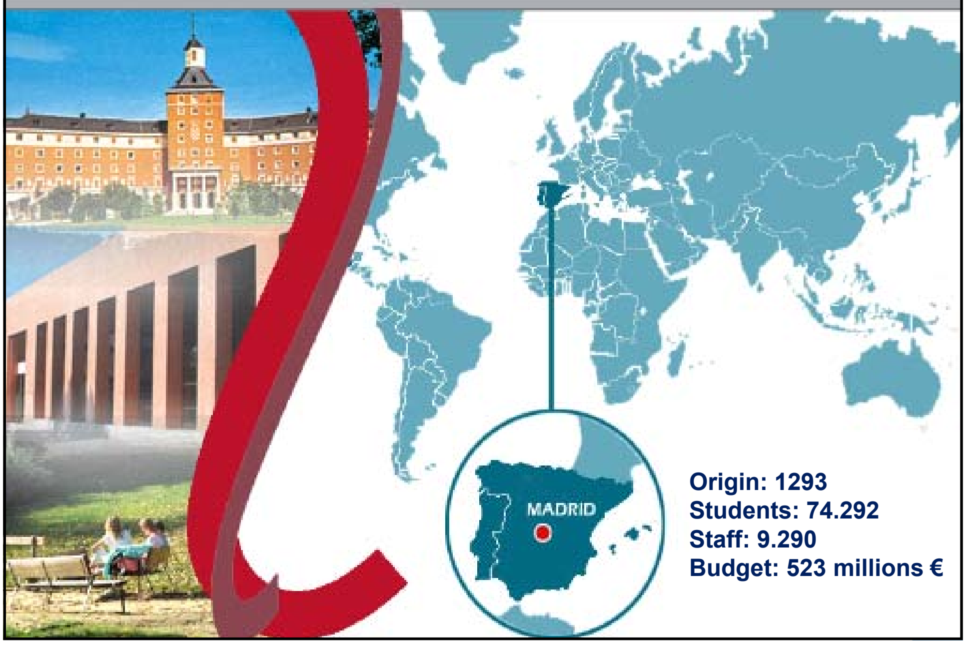
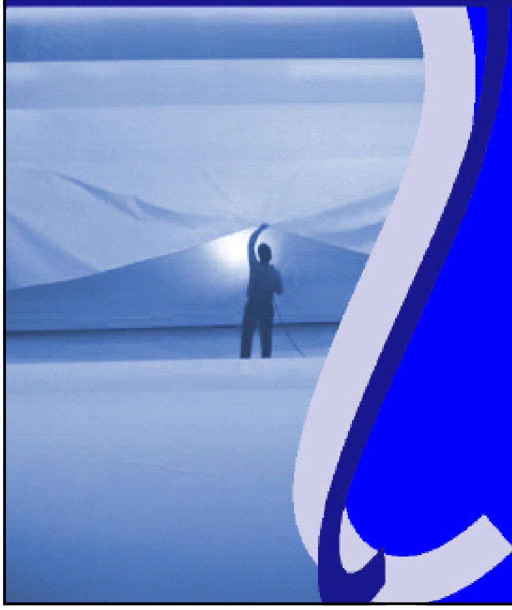


University Complutense of Madrid



Paper Research Group



Its activities are conducted in two lines: Fundamental Research and the Applied Research, in order to enhance the technical and scientific expertise of the industry. The Fundamental Research is devoted to the acquisition of new knowledge and the fundamental understanding of the phenomena taking place during pulp and papermaking. On the other hand, the Applied Research is devoted to the application of these knowledge to solve the needs of the industry and suppliers.

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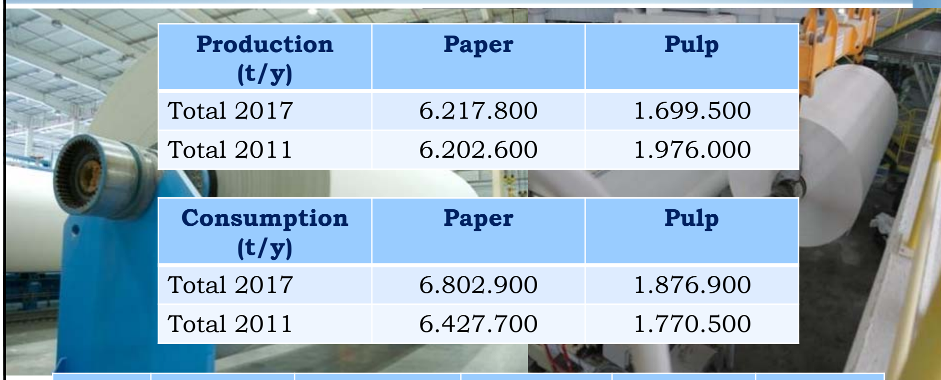
SPANISH PAPER SECTOR



Production (t/y)	Paper	Pulp
Total 2017	6.217.800	1.699.500
Total 2011	6.202.600	1.976.000

Consumption (t/y)	Paper	Pulp
Total 2017	6.802.900	1.876.900
Total 2011	6.427.700	1.770.500

	Collection	Utilisation	Collection rate	Utilisation rate	Recycling rate
Total 2017	4.560.100	5.020.000	67	80,7	73,8
Total 2011	4.722.500	5.093.800	73,5	82,1	79,2

Source: ASPAPEL, 2017

WATER USAGE AND SOURCES

	Pulp	Paper
Total water usage (m^3/t)	35,4	7,9
Effluent (m^3/t)	29	7

Water Capture per source	Million m^3
Well	23
Surface Waters	70
Supply Net	12,5
Recovered Water	**3,5**
TOTAL	**109**

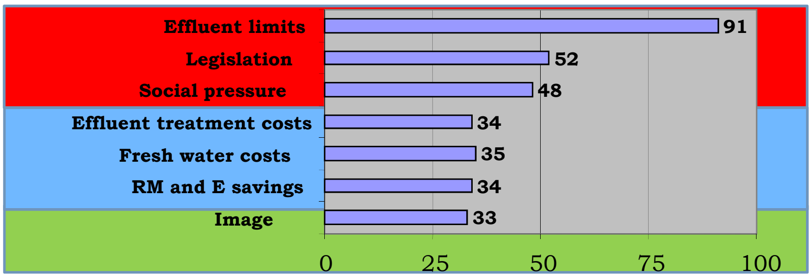
WASTE WATER EFFLUENTS

Onsite Waste Water Treatments	% of Total
Primary	8
Primary + Secondary	75
Primary + Secondary + Tertiary	17

Effluent Quality	Kg/t
COD (pulp)	7,2
COD (paper)	2,2
TSS (pulp)	1,0
TSS (paper)	0,4

Waste Water effluents	Million m^3
Rivers and Lakes	34
Sea	36
Urban Sewers	**21**
Estuaries	2
TOTAL WATER DISCHARGES	**93**

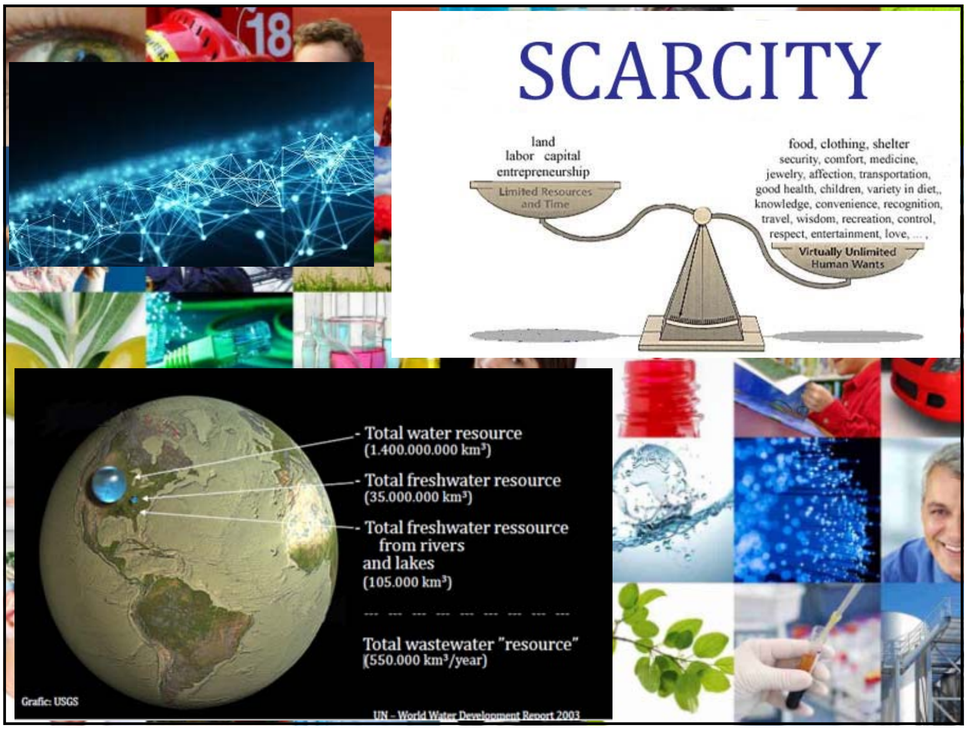
Fresh water reduction Drivers

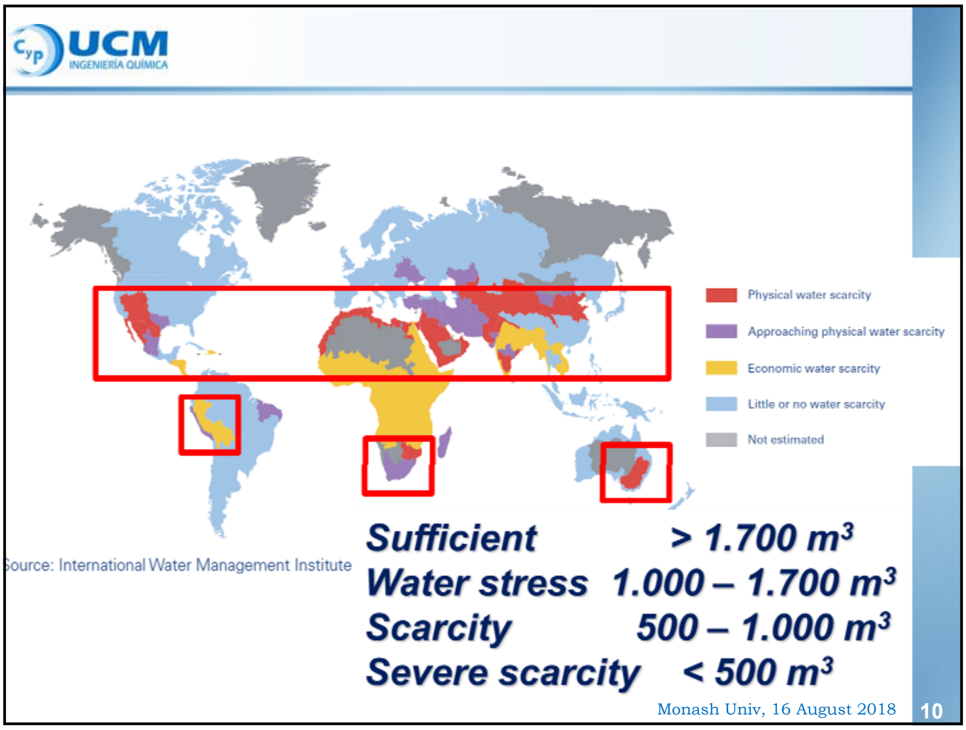


- ✓ **Towards Closed water circuits**
- ✓ **Closure degree varies with grades**
- ✓ **90% reduction of water consumption in 3 decades**

⇩

- **Minimize water footprint of the paper industry**
- **Water quality appropriate for type of use**


SCARCITY
land
labor capital
entrepreneurship
Limited Resources and Time
food, clothing, shelter
security, comfort, medicine,
jewelry, affection, transportation,
good health, children, variety in diet,,
knowledge, convenience, recognition,
travel, wisdom, recreation, control,
respect, entertainment, love, ...,
Virtually Unlimited Human Wants
- Total water resource
(1.400.000.000 km³)
- Total freshwater resource
(35.000.000 km³)
- Total freshwater ressource
from rivers
and lakes
(105.000 km³)
Total wastewater "resource"
(550.000 km³/year)
Grafic: USGS
UN – World Water Development Report 2003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Physical water scarcity
Approaching physical water scarcity
Economic water scarcity
Little or no water scarcity
Not estimated
Source: International Water Management Institute
Sufficient > 1.700 m³
Water stress 1.000 – 1.700 m³
Scarcity 500 – 1.000 m³
Severe scarcity < 500 m³
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10

Domestic

Agriculture

Recreation

Energy

Industry

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Vision

- **Water quality appropriate for type of use.**
- **Minimize water footprint.**
- **Industrial growth decoupled from resource consumption.**
- **Symbiotic approach integrating industrial, urban and rural resources**

Minimum contribution to water stress

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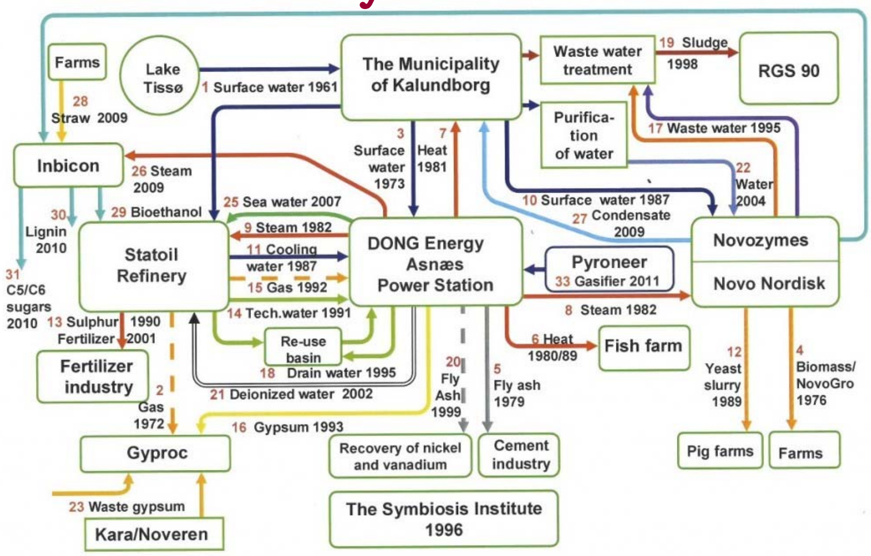
Kalunborg Industry Symbiosis



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Vision

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Minimum contribution to water stress

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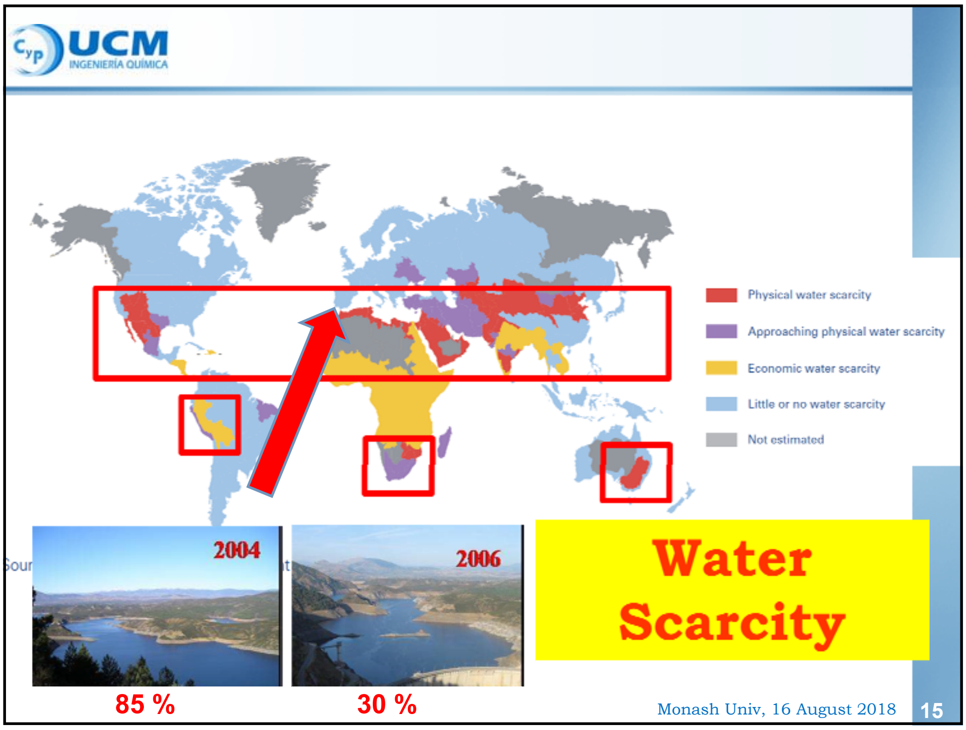

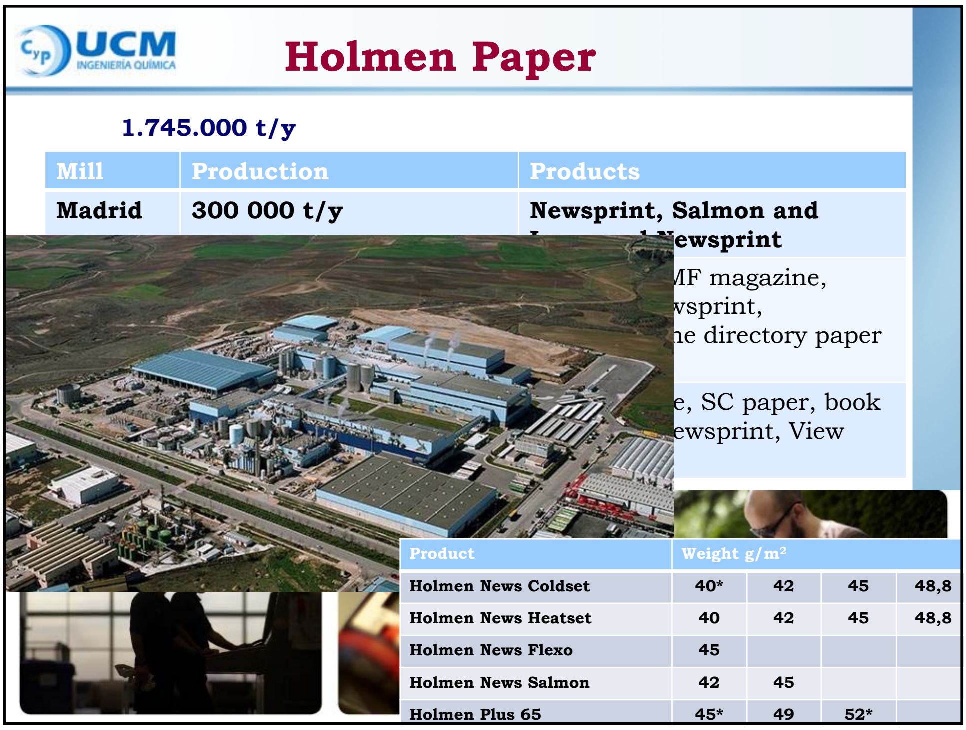

Mill	Production	Products
Madrid	300 000 t/y	Newsprint, Salmon and

Product	Weight g/m²			
Holmen News Coldset	40*	42	45	48,8
Holmen News Heatset	40	42	45	48,8
Holmen News Flexo	45			
Holmen News Salmon	42	45		
Holmen Plus 65	45*	49	52*	

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Process & water management

1. HIGH PRODUCTIVITY

- Formation
- Retention
- Drainage

Max. production
Without breaks
Minimum cost

WATER MANAGEMENT

2. HIGH QUALITY PRODUCTS

Opacity, brightness, strength, ….

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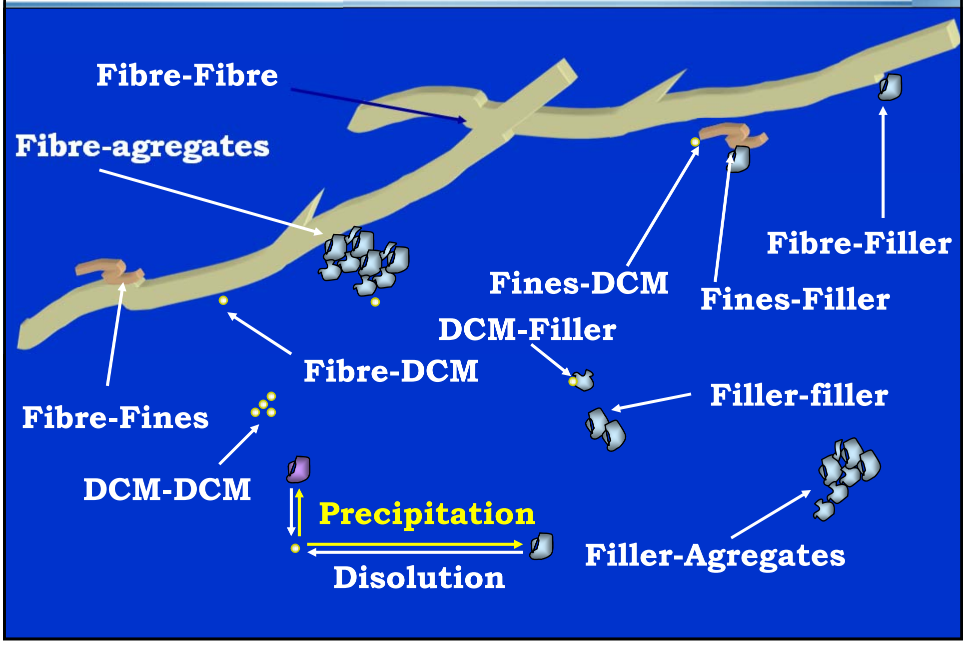
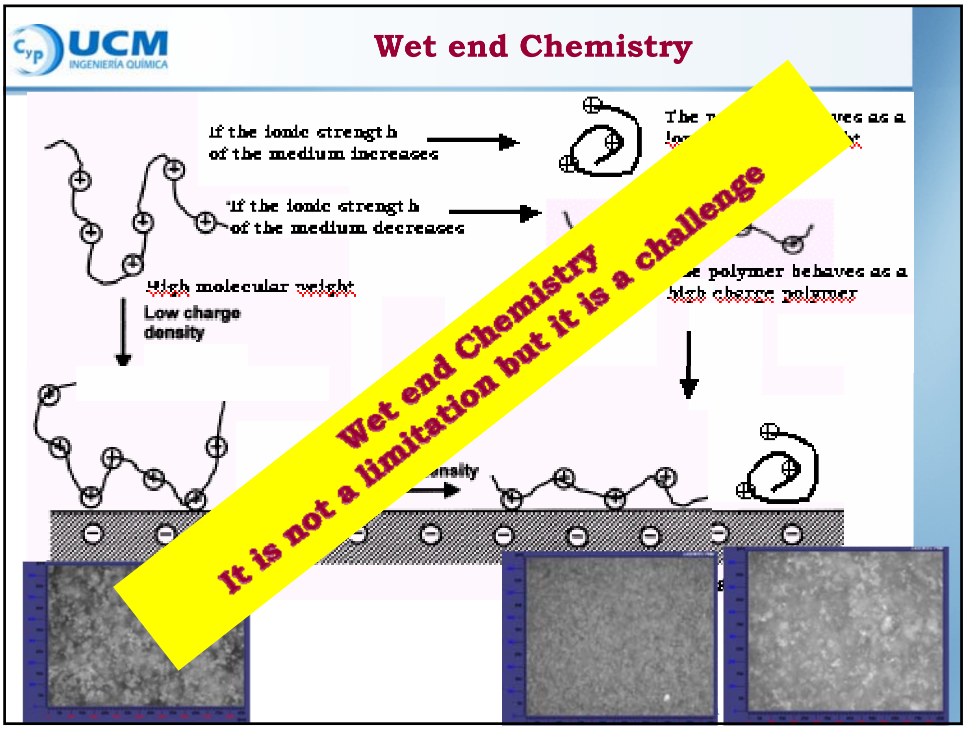
Water Quality- interactions





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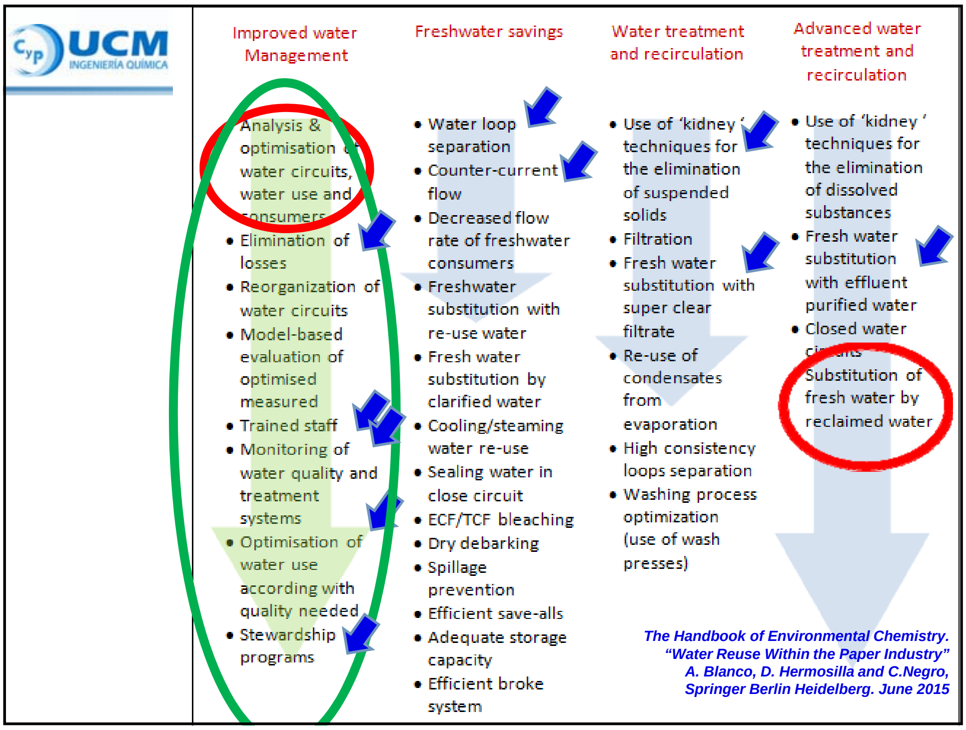
Wet end Chemistry
If the ionic strength of the medium increases
If the ionic strength of the medium decreases
High molecular weight
Low charge density
polymer behaves as a high charge polymer
Wet end Chemistry
It is not a limitation but it is a challenge



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Improved water Management
Freshwater savings
Water treatment and recirculation
Advanced water treatment and recirculation
Analysis & optimisation water circuits, water use and consumers
Elimination of losses
Reorganization of water circuits
Model-based evaluation of optimised measured
Trained staff
Monitoring of water quality and treatment systems
Optimisation of water use according with quality needed
Stewardship programs
Water loop separation
Counter-current flow
Decreased flow rate of freshwater consumers
Freshwater substitution with re-use water
Fresh water substitution by clarified water
Cooling/steaming water re-use
Sealing water in close circuit
ECF/TCF bleaching
Dry debarking
Spillage prevention
Efficient save-alls
Adequate storage capacity
Efficient broke system
Use of 'kidney' techniques for the elimination of suspended solids
Filtration
Fresh water substitution with super clear filtrate
Re-use of condensates from evaporation
High consistency loops separation
Washing process optimization (use of wash presses)
Use of 'kidney' techniques for the elimination of dissolved substances
Fresh water substitution with effluent purified water
Closed water circuits
Substitution of fresh water by reclaimed water
The Handbook of Environmental Chemistry.
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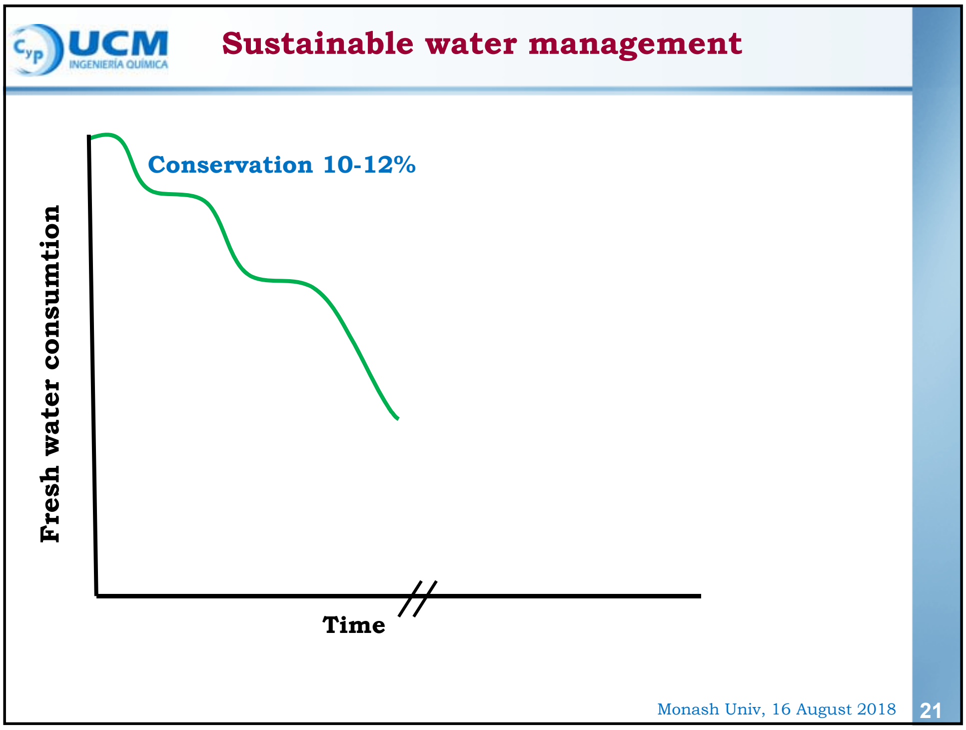
A. Blanco, D. Hermosilla and C.Negro,
Springer Berlin Heidelberg. June 2015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Sustainable water management
Conservation 10-12%
Fresh water consumtion
Time
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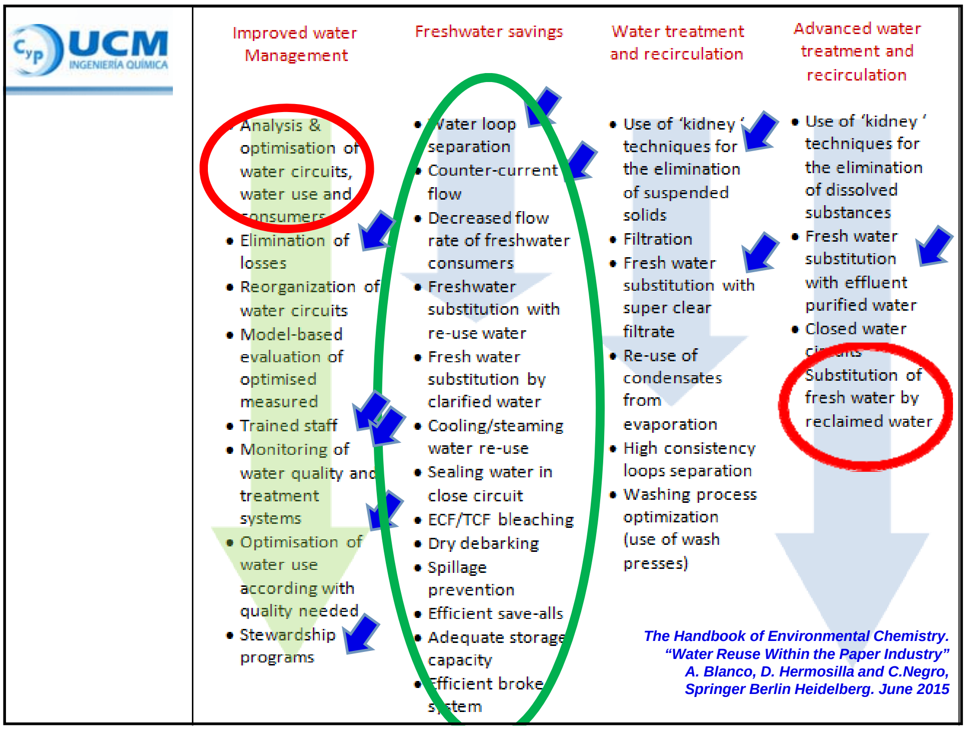
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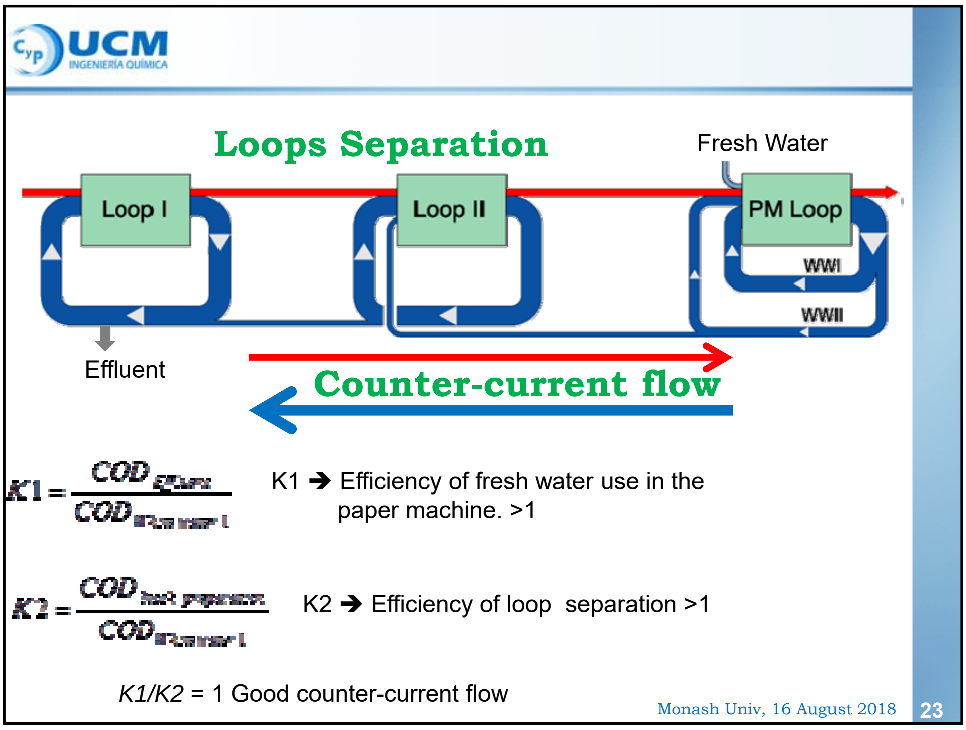
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Loops Separation
Fresh Water
Loop I
Loop II
PM Loop
WWI
WWII
Effluent
Counter-current flow
K1 =
COD
COD
K1 ➔ Efficiency of fresh water use in the paper machine. >1
K2 =
COD
COD
K2 ➔ Efficiency of loop separation >1
K1/K2 = 1 Good counter-current flow
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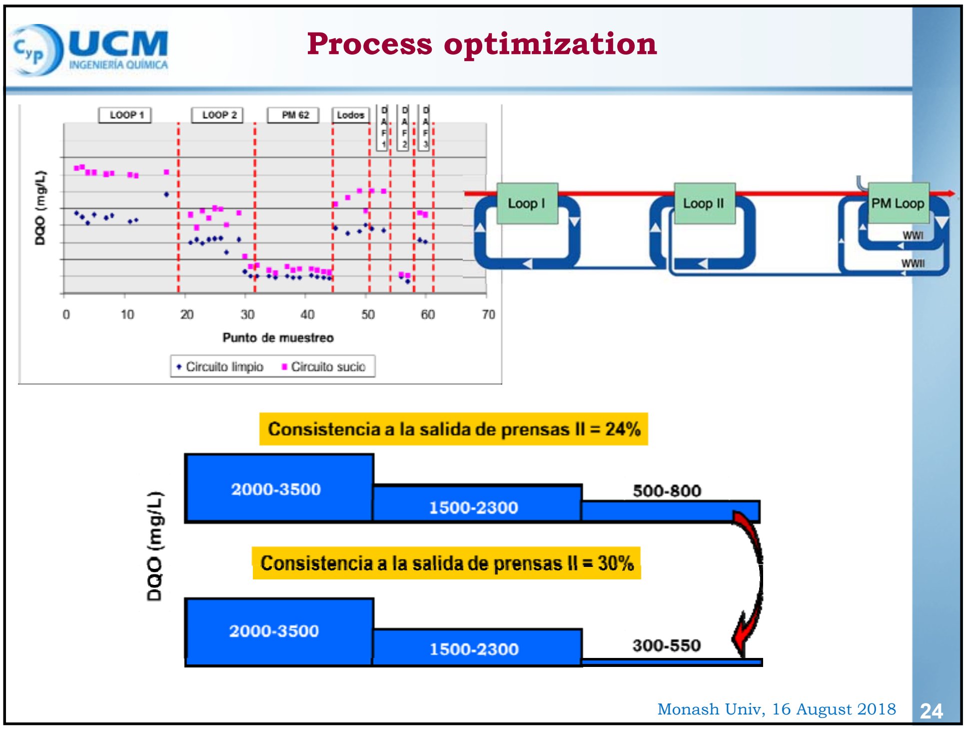
23


UCM
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Process optimization
LOOP 1
LOOP 2
PM 62
Lodos
DQO (mg/L)
0
10
20
30
40
50
60
70
Punto de muestreo
Circuito limpio
Circuito sucio
Loop I
Loop II
PM Loop
WWI
WWII
Consistencia a la salida de prensas II = 24%
DQO (mg/L)
2000-3500
1500-2300
500-800
Consistencia a la salida de prensas II = 30%
2000-3500
1500-2300
300-550
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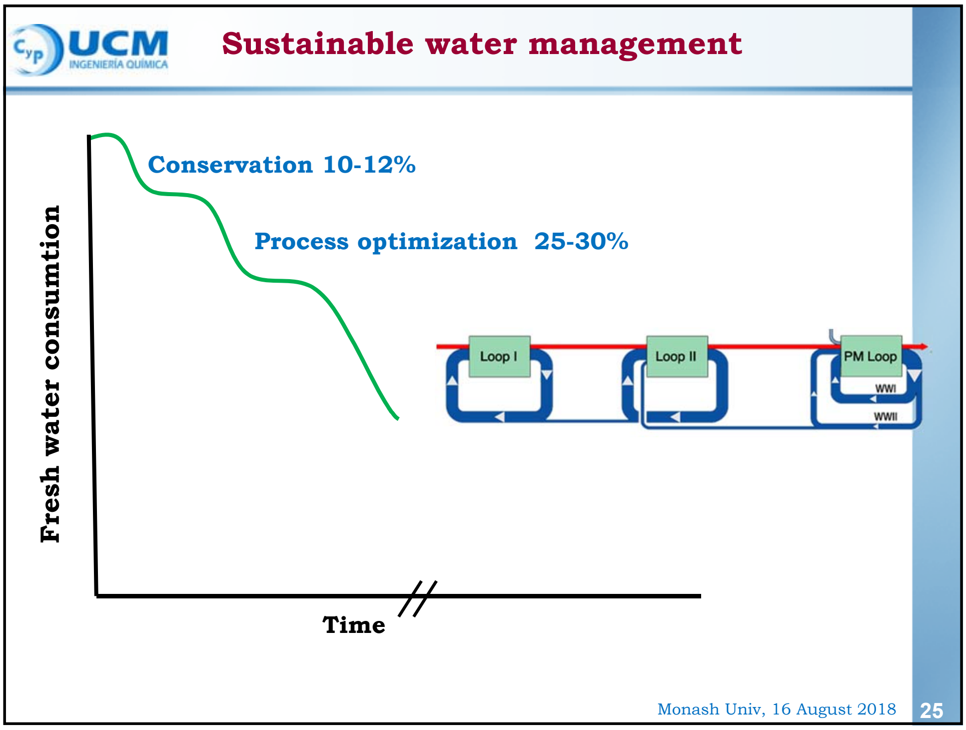
24


UCM INGENIERÍA QUÍMICA
Sustainable water management
Fresh water consumtion
Conservation 10-12%
Process optimization 25-30%
Loop I
Loop II
PM Loop
WWI
WWII
Time
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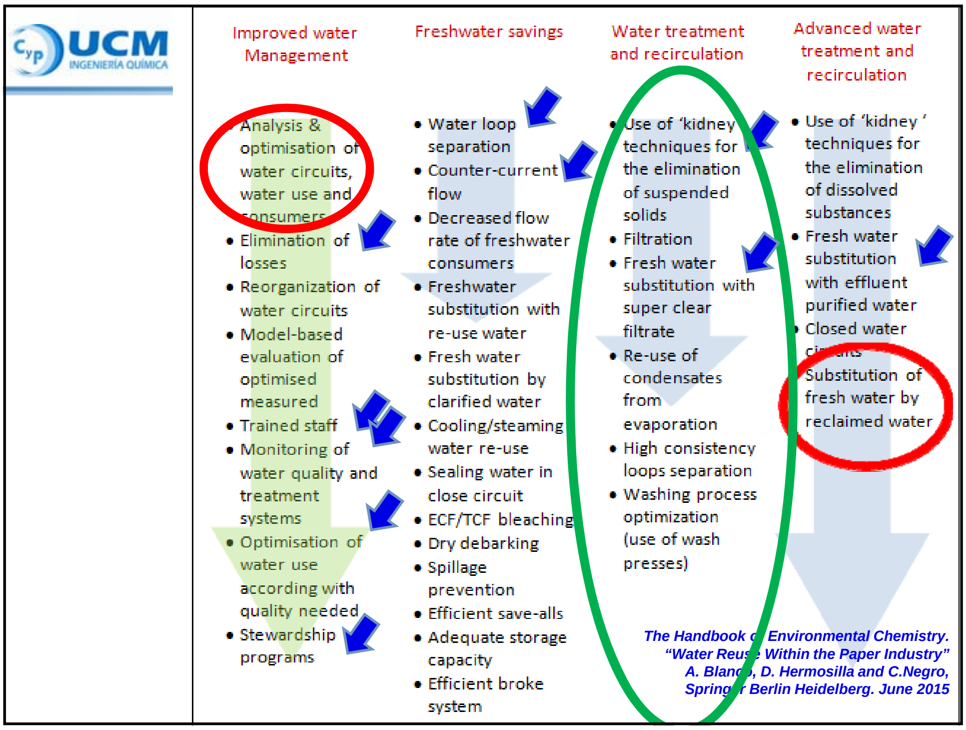
25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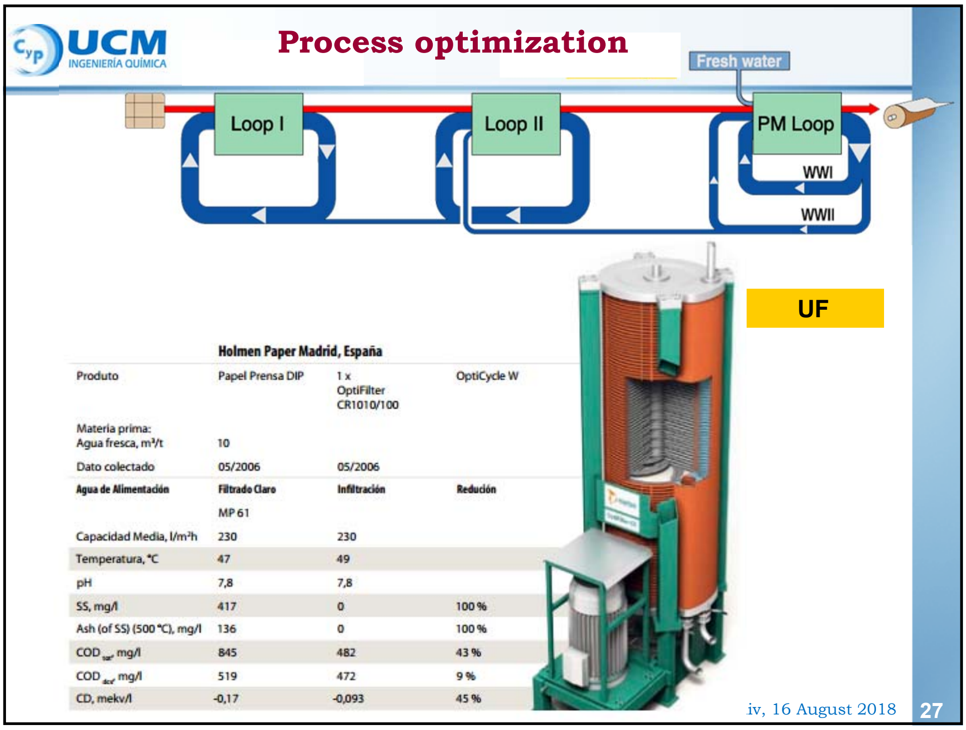
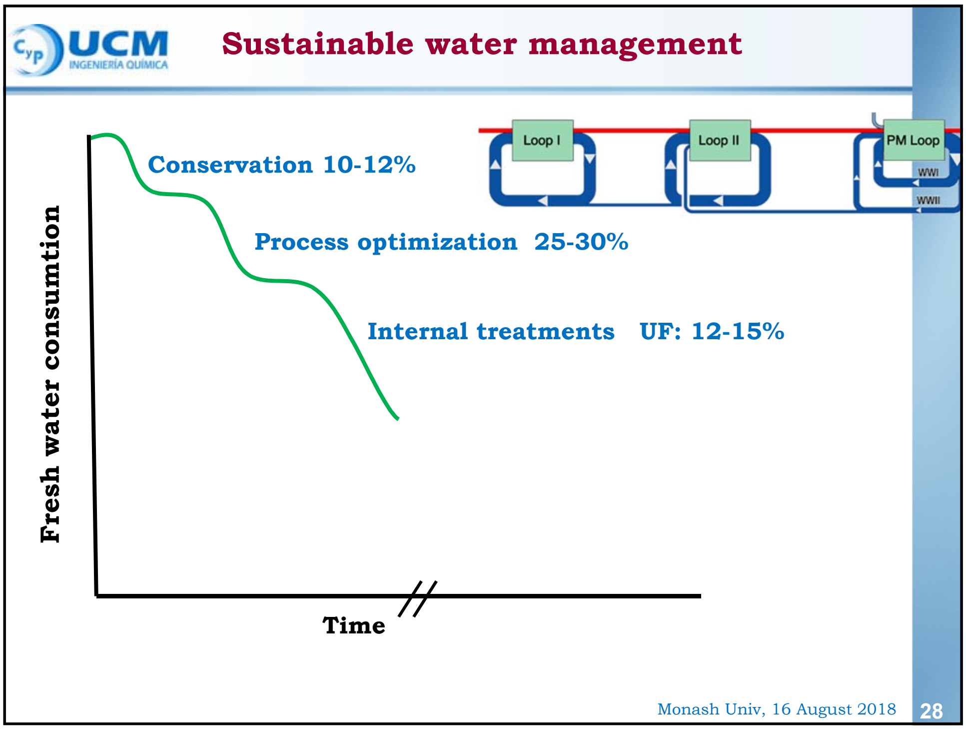
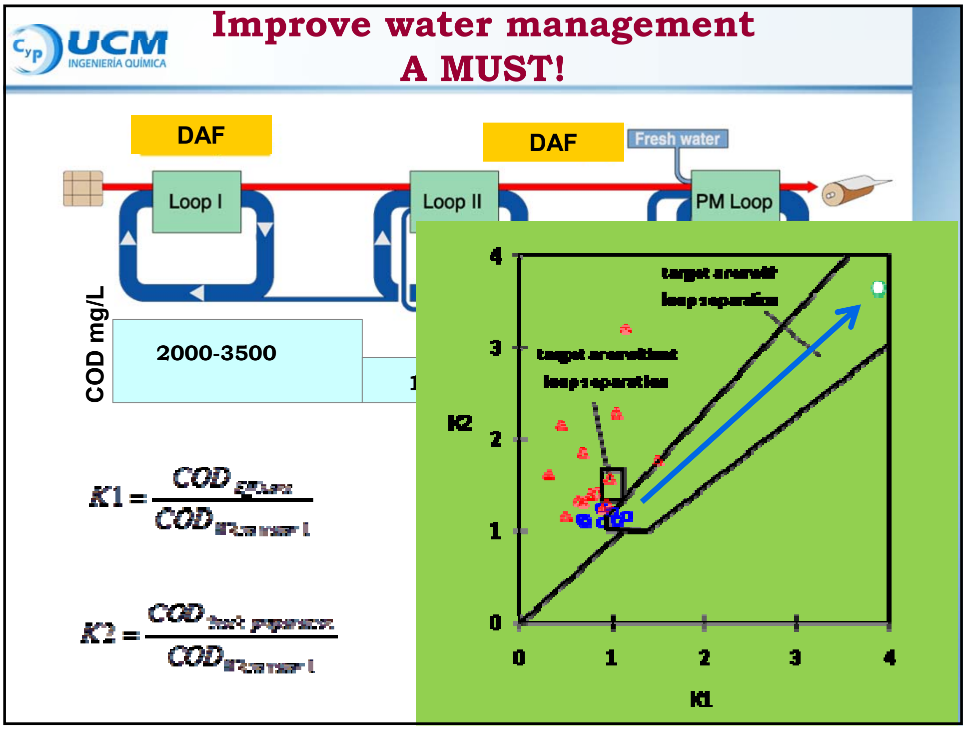


	Holmen Paper Madrid, España		
Produto	Papel Prensa DIP	1 x OptiFilter CR1010/100	OptiCycle W
Materia prima: Agua fresca, m³/t	10		
Dato colectado	05/2006	05/2006	
Agua de Alimentación	**Filtrado Claro**	**Infiltración**	**Redución**
	MP 61		
Capacidad Media, l/m²h	230	230	
Temperatura, °C	47	49	
pH	7,8	7,8	
SS, mg/l	417	0	100 %
Ash (of SS) (500 °C), mg/l	136	0	100 %
COD [illegible], mg/l	845	482	43 %
COD [illegible], mg/l	519	472	9 %
CD, mekv/l	-0,17	-0,093	45 %

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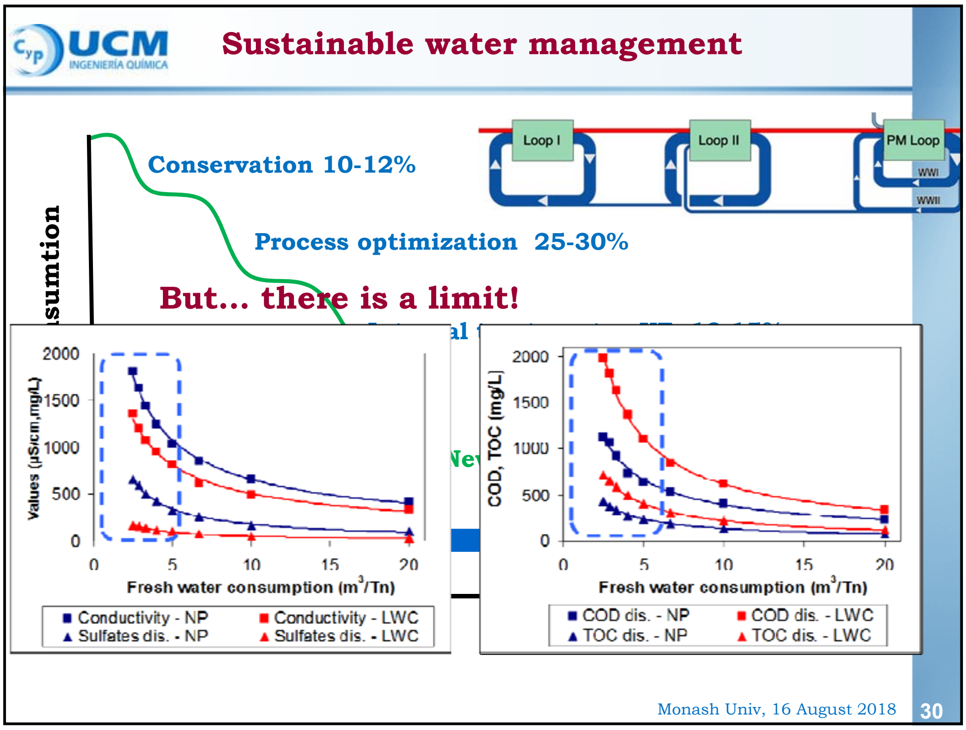
Improve water management
A MUST!
DAF
DAF
Fresh water
Loop I
Loop II
PM Loop
COD mg/L
2000-3500
K2
K1
0
1
2
3
4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Sustainable water management
Loop I
Loop II
PM Loop
Conservation 10-12%
Process optimization 25-30%
But… there is a limit!
Values (μS/cm, mg/L)
Fresh water consumption (m³/Tn)
Conductivity - NP
Conductivity - LWC
Sulfates dis. - NP
Sulfates dis. - LWC
COD, TOC (mg/L)
Fresh water consumption (m³/Tn)
COD dis. - NP
COD dis. - LWC
TOC dis. - NP
TOC dis. - LWC
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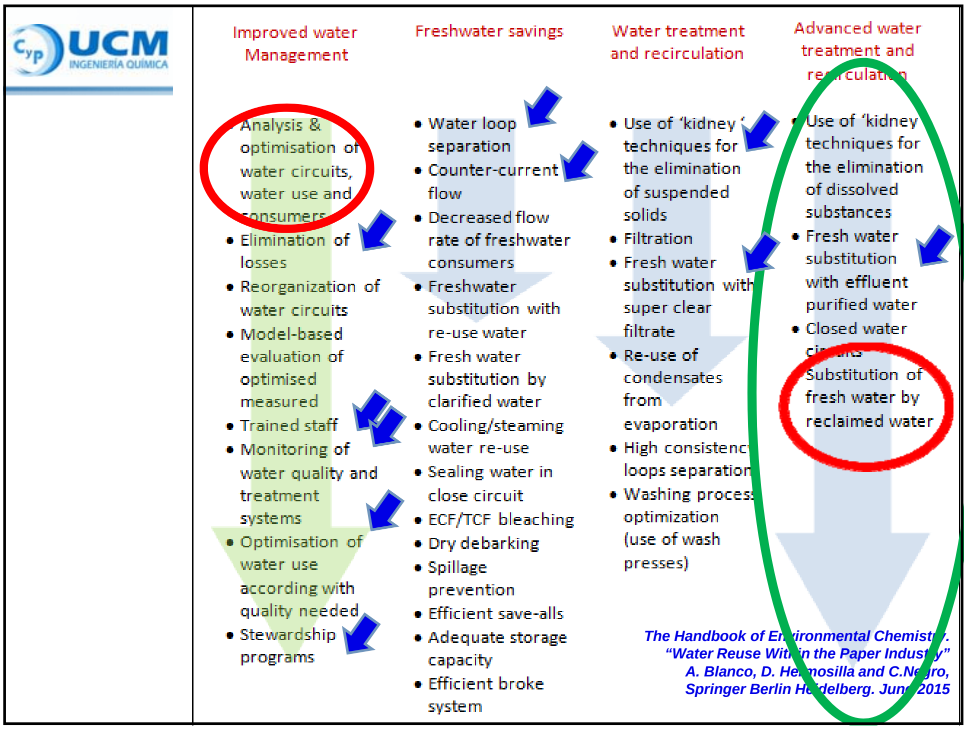
30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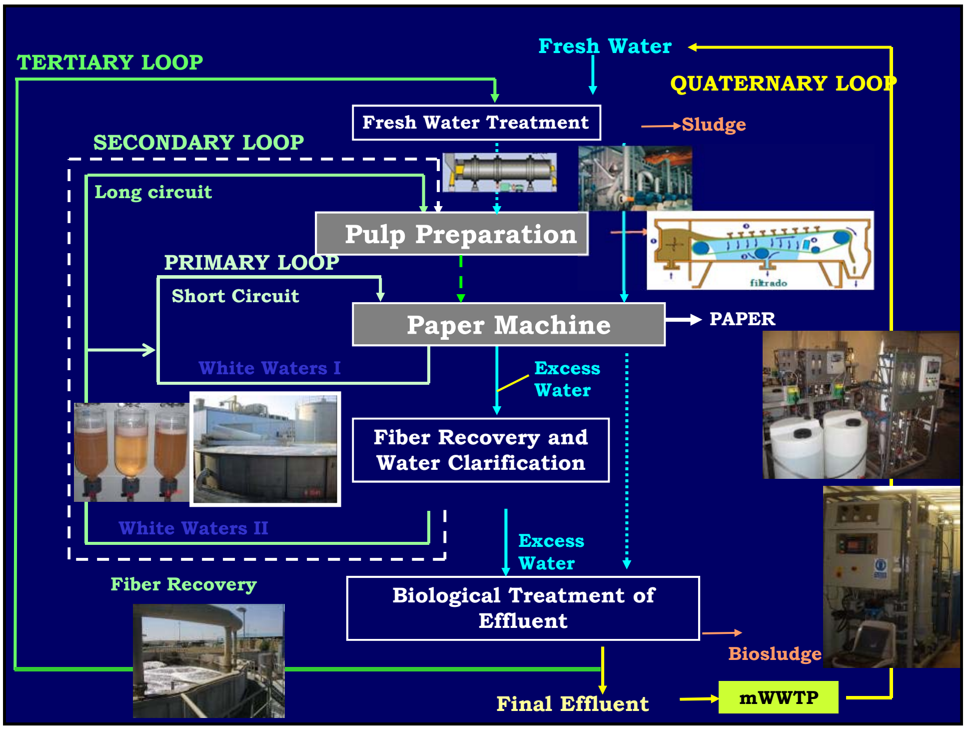
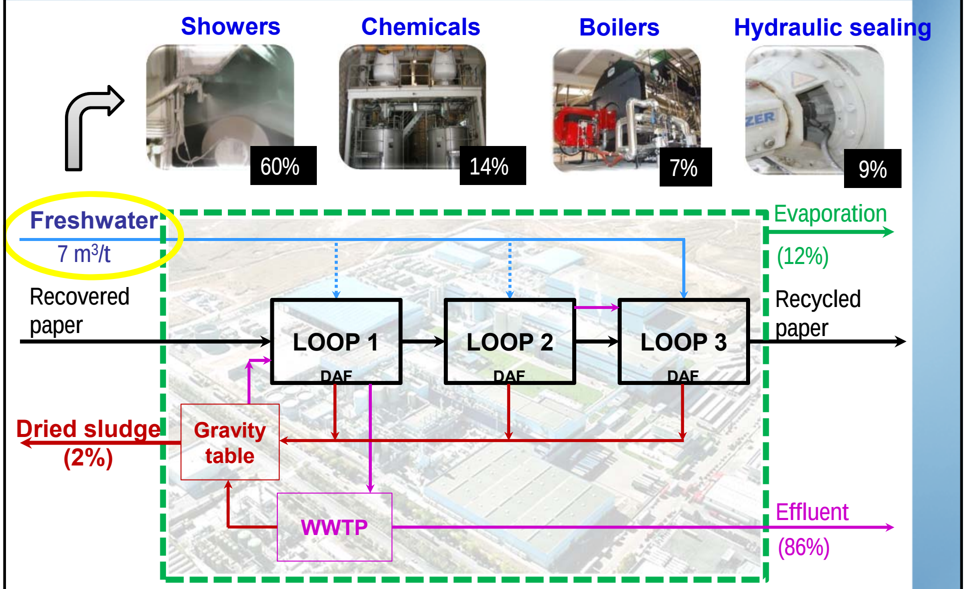

TERTIARY LOOP
Fresh Water
QUATERNARY LOOP
Fresh Water Treatment
Sludge
SECONDARY LOOP
Long circuit
Pulp Preparation
PRIMARY LOOP
Short Circuit
Paper Machine
PAPER
White Waters I
Excess Water
Fiber Recovery and Water Clarification
White Waters II
Excess Water
Fiber Recovery
Biological Treatment of Effluent
Biosludge
Final Effluent
mWWTP

Fresh water uses



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Water uses & quality

Minimum quality required for showers

PARAMETER	VALUE
Hardness, $mgCaCO_3/L$	<200
Alkalinity, $mgCaCO_3/L$	<100
Suspended solids (TSS), mg/L	<5
COD, mg/L	<5
Conductivity, µS/cm	<500
Iron, mg/L	<0,1
Aluminium, mg/L	0,1
Magnesium, mg/L	<15
Chloride, mg/L	<50
Sulfates, mg/L	<100
Microorganisms, CFU/100mL	<1

Deposits of $CaCO_3$

Deposits, biofilms, abrasion

Scaling, corrosion, odours

Aerosols

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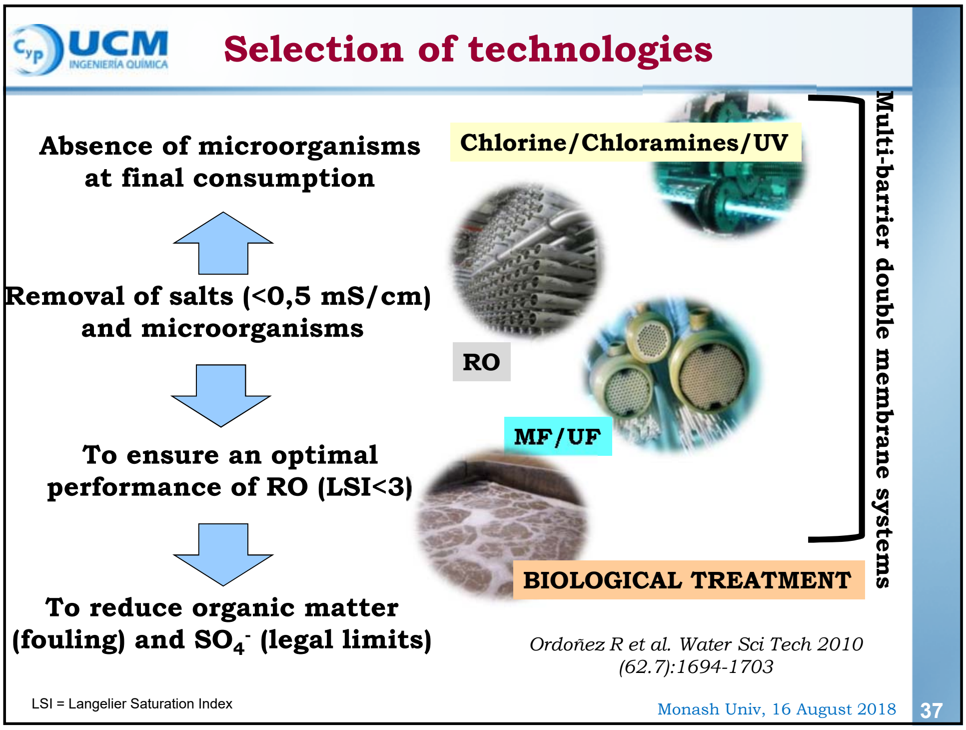
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Selection of technologies
Absence of microorganisms at final consumption
Removal of salts (<0,5 mS/cm) and microorganisms
To ensure an optimal performance of RO (LSI<3)
To reduce organic matter (fouling) and SO_4^- (legal limits)
Chlorine/Chloramines/UV
RO
MF/UF
BIOLOGICAL TREATMENT
Multi-barrier double membrane systems
Ordoñez R et al. Water Sci Tech 2010 (62.7):1694-1703
LSI = Langelier Saturation Index
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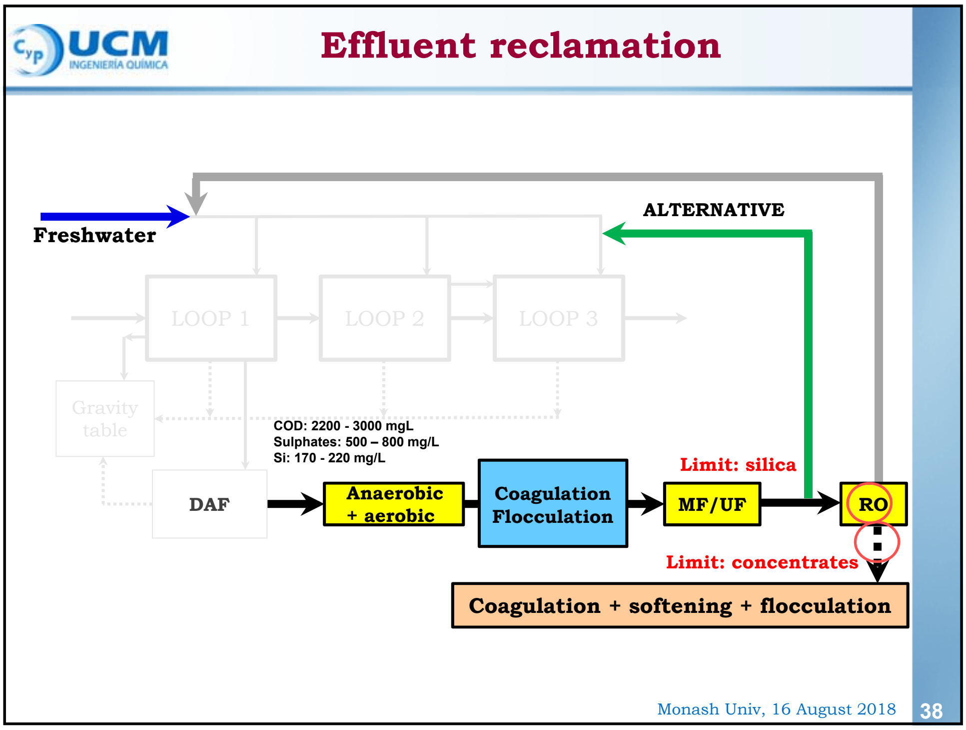
37


UCM INGENIERÍA QUÍMICA
Effluent reclamation
Freshwater
ALTERNATIVE
LOOP 1
LOOP 2
LOOP 3
Gravity table
DAF
COD: 2200 - 3000 mgL
Sulphates: 500 – 800 mg/L
Si: 170 - 220 mg/L
Anaerobic + aerobic
Coagulation Flocculation
Limit: silica
MF/UF
RO
Limit: concentrates
Coagulation + softening + flocculation
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38

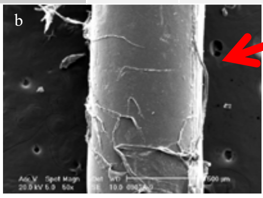
Performance of biological systems

Anaerobic treatment

	COD, %	BOD5, %	SO_4^{2-} %
PP-A UASB	45 ± 8	72 ± 11	28 ± 16
PP-B EGSB	54 ± 8	68 ± 9	30 ± 16

Aerobic treatment

	COD, %	BOD5, %
PP-A Actived sludge	60 ± 12	86 ± 12
PP-B MBR	64 ± 7	95 ± 2



Biogas profitability

0,25 Nm^3biogas/m^3 treated water

→ 1,5 kW·h/m^3 treated water

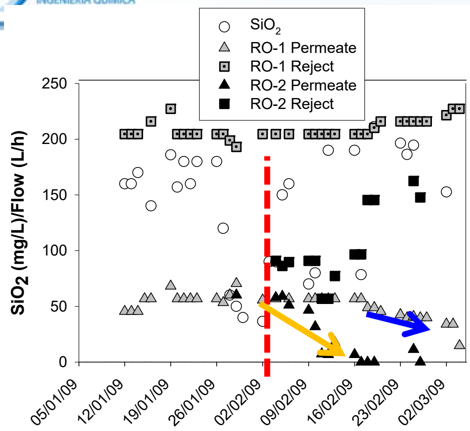
Effluent quality:

PARAMETER	ACTIVATED SLUDGE	MBR
pH	7,91	7,82
TSS, mg/L	315	0
dCOD, mg/L	450	374
BOD_5, mg/L	43	17
SO_4, mg/L	383	333

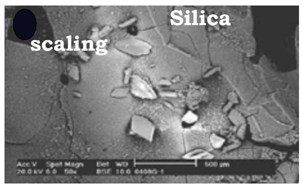
Irreversible fouling

Hollow fibre membranes with fibre deposits

Reverse osmosis



SILICA IS A LIMITATION FOR RO



Permeate

→ Excelent quality to substitute fresh water

→ Recovery of 20% → Limitation

Concentrate

PARAMETER	VALUES	LAW
pH	8	-
Conductivity, mS/cm	9,1	7,5
tCOD, mg/L	2365	1750

>20%

>30%

Treatment of RO concentrates

Optimum coagulant: PAC Dose (2-2,5-3 g/L)
Lime softening: pH (8, 9,5 y 10,5)
Flocculation
- **Flocculant type (aPAM, cPAM)**
- **Dose (3-5-7 g/L)**

Coagulant (mg/L)	Lime (pH)	Floculant (mg/L)	COD removal (%)		Conductivity removal (%)	
2500 PAC	NO	NO	30		0	
	NO	5 (aPAM)	40	+10%	0	=
	9.5	3 (aPAM)	60	+30%	45	+45%
	9.5	5 (aPAM)	60		45	
	10.5	5 (aPAM)	60	=	55	+10%

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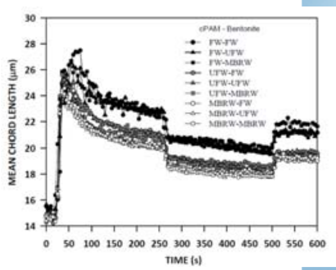
Mill effluent treatment and reuse

- **Water recovery in RO units is limited by silica**
  20-40% RO recovery → Anaerobic + MBR + RO
  80% RO recovery if silica is removed. **Limitation**
- **MBR permeate can be reuse**
  √ **Showers and preparation of some chemicals**
  X **Not suitable to prepare cPAM-bentonite retention system due to its anionic nature which reduce their efficiency.** **Limitation**



- **Important fresh water savings can be achieved**
- **There is a limit: 1.5-2 m^3/t still necessary**

This solution is not sustainable in water stress areas!

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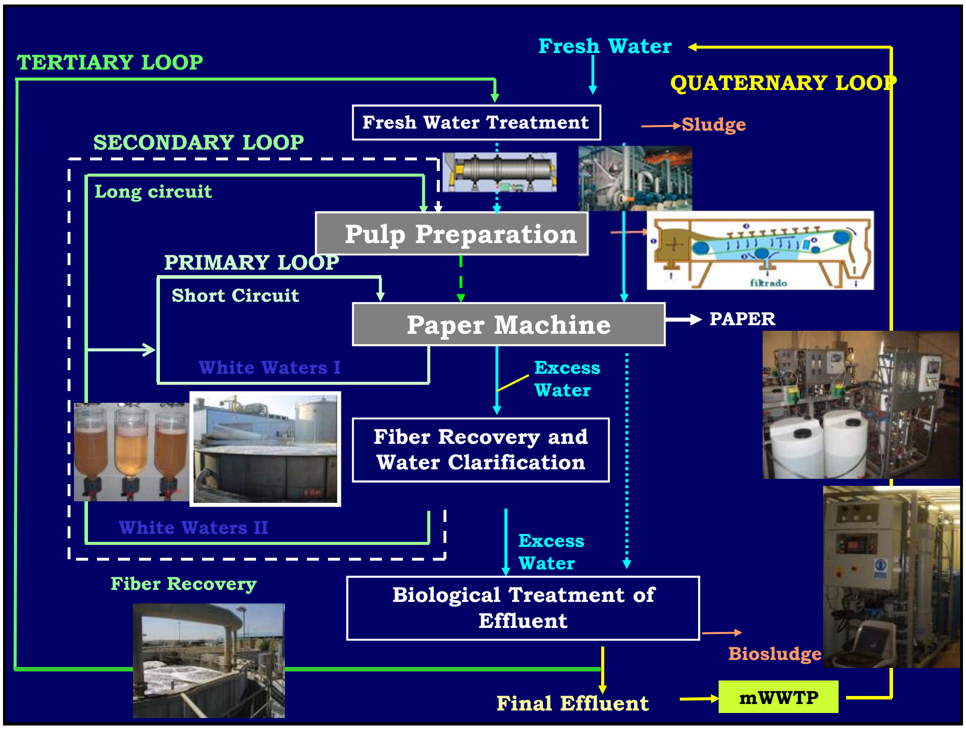
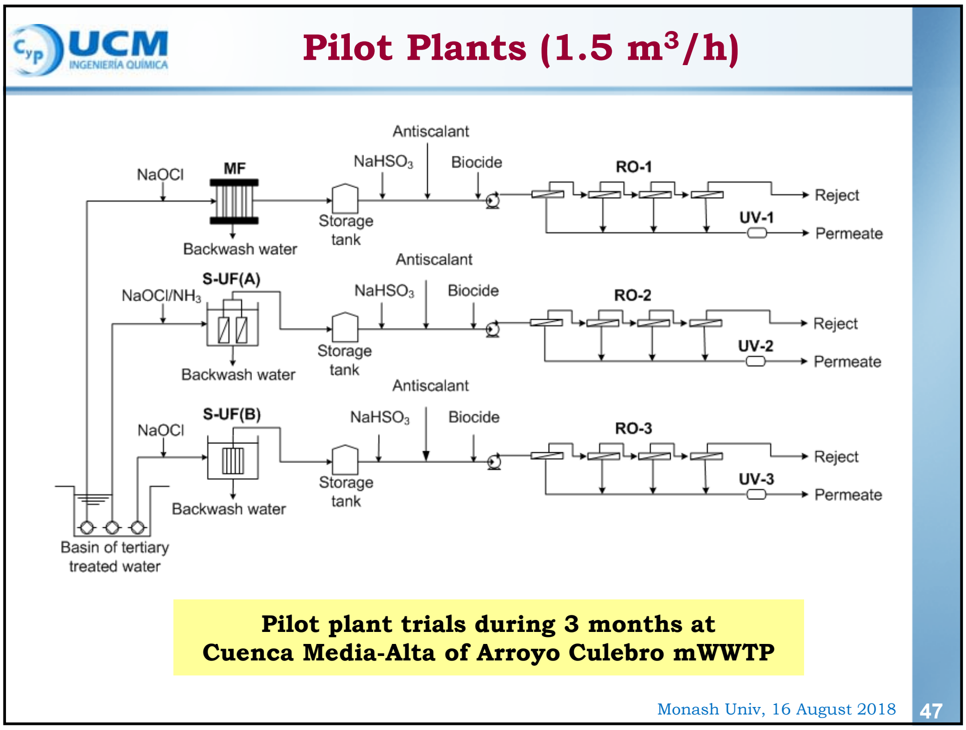


TERTIARY LOOP
Fresh Water
QUATERNARY LOOP
Fresh Water Treatment
Sludge
SECONDARY LOOP
Long circuit
Pulp Preparation
PRIMARY LOOP
Short Circuit
Paper Machine
PAPER
White Waters I
Excess Water
Fiber Recovery and Water Clarification
White Waters II
Excess Water
Fiber Recovery
Biological Treatment of Effluent
Biosludge
Final Effluent
mWWTP



UCM
INGENIERÍA QUÍMICA
Pilot Plants (1.5 m³/h)
Antiscalant
NaOCl
MF
NaHSO₃
Biocide
RO-1
Reject
UV-1
Permeate
Storage tank
Backwash water
Antiscalant
S-UF(A)
NaOCl/NH₃
NaHSO₃
Biocide
RO-2
Reject
UV-2
Permeate
Storage tank
Backwash water
Antiscalant
S-UF(B)
NaOCl
NaHSO₃
Biocide
RO-3
Reject
UV-3
Permeate
Storage tank
Backwash water
Basin of tertiary treated water
Pilot plant trials during 3 months at
Cuenca Media-Alta of Arroyo Culebro mWWTP
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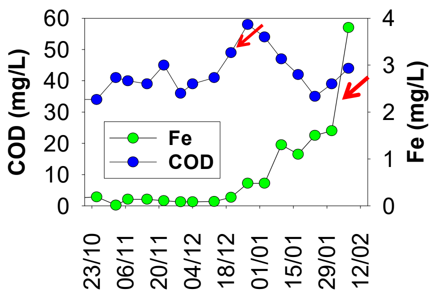
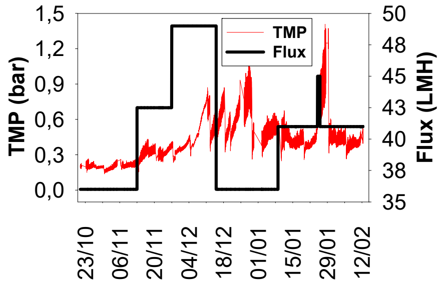
47

Pre-treatments performance



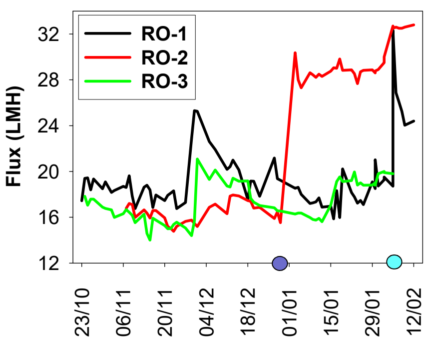
Tertiary treated water
!!!



Pressurized MF

100% SS removal
25% DBO_5 removal

Reverse osmosis performance



Parameter	RO-1	RO-2	RO-3	Limit
Conductivity, µS/cm	12	9	11	<500
tCOD, mg/L	<5	<5	<5	<5
SO_4, mg/L	<3	<3	<3	<100
TSS, mg/L	<2	<2	<2	<5
Hardness, mg/L	<7	<7	<7	<200
NO_3, mg/L	0,69	0,23	0,24	<1
P, mg/L	0,07	0,06	0,06	<0,2

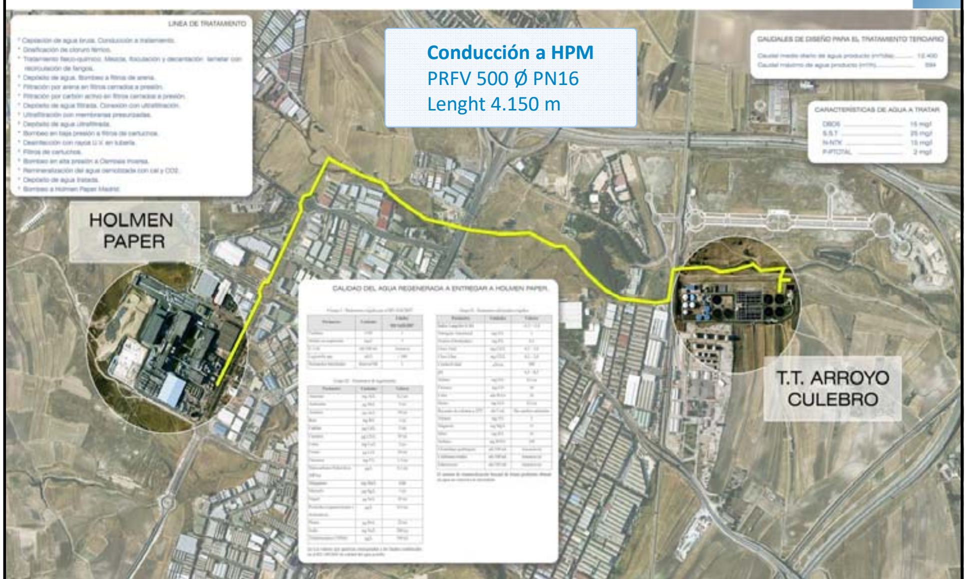
- **Membrane change in RO-2. Chloramines addition in this line.**
- **Uncontrolled dumping of free chlorine within the tertiary treatment → increased flux & did not oxidized the membrane.**

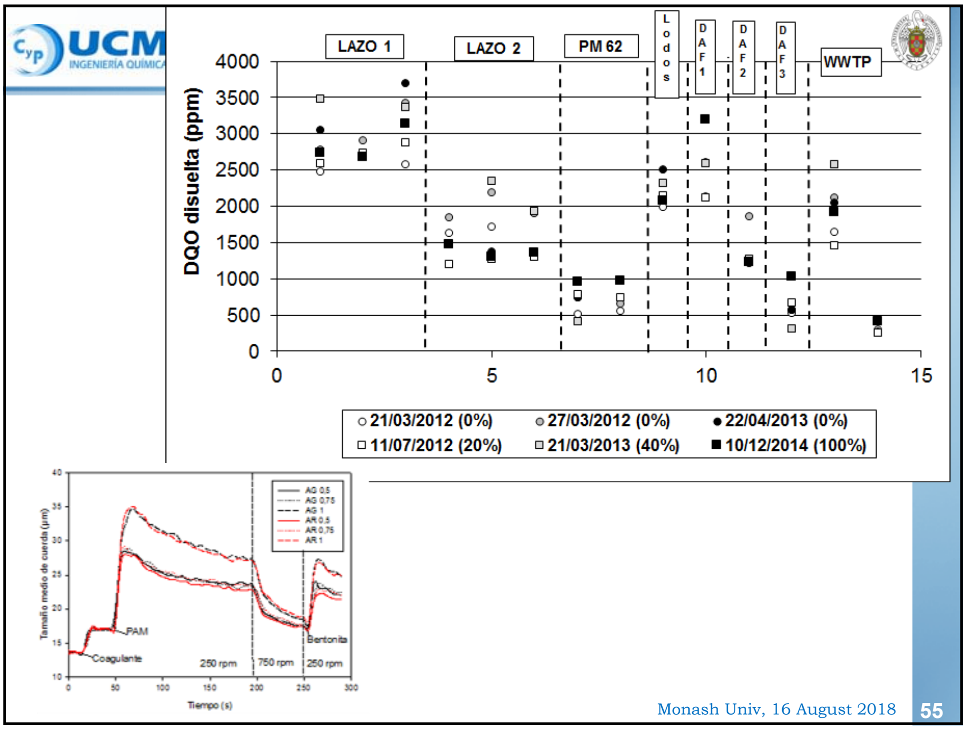
Ordoñez R et al. CEJ, 2010

In 2012 CYII built a WWRP, based on this multi-barrier membrane system, to supply Holmen Paper Madrid with reclaimed water instead of drinking water

Limits/barriers:

- **Quality of the municipal waste water effluent**
- **Legislation**
- **Aceptation**
- **Water price**




UCM INGENIERÍA QUÍMICA
LAZO 1
LAZO 2
PM 62
Lodos
DAF 1
DAF 2
DAF 3
WWTP
DQO disuelta (ppm)
○ 21/03/2012 (0%)
□ 11/07/2012 (20%)
27/03/2012 (0%)
21/03/2013 (40%)
● 22/04/2013 (0%)
■ 10/12/2014 (100%)
PAM
Coagulante
Bentonita
250 rpm
750 rpm
250 rpm
Tiempo (s)
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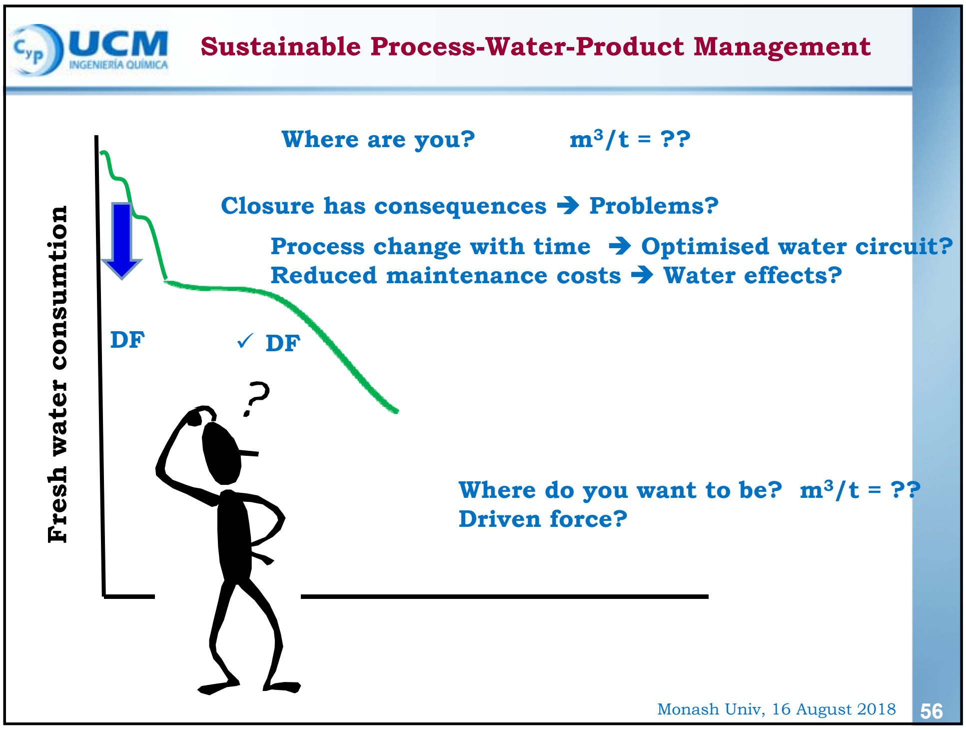
55


UCM INGENIERÍA QUÍMICA
Sustainable Process-Water-Product Management
Where are you? m³/t = ??
Closure has consequences ➔ Problems?
Process change with time ➔ Optimised water circuit?
Reduced maintenance costs ➔ Water effects?
DF
✓ DF
Fresh water consumtion
Where do you want to be? m³/t = ??
Driven force?
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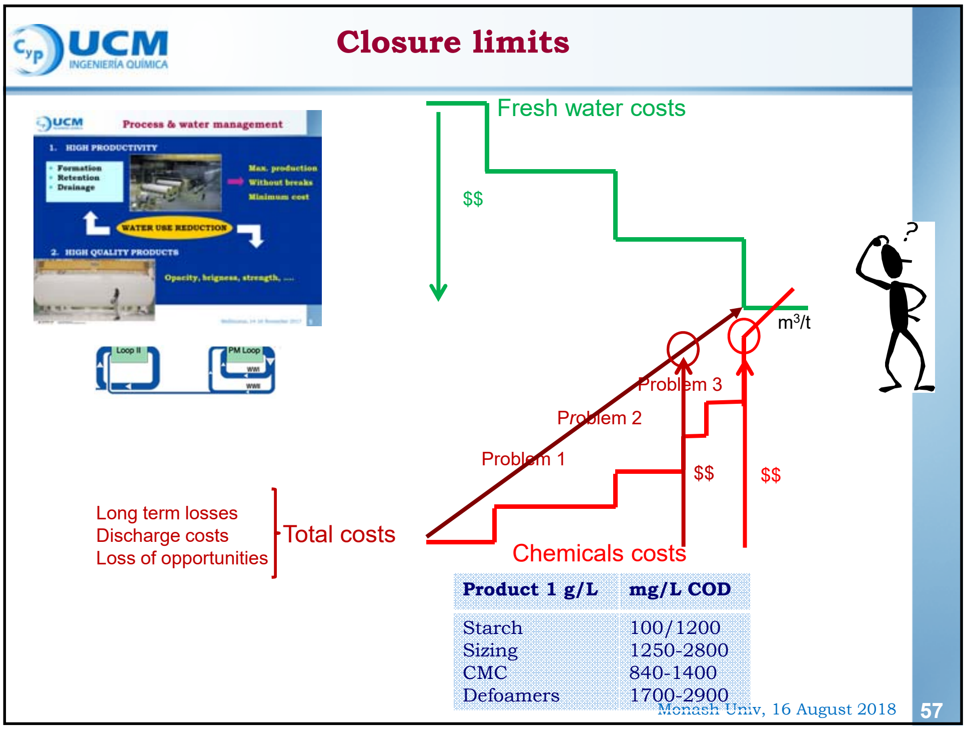
56


UCM INGENIERÍA QUÍMICA
Closure limits
Process & water management
Fresh water costs
$$
m3/t
Problem 3
Problem 2
Problem 1
$$
$$
Long term losses
Discharge costs
Loss of opportunities
Total costs
Chemicals costs
Product 1 g/L
mg/L COD
Starch
Sizing
CMC
Defoamers
100/1200
1250-2800
840-1400
1700-2900
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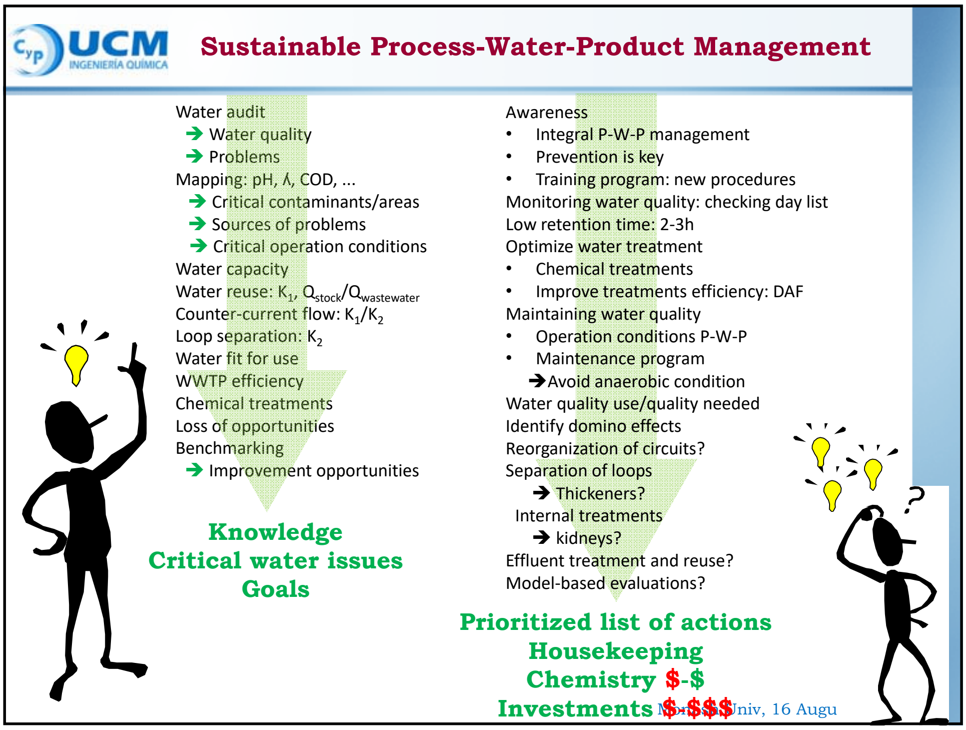
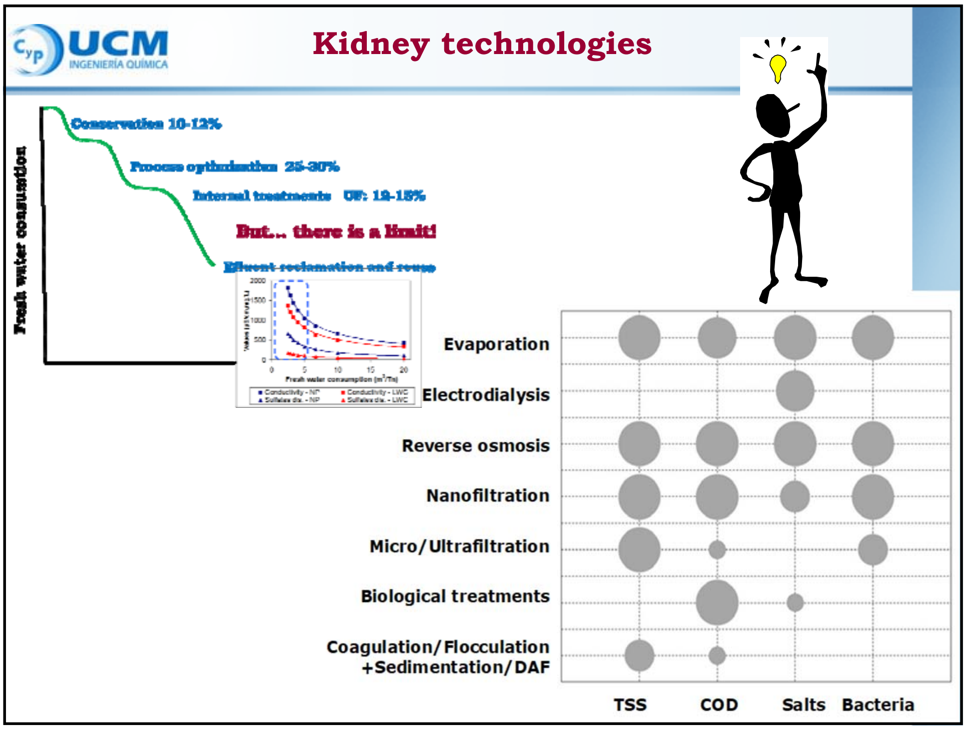
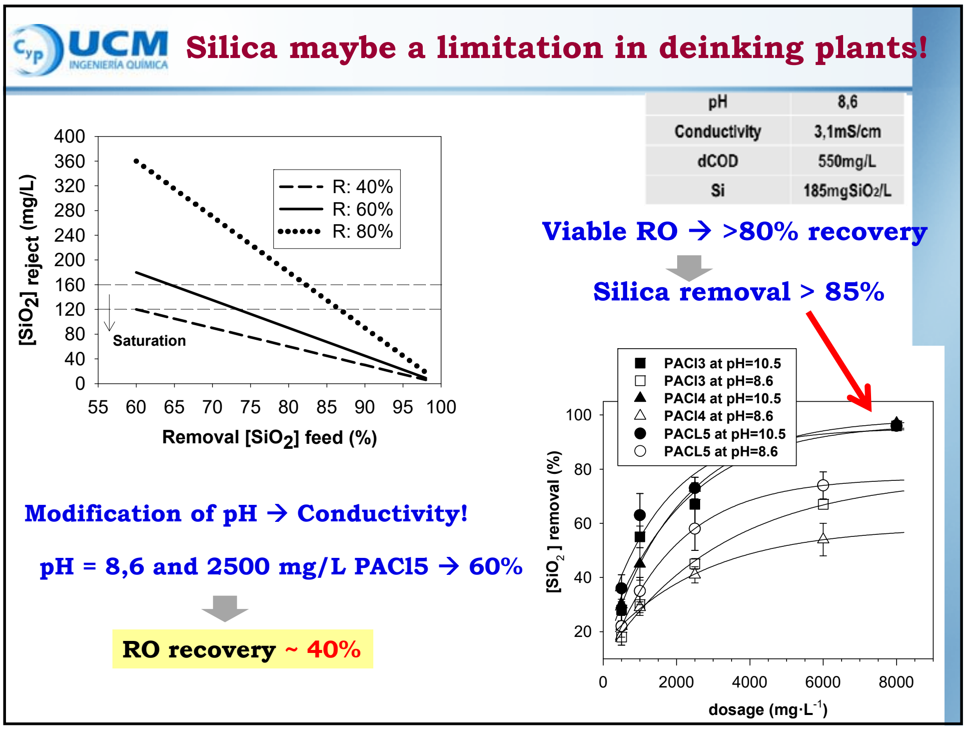
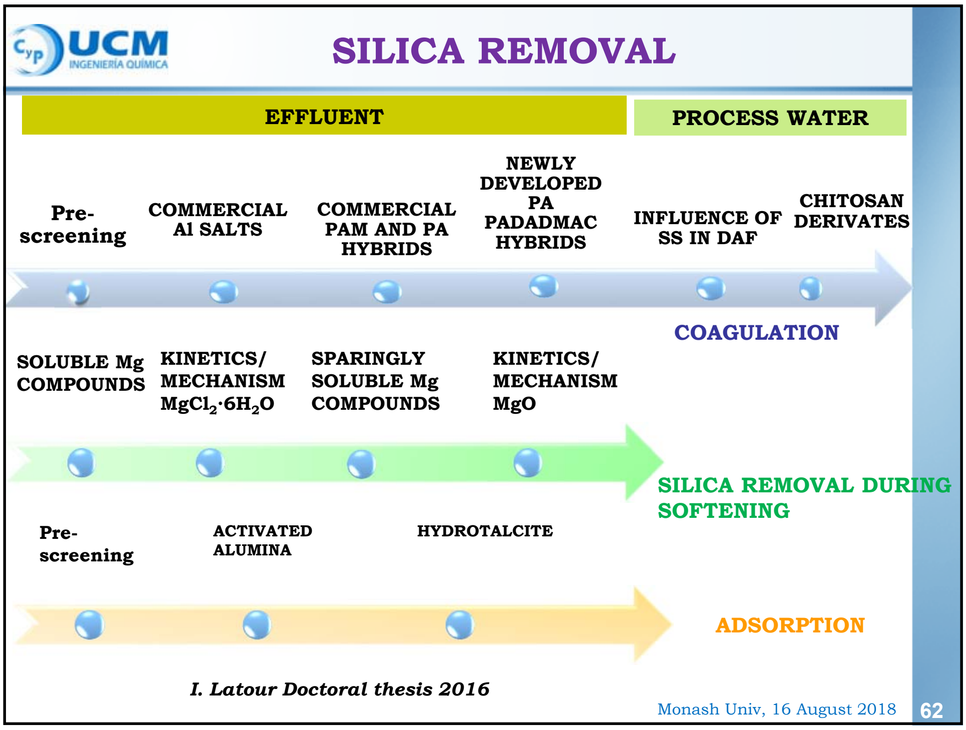
57


UCM INGENIERÍA QUÍMICA
Sustainable Process-Water-Product Management
Water audit
➔ Water quality
➔ Problems
Mapping: pH, Λ, COD, ...
➔ Critical contaminants/areas
➔ Sources of problems
➔ Critical operation conditions
Water capacity
Water reuse: K1, Qstock/Qwastewater
Counter-current flow: K1/K2
Loop separation: K2
Water fit for use
WWTP efficiency
Chemical treatments
Loss of opportunities
Benchmarking
➔ Improvement opportunities
Knowledge
Critical water issues
Goals
Awareness
• Integral P-W-P management
• Prevention is key
• Training program: new procedures
Monitoring water quality: checking day list
Low retention time: 2-3h
Optimize water treatment
• Chemical treatments
• Improve treatments efficiency: DAF
Maintaining water quality
• Operation conditions P-W-P
• Maintenance program
➔Avoid anaerobic condition
Water quality use/quality needed
Identify domino effects
Reorganization of circuits?
Separation of loops
➔ Thickeners?
Internal treatments
➔ kidneys?
Effluent treatment and reuse?
Model-based evaluations?
Prioritized list of actions
Housekeeping
Chemistry $-$
Investments $-$$$





pH	8,6
Conductivity	3,1mS/cm
dCOD	550mg/L
Si	185mgSiO_2/L



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TREATMENT SELECTION

Characteristics of the treatments to achieve high silica removal rates (>90%) for the treatment of high silica content (150-200 mg/L) and low hardness waters (2-7 mg/L)

	COAGULATION	SILICA REMOVAL DURING PRECIPITATIVE SOFTENING		ADSORPTION
ADDITIVE	Hybrid coagulant (PANS-PA2)	Soluble Mg compounds ($MgCl_2 \cdot 6H_2O$)	Sparingly soluble Mg compounds (MgO)	Calcined hydrotalcite
TEMPERATURE	25ºC	25ºC	≥ 35ºC	25ºC-50ºC
pH	10.5	11.5	8.5	8.5
DOSAGE	2500 mg/L	1500 mg/L	500 mg/L	1500 mg/L (50ºC)-2500 mg/L(25ºC)
COD REMOVAL	↑↑	-	-	↑
FINAL CONDUTIVITY	↑↑	↑↑↑	↑	↑
SLUDGE GENERATION	↑↑	↑↑↑	↑↑	↑
COST	↑↑↑	↑↑	↑	↑↑

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67

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CONCLUSIONS

- **How far can we go?**
  - **Board/packaging 0-3 m^3/t**
  - **Liner 0-3.5 m^3/t**
  - **Graphic paper 6-15 m^3/t** **100% Reclaimed water**
  - **Tissue 6-12 m^3/t**

- **Optimal SWM = SPWPM ➔ Global approach but local solutions**
- **Look outside your fence!**
- **Pre-treatments are essential and cheaper**
- **Limits are further that what we expect**
- **R&D studies focus**
  - **Concentrates**
  - **Scaling / Fouling**
  - **Energy**
- **Post-treatments are available if needed**
- **Barriers: legal, acceptation**
- **Costs**

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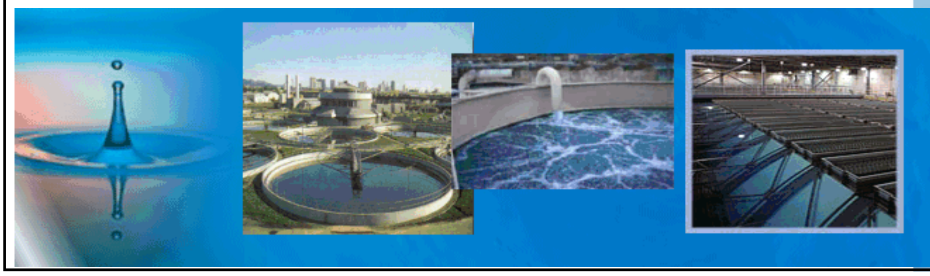
INTEGRAL WATER MANAGEMENT IN THE PAPER INDUSTRY: A CASE STUDY

A. Blanco and C. Negro
Complutense University of Madrid



Diapositiva 68

H1 HP, 14/08/2018