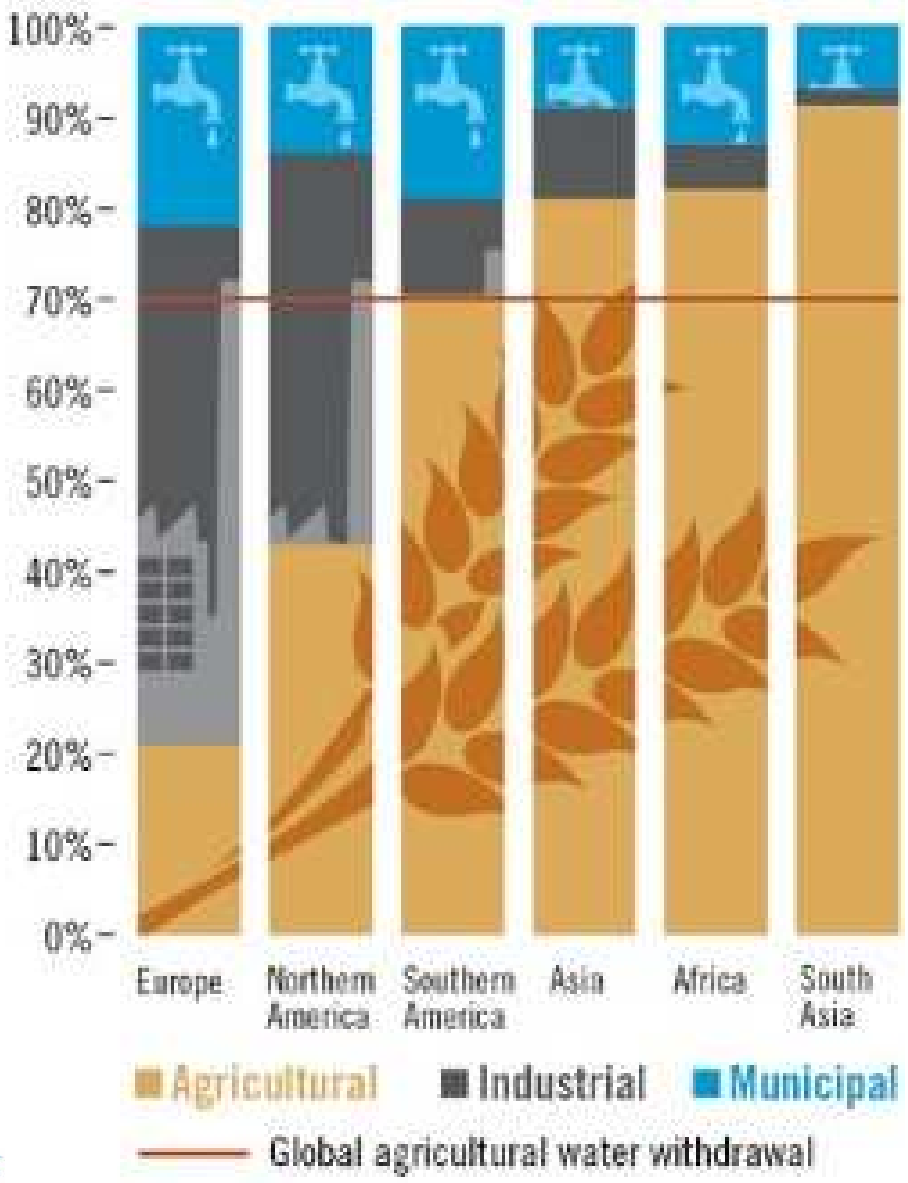
Water reuse in farming

Carme Bosch and Marta Terré
Barcelona, 13th June 2016

Date / Author

INTRODUCTION



Source:
Thirsty agriculture: Water withdrawals for agriculture, industry and households in different world regions. Source: Aquastat (2014)

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

OBJECTIVE

To explore the potential use of reclaimed water for livestock production

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

REUSE APPLICATION

Source: Groundwater
Total water consumed: 86 m^3/d

Chlorination

Drinking (70%)	Cleaning milking parlor (17.6%)	Cooling cows (sprinklers) (4.2%)	Cleaning milking equipment (1.1%)	Other services (7.1%)	Yard flushing

18.2 m^3/d

15.1 m^3/d

3.6 m^3/d

0.9 m^3/d

6.1m^3/d

Manure Pit

Milk

40.3 m^3/d

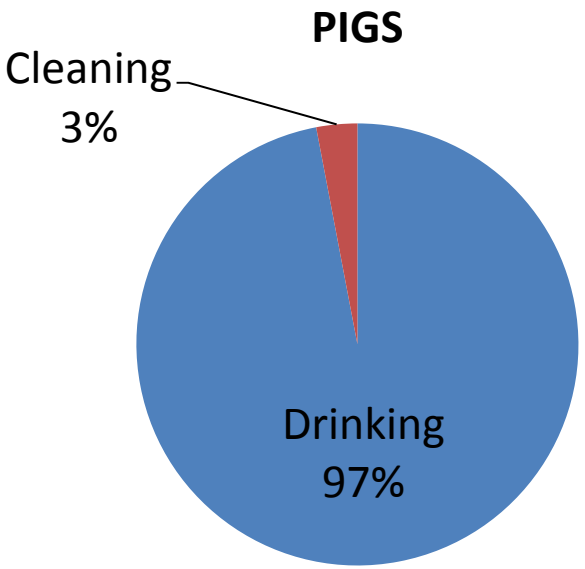
Field

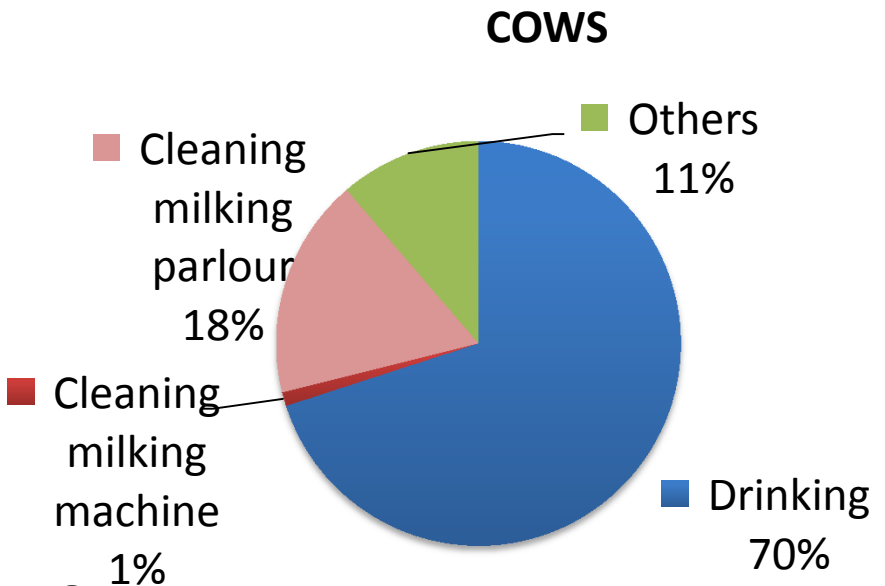
Anaerobic digestor

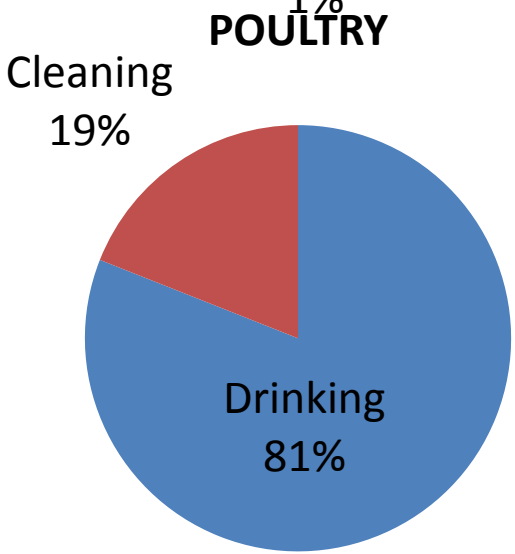
SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

REUSE APPLICATION







SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

REGULATORY REQUERIMENTS

Spanish standards for water reuse **in agriculture** (Royal Decree 1620/2007):

	APPLICATIONS	E.Coli (CFU/100ml)	Nematodes (eggs/10L)	Legionella spp (CFU/L)	SS (mg/L)	Turbidity (NTU)	Treatment train
2.1	·Irrigation of fresh products for human consumption allowing direct contact of regenerated water with edible parts.	<100	<1	<1000	20	10	Chemical precipitation, depth filtration and disinfection (ultraviolet radiation together with chlorination); residual chlorine may be needed in distribution system
2.2	·Irrigation of not fresh products for human consumption not avoiding direct contact of regenerated water with edible parts (with industrial post-treatment). ·Irrigation of pastureland for milk or meat producing animals. ·Aquaculture	<1000	<1	No limit set	35	No limit set	Filtration and disinfection (tendency to use ultraviolet radiation followed by residual chlorine)
2.3	·Localized irrigation of ligneous crops impeding contact of regenerated water with food for human consumption. ·Irrigation of ornamental flowers and greenhouses with no direct contact of regenerated water with crops	<10000	<1	<100	35	No limit set	

No standards for **livestock drinking in Spain**

REGULATORY REQUERIMENTS

Minimum Reclaimed WATER CLASS for livestock production in Australia:

Type of water usage	Class of water (with helminth treatment)		
	Class A	Class B	Class C
Livestock drinking water	✓	✓	✗
Dairy shed wash-down	✓	✓[1]	✗

✓ use is recommended (subject to comments, if any, below)
✗ not to be used for this purpose
[1] but not for milking machinery

Class	Treatment processes	Water quality objectives
B	Secondary treatment + Pathogen disinfection **Suggested best practice:** UV, chlorination or ozonation (and helminth reduction)	**Bacteriological criteria:** · <100 *E.coli* org/100 ml **Helminth and other pathogens:** Helminth reduction for cattle grazing **Others:** · pH 6 – 9 · < 20 mg/L BOD · < 30 mg/L SS

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

WATER QUALITY REQUIREMENTS FOR LIVESTOCK

GOOD QUALITY WATER
(taste, smell, turbidity, electrical conductivity and presence of certain substances)

ACCEPTABILITY AND EFFECTS ON ANIMAL PERFORMANCE

Element	Upper level (mg/l)	Maximum upper level (mg/l)
Total disolved solids (TDS)	960	5000
Sulphate	150	900
Nitrate-N	20	100
Fe	0,2	0,4
Mn	0,05	0,5

Socha et al., 2003. Variability of Water Composition and Potential Impact on Animal Performance

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

SPECIFIC OBJECTIVE

Use of reclaimed water from Caldes de Montbui WWTP for livestock drinking

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

FEED WASTEWATER CHARACTERISTICS

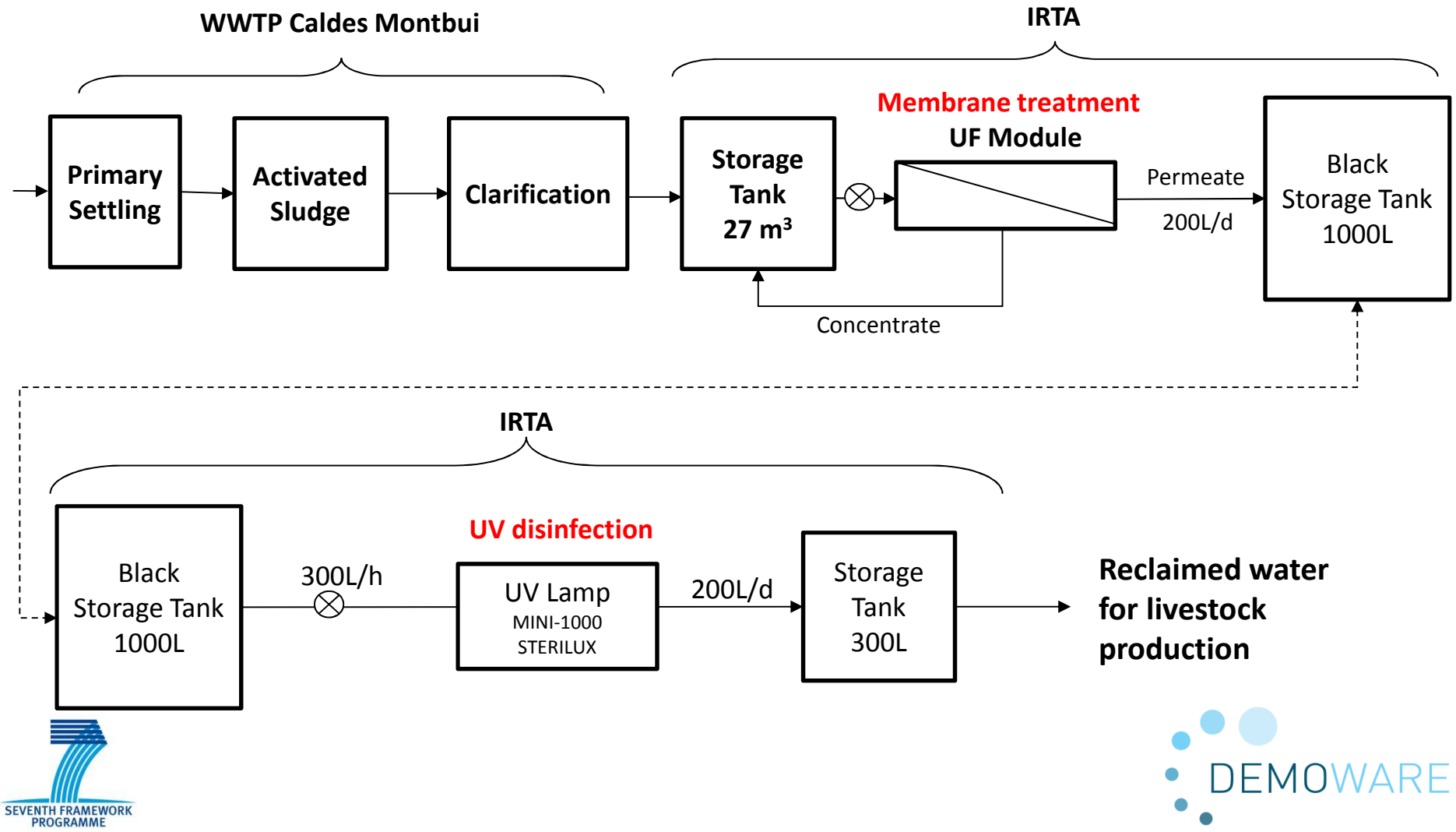
Secondary effluent WWTP Caldes Montbui	Water quality objectives for Class B (Australian Guidelines for Water Reuse)	Water quality guidelines for livestock drinking (Socha et al., 2003)
· pH 7.45 ✓ · 15.5 mg/L BOD ✓ · 14.3 mg/L SS ✓ · ~ 9 NTU ✓ · 61,000 ufc/100 mL *E. coli* ✗ · NO3-N ~ 4 mg/l ✓ · SO4 ~ 60 mg/l ✓ · Mn ~ 0.003 mg/l ✓	**Bacteriological criteria:** · <100 *E.coli* org/100 ml **Helminth and other pathogens:** Helminth reduction for cattle grazing **Others:** · pH 6 – 9 · < 20 mg/L BOD · < 30 mg/L SS	TDS < 960-5000 mg/l NO3-N < 20-100 mg/l SO4 < 150-900 mg/l Fe < 0.2 mg/l Mn < 0,05 mg/l …

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

SELECTION OF TREATMENT TECHNOLOGY

Implementation of a demonstration case study at IRTA facilities to use the secondary effluent from a wastewater treatment plant for livestock drinking



SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

ULTRAFILTRATION PERFORMANCE

Rationale of the treatment: elimination of suspended solids, colloids, bacteria, protozoa and some viruses from water, also helminth eggs and spores

Membrane and UF module specifications:

Module Type:	**MO P13U(1m)_I8**	
Module Material:	PVC-U, resin	
Membrane Type:	66.03 I8	
Membrane Material:	PVDF	
Molecular Weight Cut-off:	30	nm
Membrane area:	0.32	m^2
Nº Channels	13	channels
Inner tubes diameter	8	mm
Membrane length	100	cm
pH tolerance	2-10	
Maximum pressure	6	bar
Maximum temperature	40	ºC
Filtration area	0.3267	m^2
Filtration transversal area	6.53	cm^2

UF performance with the secondary WWTP effluent from Caldes:

Average permeate flowrate	32.4	L/h
Membrane flux (LMH)	99	LMH ($L/m^2 \cdot h$)
Cross Flow Velocity (CFV)	0.69	m/s
Qf, feedwater flowrate	1612	L/h
Qc, concentrate flowrate (Crossflow)	1579	L/h

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

ULTRAFILTRATION PERFORMANCE

UV DISINFECTION PERFORMANCE

- **Rationale of the treatment:** elimination microbial contamination including bacteria, viruses and protozoa

Recommended UV doses for reclaimed water systems (Source: *Water Reuse: Issues, Technologies, and Applications*):

- 100 mJ/cm^2 for granular medium filtration effluent
- **80 mJ/cm^2 for membrane filtration effluent**
- 50 mJ/cm^2 for reverse osmosis effluent

The dosage selected is intended to provide 4 log of poliovirus inactivation with a factor of safety of about 2.

Table 1 – UV sensitivity of viruses for monochromatic (MC) and polychromatic (PC) UV radiation determined with collimated beam tests

	Studies (n)	UV fluence (mJ/cm^2)	UV	k[a] (±95%CI; r^2)	MIC$_{max}$ (log)
Poliovirus type 1	6 (61)[b,c,d,e,f,g]	5–50	MC	0.135 (0.007; 0.79)	5.4
Adenovirus ST2,15, 40, 41	5 (98)[g,h,i,j,k]	8–306	MC	0.024 (0.001; 0.87)	6.4
Adenovirus ST40	1 (29)[i]	8–184	MC	0.018 (0.004; 0.88)	3.0
Adenovirus ST2, 41	1 (18)[k]	30–90	PC	0.040 (0.003; 0.77)	4.3
Rotavirus SA-11	5 (55)[b,d,e,k,l]	5–50	MC	0.102 (0.006; 0.78)	4.1
Rotavirus SA-11	1 (11)[k]	5–30	PC	0.154 (0.011; 0.92)	4.6
Calicivirus feline, canine	3 (29)[i,m,n]	4–49	MC	0.106 (0.010; 0.67)	5.5
Calicivirus bovine	1 (20)[k]	4–33	MC	0.190 (0.008; 0.96)	5.7
Calicivirus bovine	1 (20)[k]	2–15	PC	0.293 (0.010; 0.97)	5.9
Hepatitis A	3 (13)[e,l,o]	5–28	MC	0.181 (0.028; 0.70)	5.4
Coxsackie virus B5	2 (12)[h,l]	5–40	MC	0.119 (0.006; 0.97)	4.8

UV DISINFECTION PERFORMANCE

Table 3 – UV sensitivity of bacteria and bacterial spores for monochromatic (MC) and polychromatic (PC) UV radiation determined with collimated beam tests

	Studies (data)	Fluence (mJ/cm^2)	UV	k (±95%CI; r^2)	Offset[a] (mJ/cm^2)	MIC_{max} (log)
Salmonella typhi	2 (26)[b,c]	2–10	MC	0.515 (0.047; 0.83)	0	5.6
Campylobacter jejuni	2 (27)[c,d]	0.5–6	MC	0.880 (0.124; 0.65)	0	5.3
Yersinia enterocolitica	2 (34)[c,d]	0.6–5	MC	0.889 (0.060; 0.87)	0	5.0
Shigella dysenteriae	1 (9)[c]	1–5	MC	1.308 (0.087; 0.95)	0	5.9
Shigella sonnei	1 (9)[b]	3–8	MC	0.468 (0.053; 0.89)	0	4.7
Vibrio cholerae	1 (10)[c]	0.6–4	MC	1.341 (0.113; 0.94)	0	5.8
Legionella pneumophila	1 (15)[c]	1–12	MC	0.400 (0.040; 0.92)	0	4.4
Legionella pneumophila	1 (4)[e]	0.5–3	MC	1.079 (0.077; 0.99)	0	3.0
Escherichia coli O157	2 (16)[c,f]	1–7	MC	0.642 (0.082; 0.85)	0	5.5
Escherichia coli	6 (41)[b,d,g,h,i,j]	1–15	MC	0.506 (0.049; 0.71)	0	6.0
Escherichia coli	1 (23)[k]	1.5–9	PC	0.539 (0.070; 0.64)	0	5.2
Streptococcus faecalis	2 (19)[b,g]	2.5–16	MC	0.312 (0.032; 0.85)	0	4.6
Bacillus subtilis	4 (30)[b,h,l,m]	5–78	MC	0.059 (0.007; 0.91)	12.3	4.0
Clostridium perfringens	1 (9)[m]	48–64	PC	0.060 (0.027; 0.81)	18	3.0

Table 4 – UV sensitivity of protozoa and *Acanthamoeba* spp. for monochromatic (MC) and polychromatic (PC) UV radiation determined with collimated beam tests

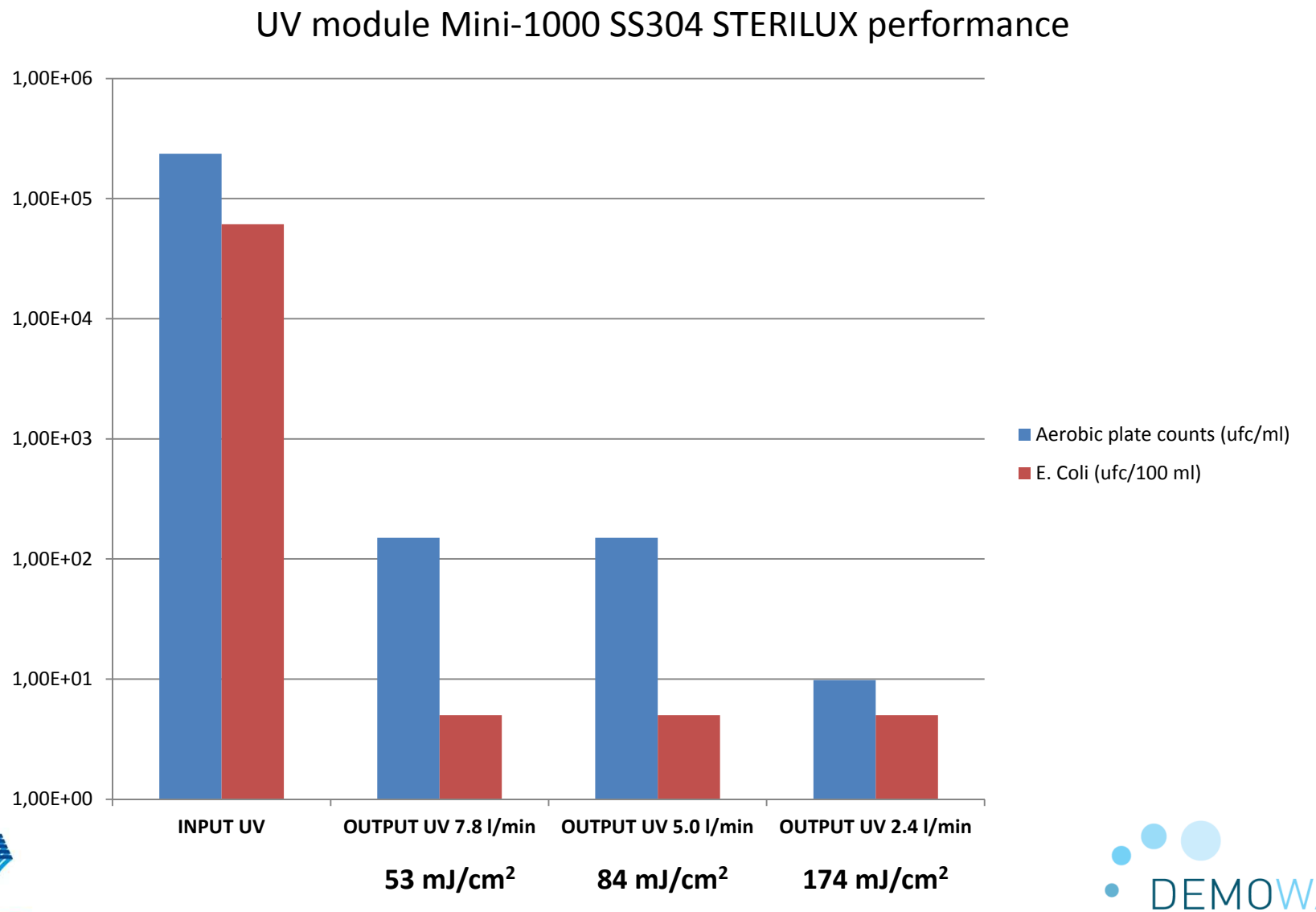
	Studies (data)	k (±95% CI; r^2)	Range (mJ/cm^2)	Intercept (95%)	MIC_{max}
C. parvum	6 (38)[a,b,c,d,e,f]	0.243 (0.08; 0.49)	0.5–6.1; PC	1.502 (0.538)	3.0
C. parvum	4 (65)[a,c,f,g]	0.225 (0.07; 0.37)	0.9–13.1; MC	1.087 (0.403)	3.0
Giardia muris	1 (4)[h]	0.122 (0.178; 0.81)	1.5–11; MC	1.303 (1.280)	2.4
Giardia lamblia	1 (2)[i]	nd	0.05–1.5; MC	nd	2.5
Acanthamoeba spp.	1 (16)[j]	0.021 (0.004; 0.94)	43–172; MC	0.499 (0.449)	4.5

SEVENTH FRAMEWORK PROGRAMME

Source: Hijnen et al., 2006

DEMOWARE

UV DISINFECTION PERFORMANCE



SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

UV DISINFECTION PERFORMANCE

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

DEMONSTRATION STUDY:
TORRE MARIMON SITE

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

EXPERIMENTAL STUDY

HYPOTHESIS: water quality standards proposed by the Australian legislation will be achieved under the proposed treatment scheme and the use of reclaimed water for drinking purposes will not affect animal safety and performance.

OBJECTIVE: to evaluate short-term effects on performance, health, and metabolism of offering reclaimed water to dairy calves from 7 to 70 d of age.

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

MATERIALS and METHODS: in vivo

- ✓ 20 Holstein calves of 7 d of age and 40 kg body weight
- ✓ Feeding program: 6 L/d of milk replacer diluted at 12.5% DM, and concentrate and forage ad libitum from the beginning of the study to 56 d of age. After that, calves will be weaned and fed with concentrate and forage until 70 d of age.
- ✓ 2 treatments:
  - ✓ T0: water for milk replacer + drinking from the public net
  - ✓ T1: water for milk replacer + drinking from the reclamation treatment (UF+UV)

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

MATERIALS and METHODS: in vivo

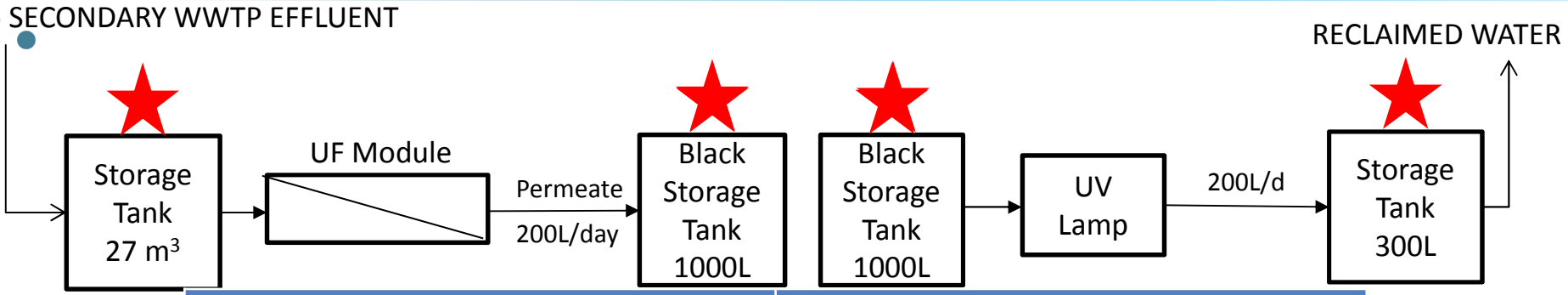
Hazard identification and reference indicators in reclaimed water:

Hazard	Indicator
Protozoa	*Giardia* spp. and *Cryptosporidium*
Bacteria	*E. Coli* *Clostridium perfringens*
Viruses	Viruses (bovine polyomaviruses as indicator of bovine faecal contamination and human adenoviruses as indicator of the disinfection performance)
Helminth	*Taenia* spp. Eggs

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

MONITORING PROGRAM TO ASSESS WATER QUALITY



Parameter	Frequency
E. coli	Bi-weekly
Helminth eggs	Bi-weekly
Suspended solids	Bi-weekly
Turbidity	Bi-weekly
DBO5	Bi-weekly
pH and conductivity	Bi-weekly
Giardia spp. and *Cryptosporidium*	3 times
Clostridium perfringens	3 times
Viruses	3 times
Taenia spp.	3 times
Anions and cations	3 times
Heavy metals	Once
Organic contaminants	Once

SEVENTH FRAMEWORK PROGRAMME

MOWARE

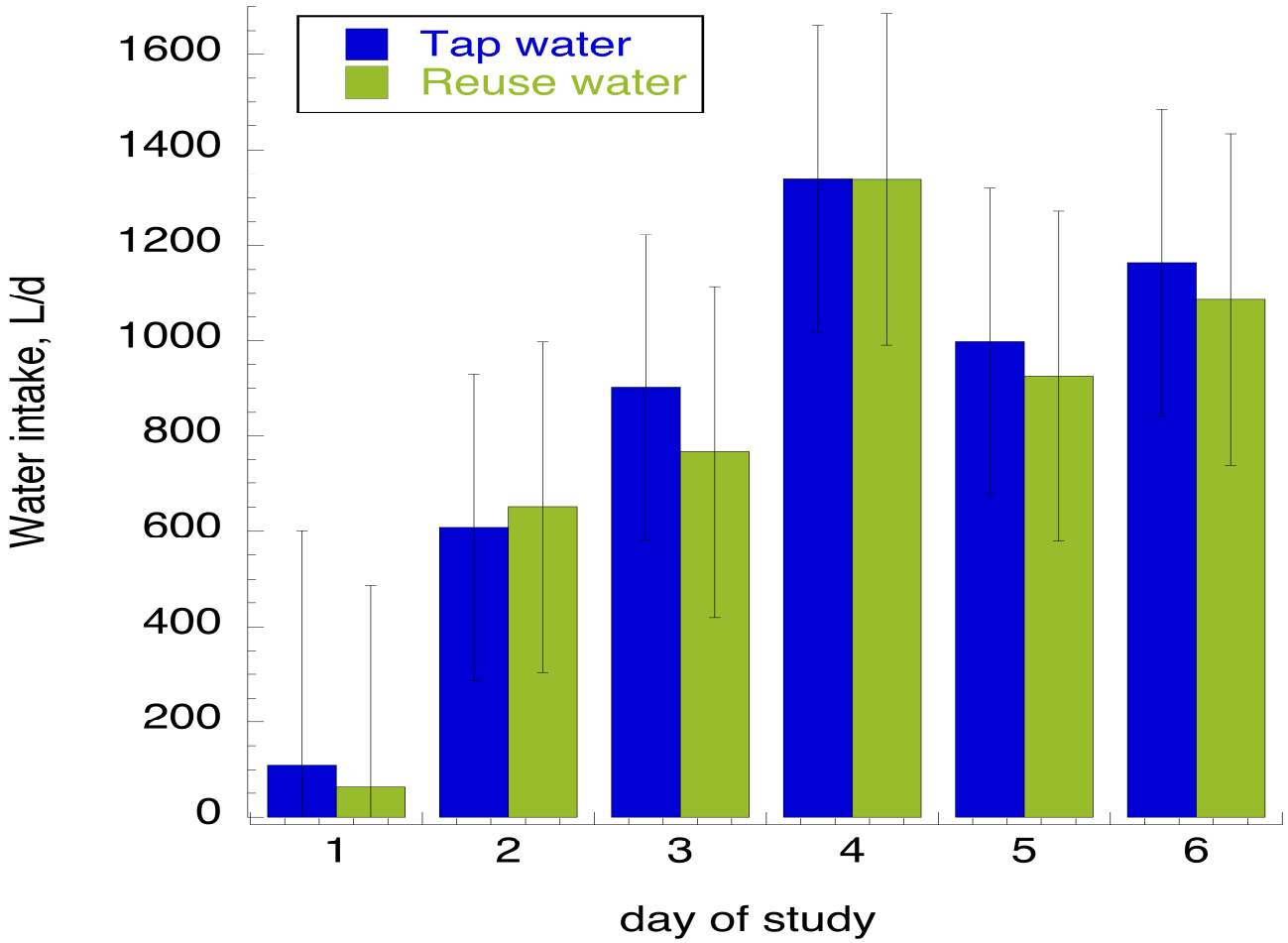
MONITORING PROGRAM TO ASSESS ANIMAL HEALTH AND PERFORMANCE

Parameter	Frequency
Body weight	Weekly
Milk, concentrate, forage and wáter intake	Daily
Veterinary treatments	Record
Faecal consistency	Daily
Biochemical and haematological parameters in blood: glucose, urea, creatinine, hepatic enzymes, NEFA, triglycerides, T3, and hemogram	3 times
Helminthic eggs in faeces	2 times

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

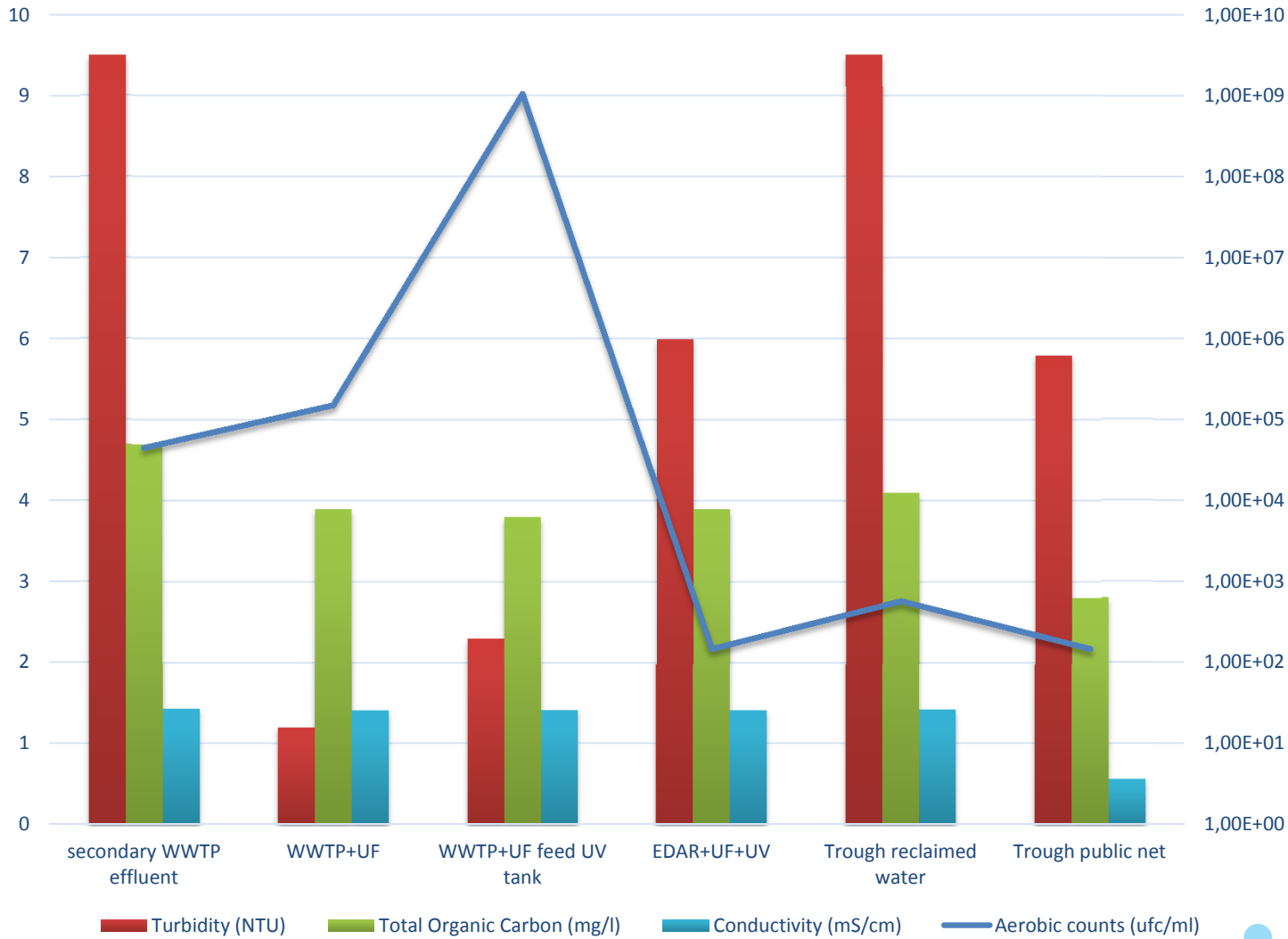
PRELIMINARY RESULTS ON ANIMAL PERFORMANCE



SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

PRELIMINARY RESULTS ON WATER QUALITY



SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

PRELIMINARY RESULTS ON RECLAIMED WATER QUALITY

Parameter	Unit	Average ± stdev (n=2)	Water quality objective
E. coli	ufc/100 ml	absence	<100
Helminth eggs	egg/10L	<1	<1
Suspended solids	mg/l	1.8±0.4	<30
Turbidity	NTU	3.6±3.4	-
pH		8.4±0.1	6-9
Conductivity	mS/cm	1.4±0.0	-
Total dissolved solids	mg/l	865	960
Total Organic Carbon	mg/l	4.9±1.4	<20 mgO_2/ml BOD
Chloride	mg/l	253±14	100
Sulphate	mg/l	61±6	150
Nitrate	mg/l	19±2.1	20
Phosphate	mg/l	5.4±0.1	-
Ca	mg/l	70±1.0	100
Mg	mg/l	19±0.1	50
Na	mg/l	185±1.4	50
K	mg/l	20±0	20

SEVENTH FRAMEWORK PROGRAMME

RE

OTHER FORESEEN DEMONSTRATION STUDIES

- Assessment of reclaimed water for cleaning purposes
- Study on water preferences by the animals

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

CONCLUSIONS

1) The most demanding water use in farming is livestock drinking
2) The proposed strategy for reclamation allows generating water of good quality to ensure livestock health and performance
3) Intermediate tanks should be removed to avoid microbial regrowth
4) There is a need for more research on water quality requirements for livestock drinking purposes and its impact on performance and on their agrofood products
5) An economic evaluation of the feasibility of the implementation of this system in a dairy farm is needed
6) More research about emergent contaminants such as endocrine disruptors, pharmaceuticals, etc. and their potential to bioaccumulate in the animal tissues

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE

Thank you for your attention

carme.bosch@ctm.com.es

marta.terre@irta.cat

SEVENTH FRAMEWORK PROGRAMME

DEMOWARE