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Combined Performance of UV Light and Chlorine during Reclaimed Water Disinfection

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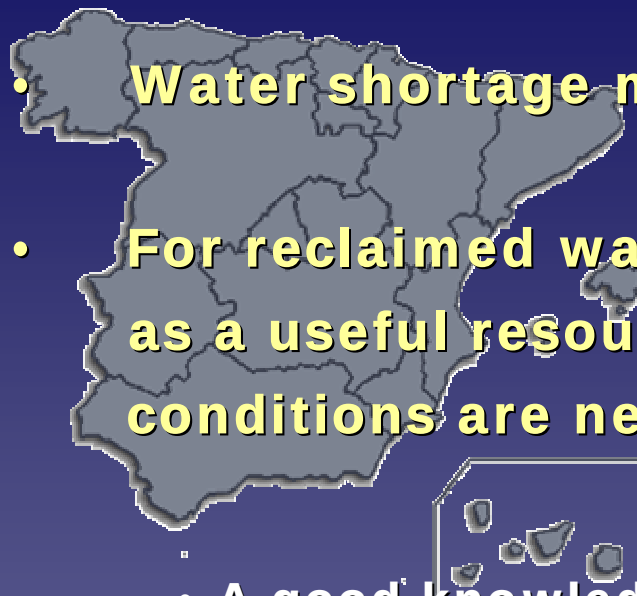
6 TH CONFERENCE ON WASTEWATER RECLAMATION AND REUSE FOR SUSTAINABILITY

Antwerp, Belgium - October 9-12, 2007

Importance of Wastewater Reuse



- Water shortage makes reuse necessary.
- For reclaimed water can be considered as a useful resource, the following conditions are needed:
  - A good knowledge of the tertiary treatment operations.
  - An acceptable level of disinfection, to reduce microbiological risk.
  - A good management of WRP's.

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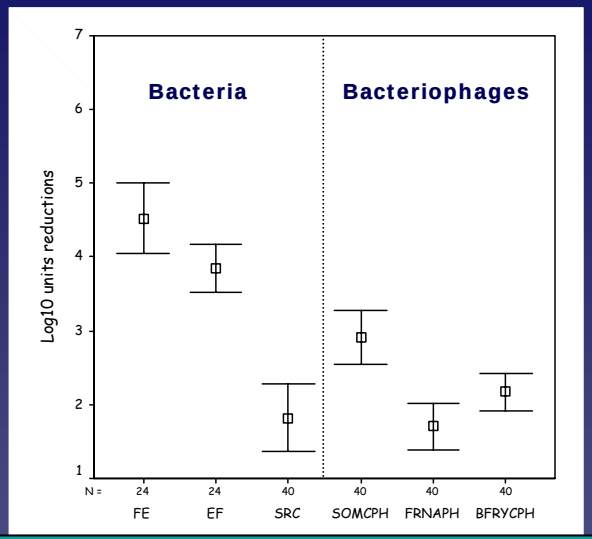
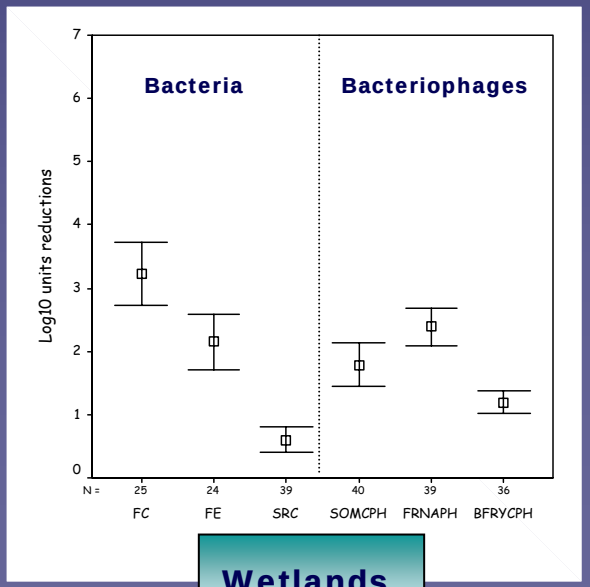
Microbial reduction in wastewater



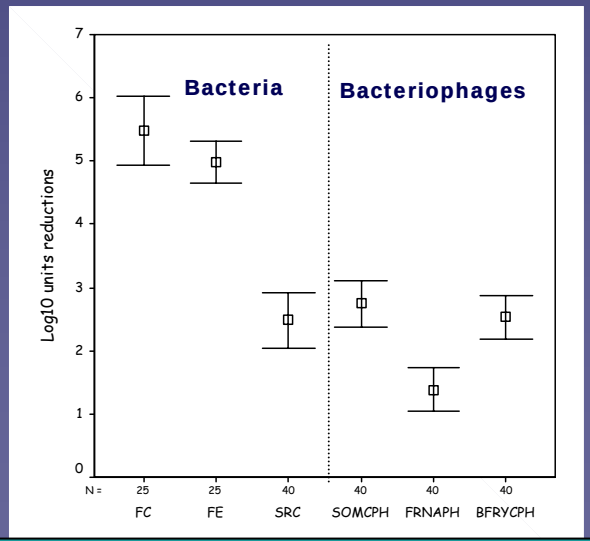
Filtration + UV light +Chlorine

LOG_{10} REDUCTIONS OBTAINED FOR THE FECAL INDICATORS, PRESENTED SIGNIFICANT DIFFERENCES BETWEEN THEM IN TERTIARY TREATMENTS.

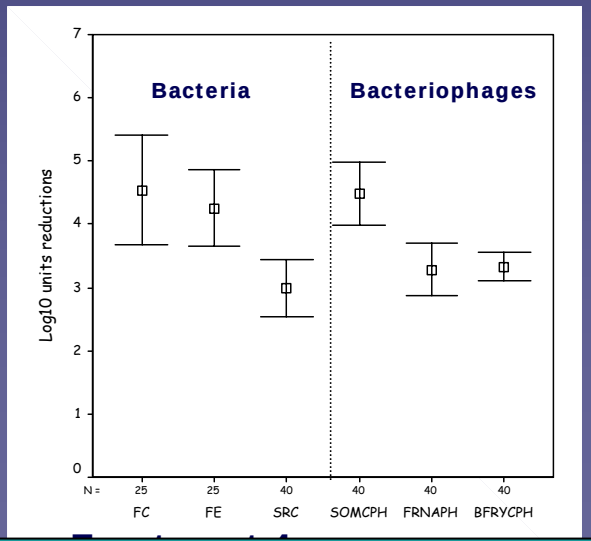
REDUCTIONS DEPEND ON THE KIND OF THE DISINFECTION TREATMENT USED.



Wetlands



Flocculation-Sedimentation + UV light

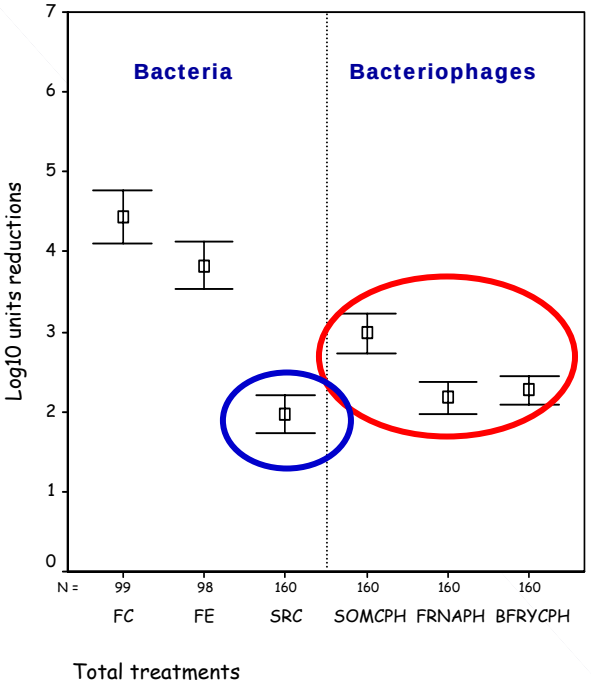


Flocculation-Sedimentation + Chlorine

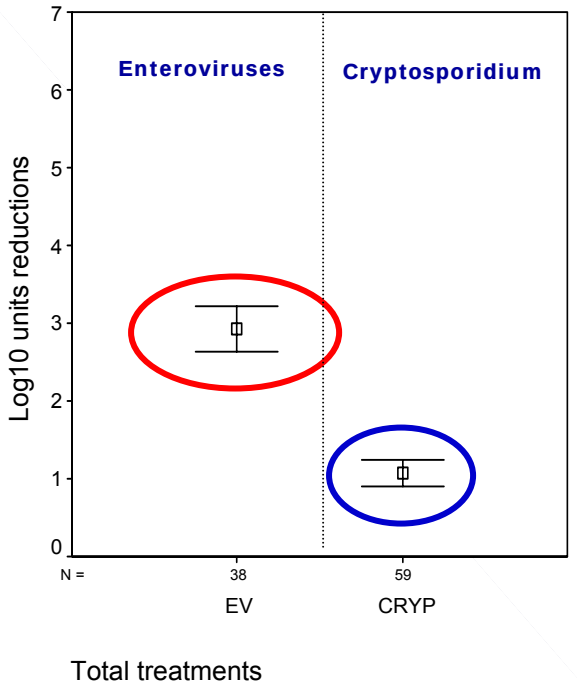
Microbial reduction in wastewater

LOG_{10} REDUCTIONS OBTAINED FOR BACTERIOPHAGES AND SPORES OF SRC ARE LOWER THAN THOSE OBTAINED FOR BACTERIA IN TERTIARY TREATMENTS.

Fecal indicators



Pathogens



(Ana Costán, et al. 2007)

Combination of disinfectant agents

- **Greater inactivation of microorganisms found in reclaimed water.**
  - Each disinfection agent has its own degree of inactivation on each type of microorganism.
- **Reduction of the disinfection dose as compared with the use of an only disinfectant.**
  - Chlorine used as a residual disinfection agent (doses < 5 ppm) , much lower than those traditionally applied.
- **Reduction in the formation of disinfection by-products (THMs).**
- **An alternative disinfection treatment is available in case of failure or maintenance of one of the systems.**

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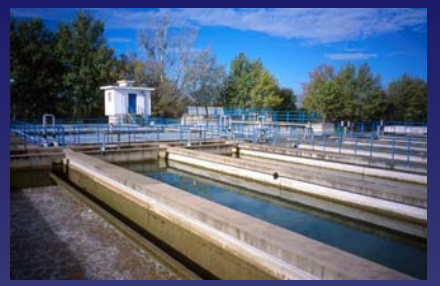
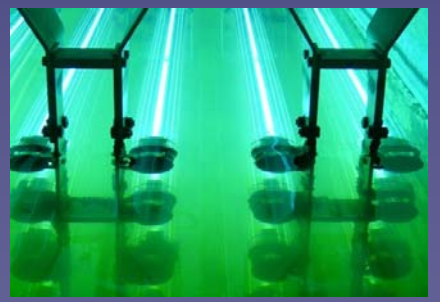
OBJECTIVES

- To assess the effect of different combinations of disinfectants agents and to measure their effects on the different groups of bacteria, viruses and pathogenic protozoa (*Cryptosporidium* spp.)

- To determine the optimum working conditions for the disinfection process at two water reclamation plants in order to ensure compliance with the microbiological water quality requirements intended for their non-potable use.

- To provide additional information to that already existing on the combined action of ultraviolet light and hypochlorite.





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WRP of Castell d'Aro

Reclaimed water main use:

Agricultural irrigation (217.000 m^3/year)

Golf course irrigation (510.000 m^3/year)

Stream flow augmentation (263.118 m^3/year)

Reclaimed water treatment: Theoretical treatment capacity of 600 m^3/h

Pulse Bed Sand filtration

Filtering surface: 80 m^2

Filtering speed: 7,8 m/h

UV Light

UV modules: 2

UV lamps/module: 4

Post-Chlorination

CL_2 Dose: 5 mg Cl_2/l

Contact time: 45 min

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Layout of the work

Disinfection treatments:

Sampling days : 6 days (2 weeks, 3 days / week) July 2005

Samples: - Secondary effluent (n=6)

- **Reclaimed water disinfected with UV light (n=9), (UV) (UV doses of 24-36 mJ/cm^2)**
- **Reclaimed water disinfected with hypochlorite (10 mg Cl_2/l) (n=9),(CL), (Cxt values of 216 mg Cl_2min/L)**
- **Reclaimed water disinfected with UV light + hypochlorite (5 mg Cl_2/l), (n=9)(UVCL),(UV doses of 24-36 mJ/cm^2 and Cxt values of 67-135 mg Cl_2min/l)**

Microorganisms:

- **Bacterial indicators: FC, FE and spores of SRC.**
- **Viral indicators: SOMCPH, FRNAPH, BFRYCPH and GA17PH.**
- **Pathogens: Total, Viable and Infectious *Cryptosporidium* oocysts**

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WRP of Blanes

Reclaimed water main use:

Groundwater recharge (3.02 Hm^3/year)

Agricultural irrigation (0.05 Hm^3/year)

Reclaimed water treatment: Theoretical treatment capacity of 700 m^3/h

Lamelar sedimentation

Nº tanks: 2

Total surface: 110,2 m^2

Pulse-bed Sand filtration

Filtering surface 82,4 m^2

Filtering speed: 8,5 m/h

UV light

4 modules (8 lamps/module)

Dose max: 189 mJ/cm^2

Post-Chlorination

Dose: 1-2 $mgCl_2/l$

Contact time: 210 min

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Layout of the work

Disinfection treatments:

Sampling days : 12 days (4 weeks, 3 days /week) May 2006

Samples: - Filtered effluent (FIL, n=12)

- 1 UV module (UV, n=12), (UV dose of 44 mJ/cm^2)
- 1 UV module + addition of 1 mg Cl_2/l of hypochlorite. (1UV1CL, n =9), (UV dose of 49 mJ/cm^2, CT chlorine value of 42)
- 1 UV module + addition of 2 mg Cl_2/l of hypochlorite.(1UV2CL, n=9), (UV dose of 39 mJ/cm^2, CT chlorine value of 100)
- 2 UV modules (2UV, n=9), (UV dose of 78 mJ/cm^2)
- 2 UV modules + addition of 1 mg Cl_2/l of hypochlorite (2UV1CL, n=9), (UV dose of 78 mJ/cm^2, CT chlorine value of 67)
- Addition of hypochlorite in doses of around 3 mg Cl_2/l to achieve total residual chlorine of 0.6 mg Cl_2/l. (0.6 CL, n=9), (CT chlorine value of 153)

Microorganisms :

- Bacterial indicators: Fecal coliform (FC), Sulphite Reducing Clostridia spores (SRC)
- Viral indicators: Somatic coliphages (SOMPH).
- Pathogens: Total, viable and infectious *Cryptosporidium* oocysts and Enteroviruses (ENT)

Microbial determinations

Bacterial indicators:

- **Fecal coliform (FC):** Standard Methods for Examination of Water and Wastewater, 20 th. Part 9222 D: Faecal Coliform Membrane Filter Procedure.

- **Fecal enterococci (FE):** ISO 7899/1 Detection and enumeration of faecal streptococci in water. Part 2: Method by membrane filtration.

- **Spores of sulphite-reducing Clostridia (SRC):** SPS Agar, medium proposed by Angelotti et al. (1962).

Microbial determinations

Viral indicators:

- **Somatic coliphages (SOMCPH).** ISO 10705-2: Water quality . Detection and enumeration of bacteriophages. Part 2.

- **F-specific RNA bacteriophages (FRNAPH).** ISO 10705-1: Water quality. Detection and enumeration of bacteriophages. Part 1.

- **Bacteriophages infecting *Bacteroides fragilis* (RYCPH and GA17PH).** ISO 10705-4: Water quality. Detection and enumeration of bacteriophages. Part 4.

Microbial determinations

Cytopathogenic enteroviruses (ENT):

- Secondary effluent samples: Directly (no concentration)
- Tertiary effluent samples: Concentration of 100 litres with the Adsorption-Elution method and organic flocculation
- Enteroviruses detection by the Double-Layer plaque assay method in BGM cell line (Mocé-Llivina *et al.* 2005).

Cryptosporidium spp. Oocysts (CRYP):

- Cryptosporidium detection by USEPA Method 1623 (USEPA 1999)
- Viability determination by vital dye stainning (Campbell *et al.* 1992).
- Infectivity determination by Cell Culture assay on HCT-8 cell line (Slifko *et al.*, 1997).

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RESULTS

WRP Castell d'Aro - Results

FC: Fecal Coliforms

FE: Fecal Enterococci

SRC: Sulphite reducing clostridia spores

SOMCPH: Somatic coliphages.

FRNAPH: Bacteriophages F-RNA specific.

RYCPH: Bacteriophages infecting Bacteroides fragilis strain RYC2056.

GA17PH: Bacteriophages infecting Bacteroides fragilis strain GA17.

CRYOT: Total Cryptosporidium spp.

CRYOV: Viable Cryptosporidium spp.

CRYOI: Infectious Cryptosporidium spp.

UV WORKING IN RATHER UNFAVOURABLE CONDITIONS (APPROX 50% TRANSMITTANCE AT 254 nm)

	Average inactivation by treatment (log.u.)		
Parameter	Chlorine	UV	UV + Chlorine
FC	5.00	1.80	5.06
FE	4.49	1.59	4.77
SRC	0.74	0.53	0.83
SOMCPH	1.58	2.21	2.88
FRNAPH	0.34	0.95	0.82
RYCPH	0.46	1.86	1.76
GA17PH	0.92	1.55	1.74
CRYOT	0.13	0.76	0.38
CRYOV	0.15	0.78	0.41
CRYOI	0.29	≥ 2.53	1.76

Low transmittance at 254nm (26%)

High turbidity (≤ 4NTU)

CRITICAL CONTROL POINTS

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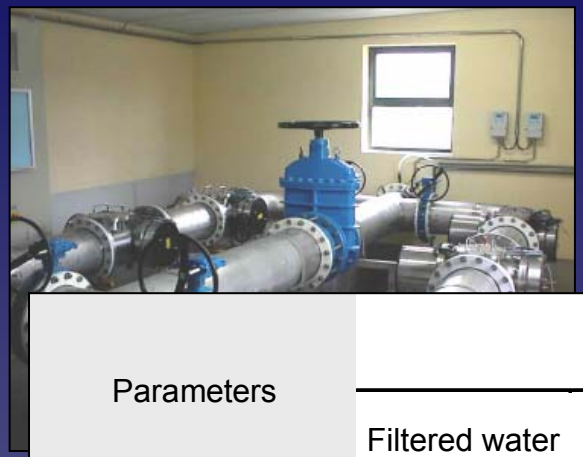
WRP Blanes - Results



PHYSICO-CHEMICAL QUALITY OF BLANES RECLAIMED WATER

Parameters	Types of water effluents						
	Filtered water	1UV	1UV1CL	1UV2CL	2UV	2UV1CL	0,6 CL
Number of samples	9	18	9	9	9	9	9
SS, mg/l	2,1± 0,5	2,1 ± 1,2	2,8 ± 3,7	2,7 ± 1,5	1,4 ± 0,9	2,5 ± 1,8	2,2 ± 0,5
Tubidity, NTU	1,7 ± 0,5	1,8 ± 1,2	1,8 ± 0,6	2,0 ± 1,7	2,0 ± 1,1	2,8 ± 1,2	1,9 ± 0,7
Transmittance at 254 nm, %	71 ± 2	71,5 ± 1,5	68 ± 8	70 ± 3	70 ± 1	69 ± 3	72 ± 3
UV dose, mJ/cm^2	-	44 ± 13,5	49 ± 26	39 ± 1	78 ± 1	78 ± 1	-
Total residual chlorine, mg Cl_2/l	-		0,2 ± 0,1	0,4 ± 0,1		0,3 ± 0,1	0,6 ± 0,2
C x t, mg Cl_2 min/L	-		42 ± 18	100 ± 25		67 ± 13	153 ± 42

PRODUCTION OF A HIGH RECLAIMED WATER QUALITY

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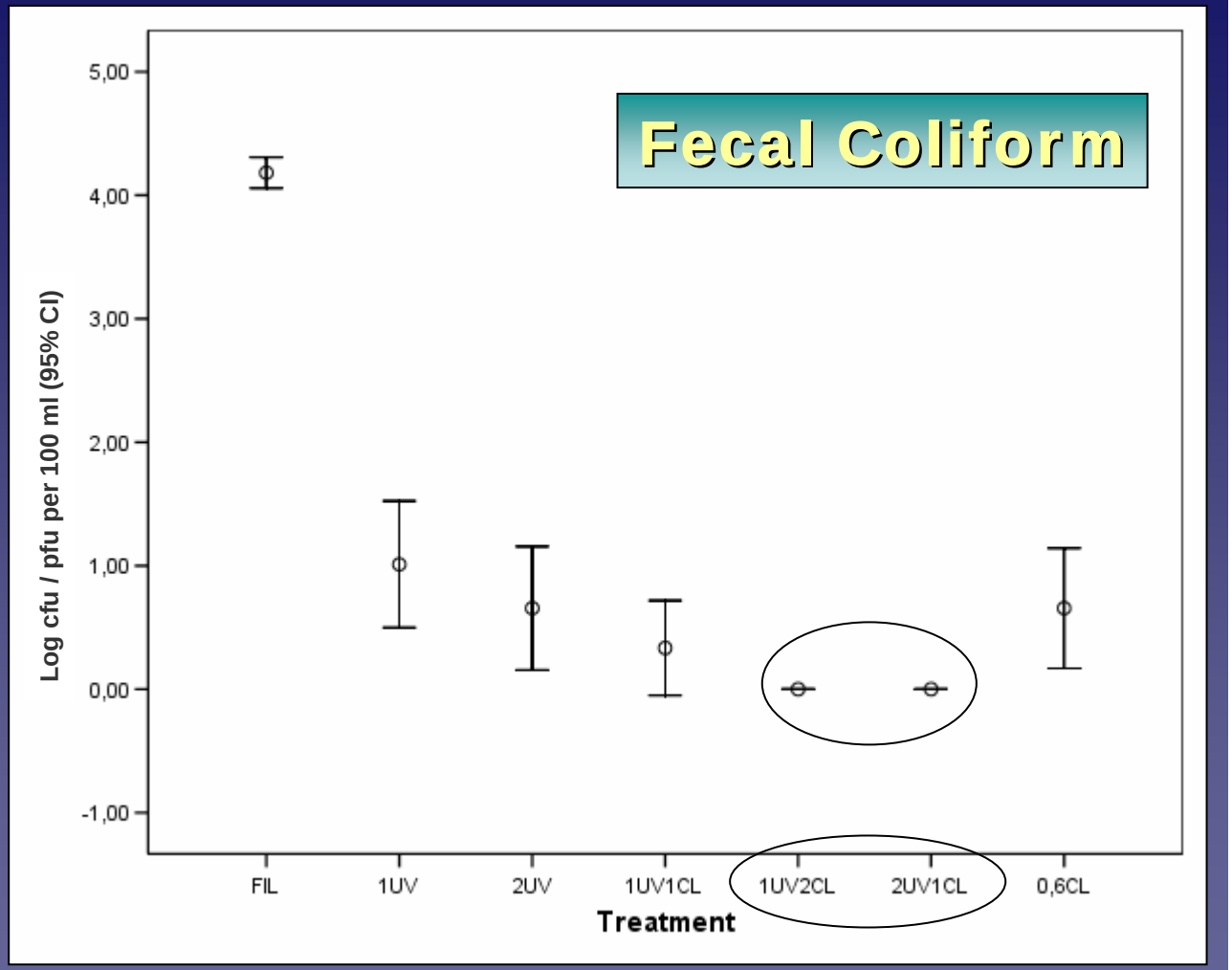
WRP Blanes - Results

THE MOST EFFICIENT DISINFECTION TREATMENTS FOR FC INACTIVATION ARE 1UV2CL AND 2UV1CL



FIL: Filtered secondary effluent
1UV / 2UV: Filtered water disinfected with one/two ultraviolet light module
1UV1CL/ 1UV2CL / 2UV1CL:Filtered water disinfected with combined ultraviolet light modules (1or 2) and the addition of hypochlorite (1 or 2 ppm).
0,6CL: Filtered water disinfected with one dose of hypochlorite of around 3 mg Cl_2/l producing constant total residual chlorine of 0.6 mg Cl_2/l

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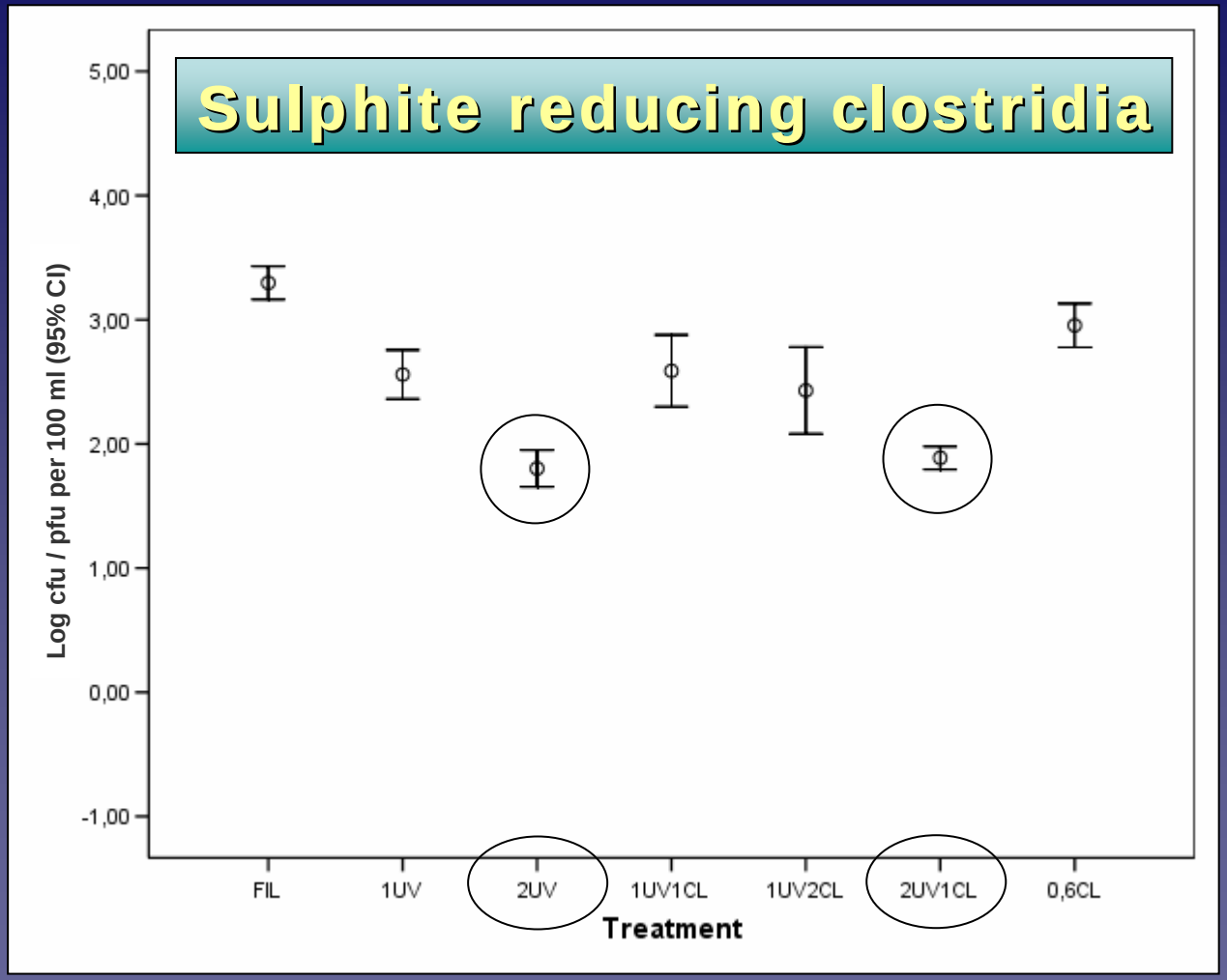
WRP Blanes - Results

THE MOST EFFICIENT DISINFECTION TREATMENTS FOR SRC INACTIVATION ARE 2UV AND 2UV1CL



FIL: Filtered secondary effluent
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0,6CL: Filtered water disinfected with one dose of hypochlorite of around 3 mg Cl_2/l producing constant total residual chlorine of 0.6 mg Cl_2/l

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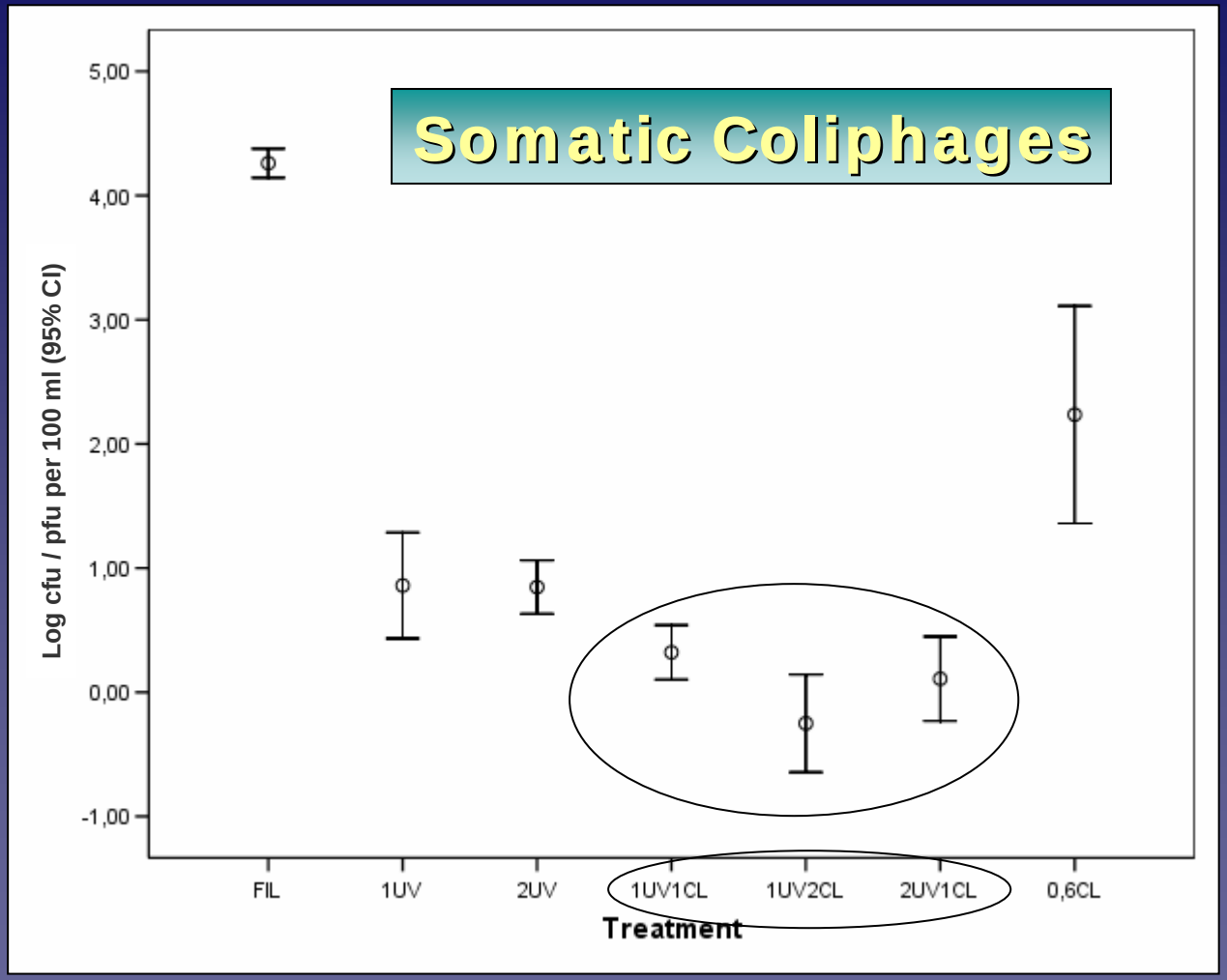
WRP Blanes - Results

THE MOST EFFICIENT DISINFECTION TREATMENTS FOR SOMCPH INACTIVATION ARE 1UV1Cl, 1UV2CL AND 2UV1CL



FIL: Filtered secondary effluent
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WRP Blanes - Results

PHATOGENIC MICROORGANISM

Types of water and/or treatment	Total oocysts		Viable oocysts		Infectious oocysts		Enteroviruses pfu/100 litres
	in 100 l	%	in 100 l	%	in 100 l	%	
Filtered water	29,6	-	9,0	30	1,6	5	2,3
1UV	7,1	-	4,5	63	0,0	0	< 1
1UV1CL	20,0	-	10,0	50	0,0	0	< 1
1UV2CL	8,8	-	0,0	0	0,0	0	< 1
2UV	23,7	-	5,9	25	0,0	0	< 1
2UV1CL	6,0	-	0,0	0	0,0	0	< 1
0,6CL	5,0	-	1,7	34	1,4	28	< 1

NO CRYPTOSPORIDIUM OOCYSTS (VIABLE AND INFECTIOUS)

NO CYTOPATHOGENIC ENTEROVIRUS

1UV + 2CL

2UV + 1CL

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WRP Blanes - Results

WHICH IS THE BEST DISINFECTION TREATMENT ?

Fecal coliform		1UV+2CL		2UV+1CL
Sulphite reducing clostridia spores			2UV	2UV+1CL
Somatic coliphages:	1UV+1CL	1UV+2CL		2UV+1CL
Cryptosporidium spp.		1UV+2CL		2UV+1CL

¿ 1UV+2CL or 2UV+1CL ?

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UV TREATMENT COMPARISON

UV DISINFECTION CAPACITY ARE AFFECTED BY PHYSICO-CHEMICAL EFFLUENT QUALITY

WRP Castell d'Aro

2 UV modules (4 lamps/module = 8 UV lamps)

WRP Blanes

1 UV module (8 lamps/module)

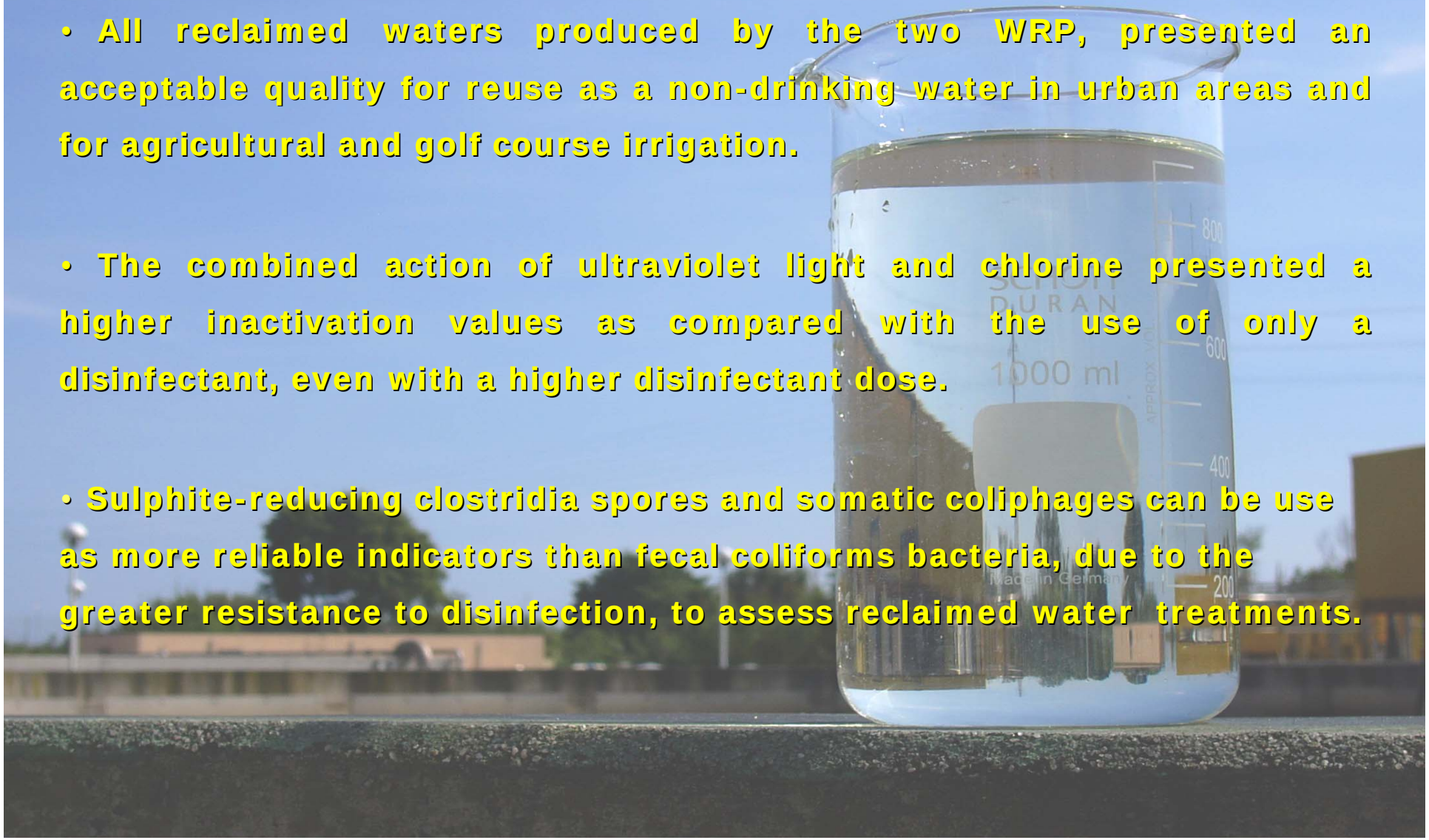
	WRP Castell d'Aro	WRP Blanes
SS (mg/L)	4,6 ± 1,7	1,8 ± 1,1
Turbidity (NTU)	2,1 ± 0,9	1,9 ± 1,1
Transmittance at 254 nm, (%)	52 ± 4,0	71 ± 1,3
UV dose (mJ/cm^2)	28,6 ± 3,7	44 ± 1,8

UV treatment (8 UV lamps)

Microbial indicators reduction (log u)

FC:	1,80	<	≥ 2,78
SRC:	0,53		0,74
SOM:	2,21		≥ 3,37

CONCLUSIONS I



- All reclaimed waters produced by the two WRP, presented an acceptable quality for reuse as a non-drinking water in urban areas and for agricultural and golf course irrigation.

- The combined action of ultraviolet light and chlorine presented a higher inactivation values as compared with the use of only a disinfectant, even with a higher disinfectant dose.

- Sulphite-reducing clostridia spores and somatic coliphages can be use as more reliable indicators than fecal coliforms bacteria, due to the greater resistance to disinfection, to assess reclaimed water treatments.

CONCLUSIONS I I

- UV disinfection treatments presented a higher bacteriophages inactivation and a total inactivation of the infectious *Cryptosporidium* oocysts in reclaimed water, even in the case of working in unfavourable conditions (WRP of Castell d'Aro).

- Chlorine disinfection treatments presented a higher non-spore forming bacteria inactivation than bacteriophages and sulphite reducing clostridia. Chlorine was not able to inactivate infectious *Cryptosporidium* oocysts.

- Enteroviruses were completely inactivated by all disinfection treatments studied

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THANK

YOU

Department of Microbiology, University of Barcelona. Spain

MARS
Microbiologia d'aigües relacionada amb la salut

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