

WASTEWATER REGENERATION FOR REUSE USING MEMBRANE BIOREACTORS (MBR)

COMPARATIVE STUDY OF FLAT SHEET AND HOLLOW FIBRE MEMBRANES

REMOSA – The company



- ✓ Remosa is an enterprise founded in Súria (Barcelona) in 1981, with a high vocation for progress and innovation.
- ✓ At present, 2 Production and Logistic Centres: Súria (Barcelona) the Headquarters & Noblejas (Toledo) cover our main markets (Spain, Portugal and France).
- ✓ The main activity is the Glass-Reinforced Plastic transformation to manufacture:
 - ✓ Wastewater treatment systems
 - ✓ Wastewater regeneration systems
 - ✓ Separation systems for light liquids (oil and petrol)
 - ✓ Liquid storage tanks and vessels
- ✓ Pilot Plant in Súria (Next to the WWTP) allows R+D+i.



Súria



Noblejas



Pilot Plant (Súria)





- ✓ In 2006 the R+D+i department started an intensive research to find the most appropriate technology for wastewater treatment and regeneration focusing on the draft copy of Spanish RD for water reuse.
 - Small equipments for existing systems: Reactor+decanter+sand filters+chlorination+(UV)
 - Troubling: Abide by the regulations
 - MBR: safety quality

- ✓ **SIREA project** (2006-2007)
 - *“Study and development of an innovative system for wastewater treatment and reuse by means of MBR”*
 - Ministerio de Industria, Turismo y Comercio (MITYC) –PROFIT Program
 - Centre Innovació i Desenvolupament Empresarial (CIDEM)



✓ OBJECTIVES

The objective of the study was to find the most appropriate membrane technology for small compact equipments to treat and regenerate wastewater.

1) Environmental and sanity quality – comply with the draft regulations → (RD 1620 1.1)

Royal Decree 1620/2007: REUSE OF PURIFIED WATERS					
Uses of Regenerated Wastewater		Biological quality		Physical/chemical quality	
		Intestinal nematodes (egg/10l)	Escherichia Coli (UFC/100 ml)	Solids in Suspension (mg/l)	Turbidity (NTU)
Urban uses	Residential	< 1	0	< 10	< 2
	Urban services	< 1	< 200	< 20	< 10

2) Adaptable configuration

3) Easy installation and maintenance

REMOSA – Project Development



✓ STATE OF THE ART

Difficulty to find scientific articles covering a comparison of systems and technologies

Many lab research

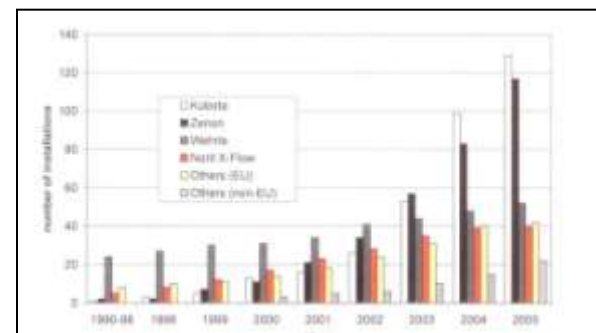
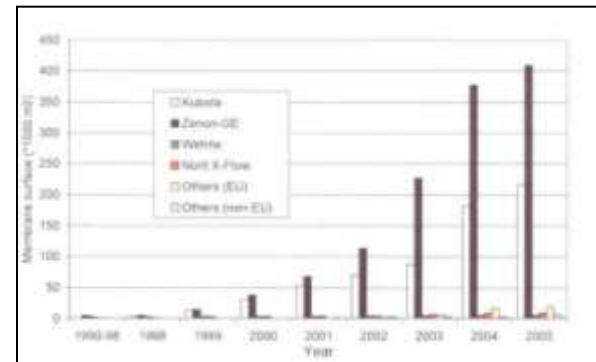
Difficulty to come to a conclusion

✓ MEMBRANE SELECTION

Configuration

INTERNAL		FS	X
		HF	X
		FS	
		HF	
EXTERNAL		M	

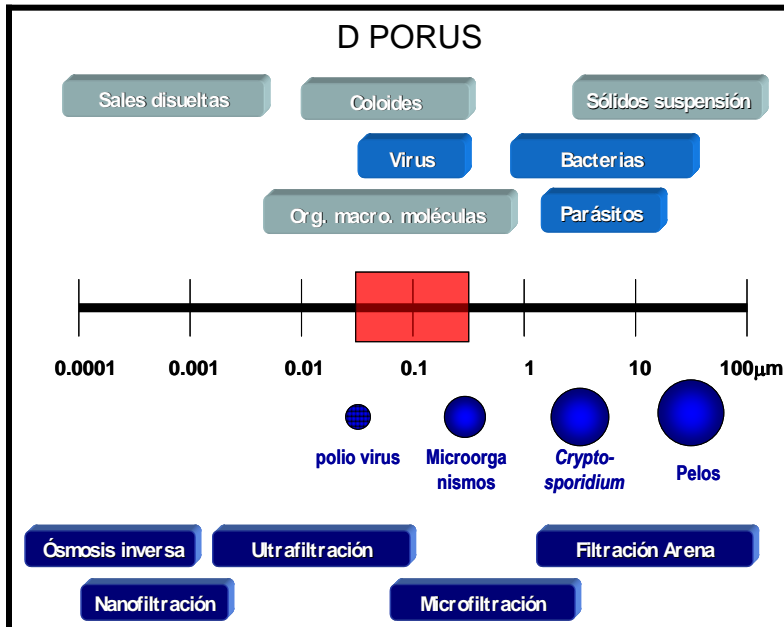
FS or HF?



Lesjean Huisjes, 2007



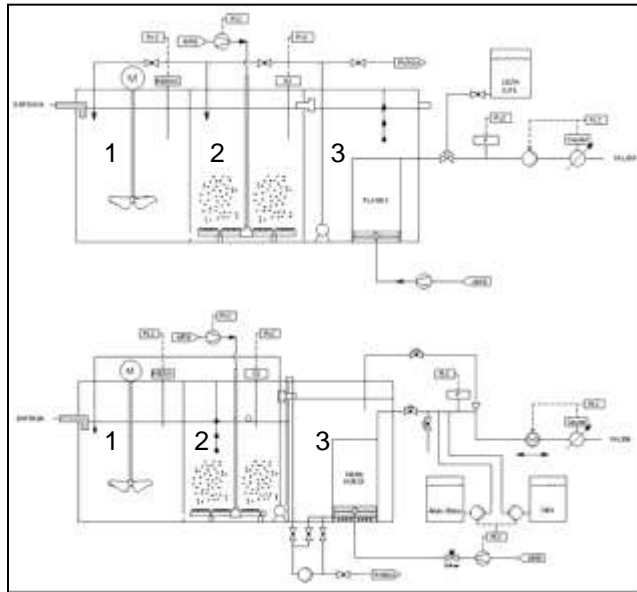
✓ Membrane selection



	SF	HF
	Micro	Ultra
MATERIAL	PE	PES
PROPERTIES	Membrane distance, pressure, clean, operation.	



- ✓ Design, manufacture and implementation to Pilot Plant of two prototypes: FS and HF.



- 1) anoxic stage: denitrification
- 2) bioreactor
- 3) filtration stage by membranes

	Equipment with flat-sheet membranes	Equipment with hollow-fibre membranes
Surface area of installed membrane	40 m ²	30 m ²
Daily flow of infeed	19 m ³ /day	7 m ³ /day
Daily flow of permeate	19 m ³ /day	7 m ³ /day
Flow of permeate extraction	25 l/m ² ·h	20 l/m ² ·h
Back-washing flow	Back-washing is not carried out	30 l/m ² ·h
Recirculation flow	400% of the infeed flow	400% of the infeed flow
MLSS in the reactor	10 g/l	10 g/l
Operating system	8 minutes permeating 2 minutes relaxation	4 minutes permeating 1 minute back-washing 0,1 minutes venting



Reactor

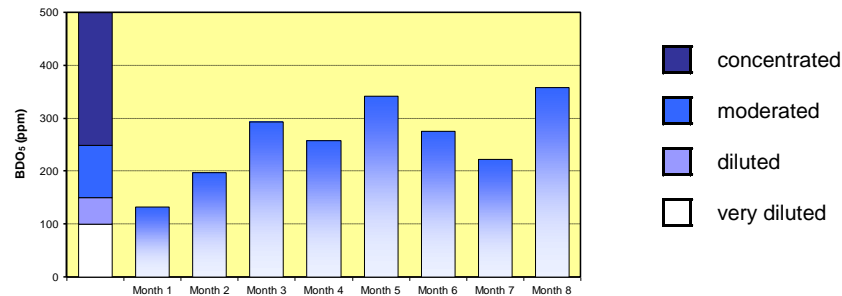


Filtration compartment

SIREA – Project Development



- ✓ Prototypes fed with inlet water of WWTP of Suria. Study with representative water.



- ✓ Experimentation lasted more than 6 months. Analysis of physical-chemical and microbiological parameters and also microscopic sludge observation.



Hollow fibres prototype



Flat Sheet prototype

Start-up: July 2007

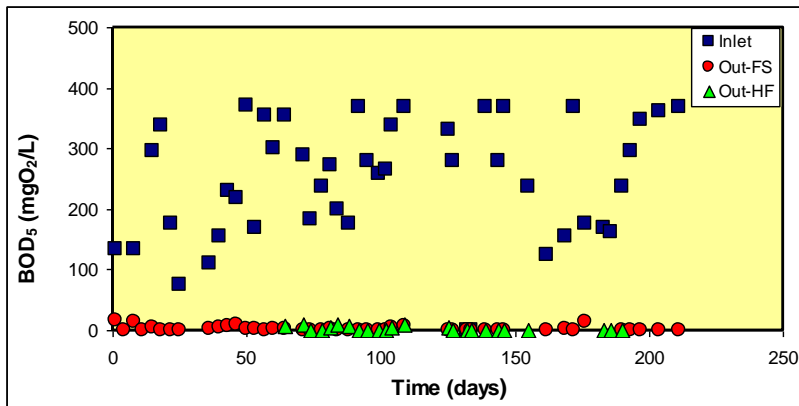
Conclusions: December 2007

But... Flat Sheet prototype: Still running today

(Long term membrane resistance and performance)



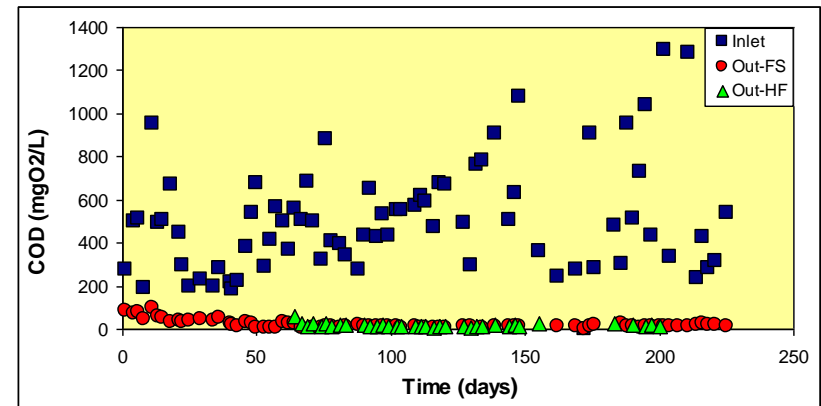
Results



Input mean: 256 ppm

Output mean FS: 3 ppm

Output mean HF: 3 ppm



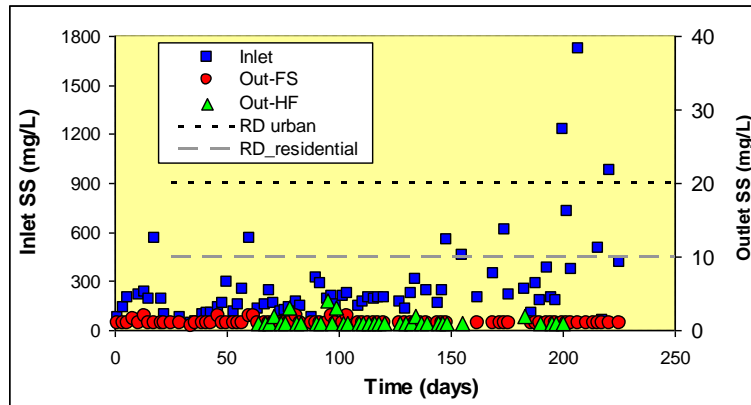
Input mean: 515 ppm

Output mean FS: 21 ppm

Output mean HF: 17 ppm



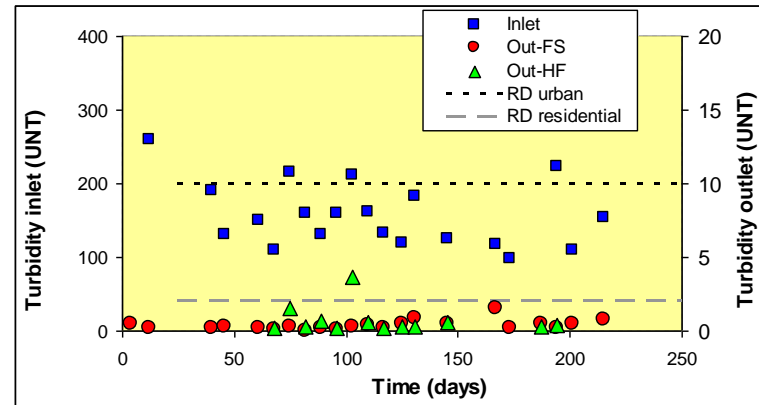
Results



Input mean: 350 ppm

Output mean FS: 1 ppm

Output mean HF: 1 ppm



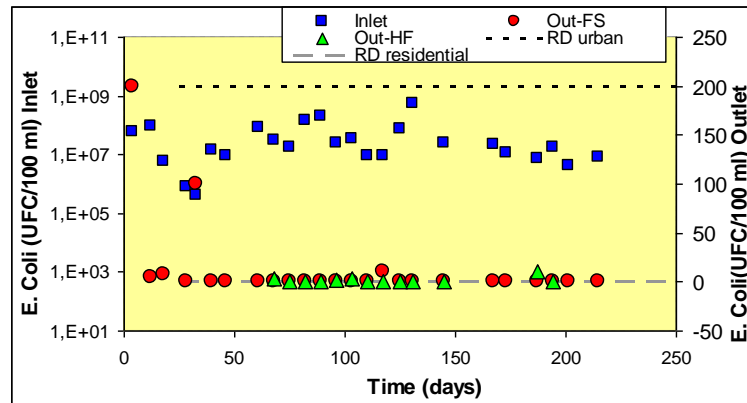
Input mean: 237 UNT

Output mean FS: 0,4 UNT

Output mean HF: 0,7 UNT



Results



Input mean: 5,00E+07 cfu/100ml

Output mean FS: < 5 cfu/100ml

Output mean HF: < 5 cfu/100ml



Results

Parameter	Wastewater	Effluent (Flat sheet)	Effluent (Hollow fiber)
BOD₅ (mgO₂/l)	265	3	3
COD (mgO₂/l)	515	21	17
TSS (mg/l)	350	1	1
Turbidity (UNT)	237	0,4	0,7
E.Coli (cfu/100ml)	5,00E+07	<5 (>85%)	<5 (>90%)
Nematode Eggs (egg/10l)	99	<3	<3

Reference
25 (91/271 CE)
125 (91/271 CE)
10 (RD 1620/2007 1.1)
2 (RD 1620/2007 1.1)
<0 (RD 1620/2007 1.1)
<1 (RD 1620/2007 1.1)

% reduction (Flat sheet)	% reduction (Hollow fiber)
98,9%	98,9%
95,9%	96,7%
99,7%	99,7%
99,8%	99,7%
7 LOG	7 LOG
97,0%	97,0%



Advantages against conventional treatments

- ✓ Better performance against inlet load variations because the bioreactor works at higher MLSS.
- ✓ Insensitive to flocculation / sedimentation problems caused by bulking or foaming.
- ✓ Higher sludge age which allows:
 - Slow degradation particles elimination.
 - Reduction of equipment size.
 - Reduction of sludge production.
- ✓ Easier installation than Conventional + Tertiary.
- ✓ Increase of effluent quality security and reduction of water discharge tax.

SIREA – The choice: FS or HF?



- ✓ Since the effluent quality was practically the same, other points were analysed...

Points	Hollow fibres	Flat sheet
Pore size	Ultra	Micro / Ultra
Installation and operation ease	✗	✓
Air score membrane unit	✓	✗
Problems caused by breakage	=	=
Maintenance: cleaning	✗	✓
Power consumption	✗	✓
Membrane unit cost	✓	✗
Effluent quality	=	=

The choice that best fits our needs: FLAT SHEET MEMBRANES



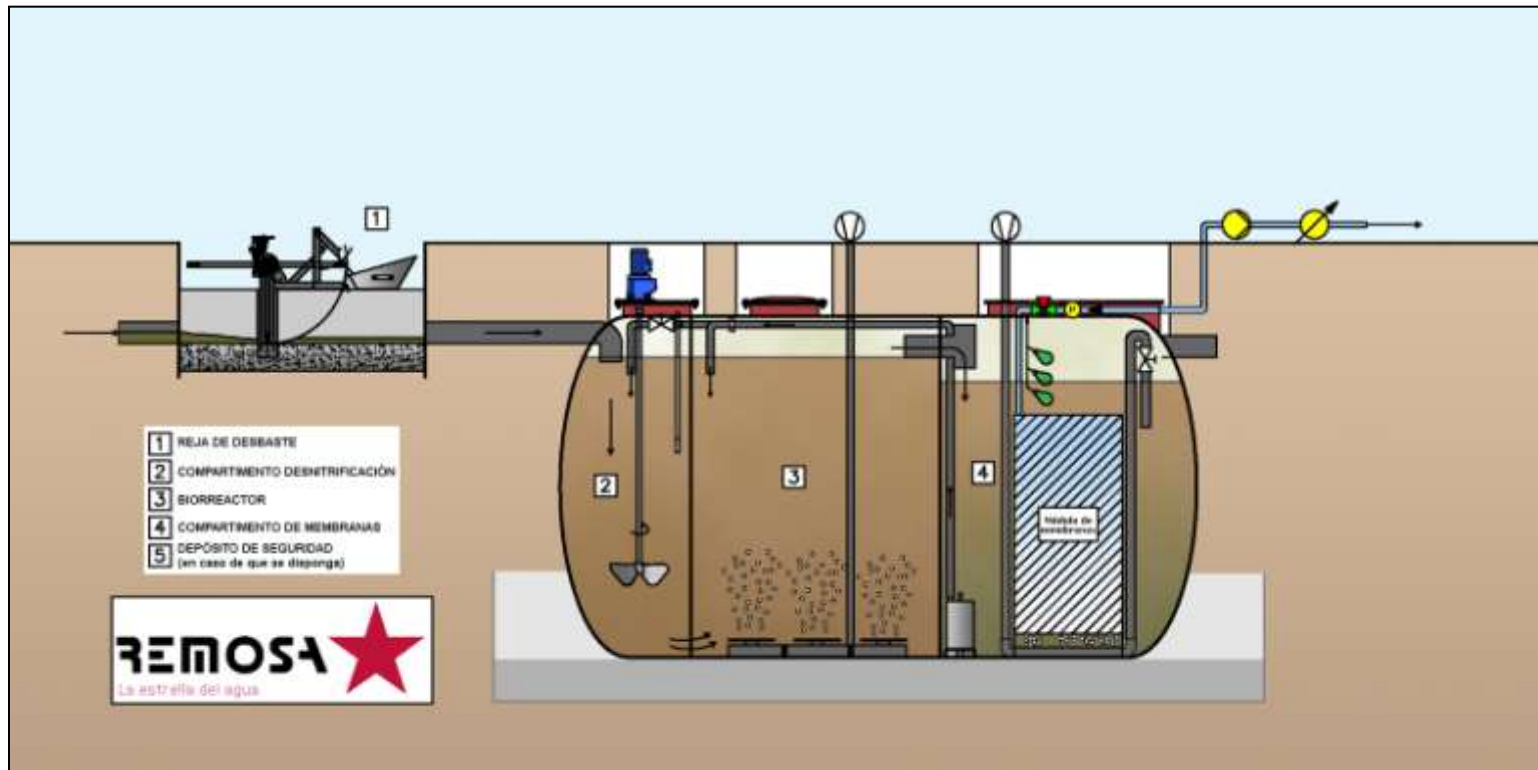
✓ **Main conclusions**

- ✓ Applying either of the two technologies, the quality of the effluents is excellent and complies with the most restrictive limits in the RD 1620/2007.
- ✓ The flat-sheet membrane format permits better integration in compact water-regeneration units for small urban communities.
- ✓ The final output obtained in permeate flow per membrane surface area is greater in the case of flat-sheet membranes. Moreover their installation, operation and maintenance are simpler.

ROX PLUS – Wastewater Regeneration Station



- ✓ As a result of SIREA project, we launched new wastewater regeneration stations: **ROX PLUS**
- ✓ From 50 to 500 Heq - Total daily flow: From 10 m³/day to 100 m³/day



REMOSA – MBR: Next applications



- ✓ Since results and conclusions of SIREA were satisfactory, we thought about different applications for membrane technology adapted to our equipment configuration.
- ✓ And the possibility of taking part in the most ambitious project of Water Sustainability in Spain appeared. SOSTAQUA Project – CENIT program.
- ✓ **SOSTAQUA project** (2007-2010)

The activity of SOSTAQUA where Remosa takes part is:

“Use membrane technology to treat water different from sewage”

At the beginning of the project we didn't exactly know which applications to choose. However, we projected to develop 2 different applications. And we started the research.

- 1st Application: Grey water regeneration - developed
- 2nd Application 2 – under development.



Grey water regeneration and reuse

- ✓ Since regenerated water would mainly be used for: irrigation, floor cleaning and toilet flushing, we took the most demanding quality of regenerated water from RD 1620/2007, which is in residential use.

“Real Decreto 1620/2007 por el que se establece el régimen jurídico de la reutilización de las aguas depuradas”

- ✓ We were convinced that with membrane technology we would achieve this quality.

USO DEL AGUA PREVISTO	VALOR MÁXIMO ADMISIBLE (VMA)				OTROS CRITERIOS
	NEMATODOS INTESTINALES ¹	ESCHERICHIA COLI	SÓLIDOS EN SUSPENSIÓN	TURBIDEZ	
1.- USOS URBANOS					
CALIDAD 1.1: RESIDENCIAL ² a) Riego de jardines privados. ³ b) Descarga de aparatos sanitarios. ³	1 huevo/10 L	0 (UFC ⁴ /100 mL)	10 mg/L	2 UNT ⁵	OTROS CONTAMINANTES ⁶ contenidos en la autorización de vertido aguas residuales: se deberá limitar la entrada de estos contaminantes al medio ambiente. En el caso de que se trate de sustancias peligrosas ⁷ deberá asegurarse el respeto de las NCAs. ⁸ <i>Legionella spp.</i> 100 UFC/L (si existe riesgo de aerosolización)
CALIDAD 1.2: SERVICIOS a) Riego de zonas verdes urbanas (parques, campos deportivos y similares). ⁹ b) Baldeo de calles. ⁹ c) Sistemas contra incendios. ⁹ d) Lavado industrial de vehículos. ⁹	1 huevo/10 L	200 UFC/100 mL	20 mg/L	10 UNT	

SOSTAQUA – Project Development



- ✓ We chose flat sheet membranes and submerged configuration.
- ✓ Design, manufacture and implementation to Pilot Plant of two prototypes.
- ✓ Prototypes fed with grey water from changing rooms in Remosa factory. Study with representative water.
- ✓ Experimentation lasted more than 9 months.



Start-up

Prototype 1 – 300 L/day – October 2007

Prototype 2 – 900 L/day – February 2008

Conclusions: December 2008

But... Still running today

(Long term membrane resistance and performance)



Results

Parameter	Grey water	Effluent (without chlorination)	Reference	% reduction
BOD ₅ (mgO ₂ /l)	138	6	25 (91/271 CE)	95%
COD (mgO ₂ /l)	302	29	125 (91/271 CE)	90%
TSS (mg/l)	58	1,3	10 (RD 1620/2007 1.1)	98%
Turbidity (UNT)	68	1,2	2 (RD 1620/2007 1.1)	98%
E.Coli (cfu/100ml)	3,30E+04	<5 (>95%)	0 (RD 1620/2007 1.1)	4 LOG
Tensactives (mg LSS/L)	7,10E+00	0,1	-----	98%

Conclusions

- ✓ Grey water regeneration systems with membrane technology allows accomplishment of most restrictive use in RD 1620/2007 (residential use).
 - High depuration efficiency.
 - High environmental and sanitary quality effluent.



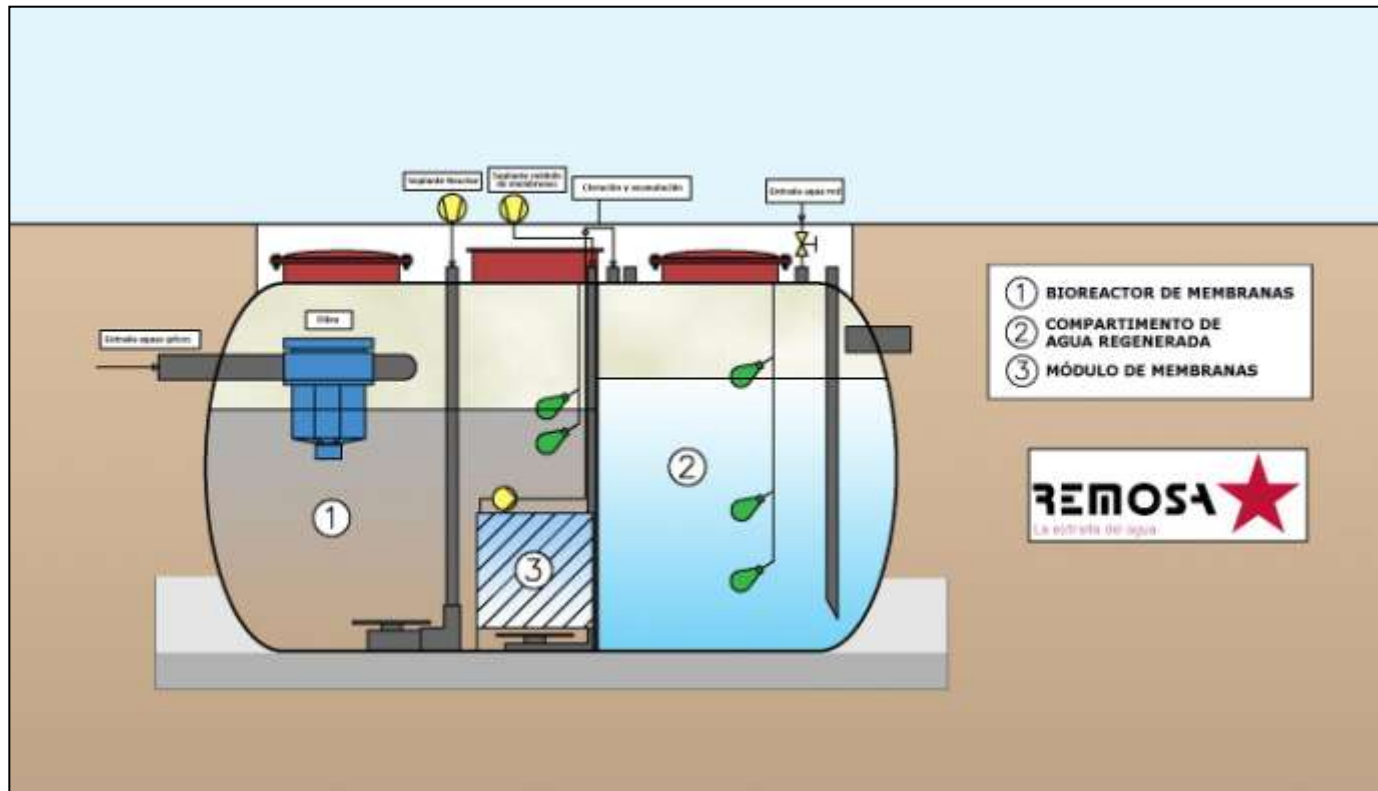
Advantages against conventional treatments

- ✓ Insensitive to flocculation / sedimentation problems caused by bulking or foaming.
- ✓ Effluent quality is assured in case inlet flow increases or decreases.
- ✓ Higher MLSS allows biomass retention so that COD and BOD efficiency increases.
- ✓ Membrane physical separation makes TSS, Turbidity, and E.Coli be independent from inlet flow fluctuation and contamination.

ROX PLUS – Grey water Regeneration Station



- ✓ As a result of SOSTAQUA project 1st application, in march 2008 (SMAGUA FAIR) we launched new grey water regeneration stations: **GREM**
- ✓ From 40 to 200 Heq - Total daily flow: From 100 L/day to 5.000 L/day





Thank you for your attention !!!