UNIVERSITAT DE BARCELONA

HRWM
Health-Related Water Microbiology

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Agència Catalana de l'Aigua

CONSORCI DE LA COSTA BRAVA

aigües de la costa brava

Report:

COMBINED ACTION OF DISINFECTANT AGENTS AT THE BLANES WATER RECLAMATION PLANT

Girona, November 2006

WORKING TEAM

Experiments and drafting the document

The people who have been involved in obtaining results, carrying out experiments and drafting this report are as follows (in alphabetical order):

- Anna Costan, Department of Microbiology, Faculty of Biology, University of Barcelona.
- Estel Dalmau, Empresa Mixta d'Aigües de la Costa Brava, SA.
- Joan Jofre, Department of Microbiology, Faculty of Biology, University of Barcelona
- Francisco Lucena, Department of Microbiology, Faculty of Biology, University of Barcelona.
- Miguel Montemayor, Department of Microbiology, Faculty of Biology, University of Barcelona.
- Rafael Mujeriego, Environmental and Health Engineering Section, Higher College of Civil Engineering, Technical University of Catalonia.
- Andrey Payán, Department of Microbiology, Faculty of Biology, University of Barcelona.
- Lluís Sala, Costa Brava Consortium.
- Montserrat Soler, Empresa Mixta d'Aigües de la Costa Brava, SA.

Revision of the document

The people who have been involved in revising and amending this report are as follows (in alphabetical order):

- Carmelo Llorente and Lluís Leyda, Teqma SL
- Joan Sanz, Veolia Water

BACKGROUND

In the summer of 2005, a study was carried out at the Castell-Platja d'Aro water reclamation plant in order to assess the effects of the combined action of different disinfectant agents – specifically ultraviolet light and hypochlorite – on the microbiological quality of the reclaimed water. This study, which was the result of co-operation between the University of Barcelona: (UB), the Technical University of Catalonia (UPC), the Costa Brava Consortium (CCB) and the company running the Castle-Platja d'Aro water reclamation plant – then SEARSA, now Empresa Mixta d'Aigües de la Costa Brava, SA – was published in July 2006 on the CCB website (Consorci de la Costa Brava, 2006a).

The conclusions of this study showed the advantage for the protection of public health of the combination of these two disinfectant agents, given the different degree of action contributed by each of them against the different groups of microorganisms. So, it was observed that, while hypochlorite acted, above all, to reduce the concentrations of bacteria, ultraviolet light, despite working in relatively unfavourable conditions at the Castell-Platja d'Aro water reclamation plant in summer, was more effective than hypochlorite when it came to reducing the concentrations of viruses and the infectiousness of pathogenic protozoa like *Cryptosporidium* spp. The study ended with the recommendation to expand this type of study on the combined action of disinfectant agents at water reclamation plants with ultraviolet light equipment in more favourable working conditions in order to assess their capacity to inactivate the micro-organisms that had shown greater resistance in the study carried out at Castell-Platja d'Aro.

In view of this, at the beginning of 2006 it was agreed to begin the process of disinfection with ultraviolet light at the Blanes water reclamation plant. This plant, in service since the end of 2002, has, since that date, been producing reclaimed water largely for the purpose of replenishing the aquifer in the lower reaches of the River Tordera, disinfected merely by adding hypochlorite. The need to bring into service disinfection with ultraviolet light has made it necessary to consider the operating system at this facility, given the different possible configurations of this disinfection process. These different configurations are based on the number of ultraviolet light models that can be put into operation (between 1 and 4) and on the variability of the hypochlorite dose to be added to refine the water quality. To date, the effectiveness of the disinfection process of the Blanes water reclamation plant has been assessed through the logarithmic inactivation of concentrations of *Escherichia coli*, although, every month since March 2004, information has been collected about the inactivation of somatic coliphages and sulphite-reducing clostridia.

So, based on both the specific operational and maintenance needs of the Blanes water reclamation plant and on the results obtained in the study of the combined action of disinfectant agents as the Castell-Platja d'Aro water reclamation plant carried out in summer 2005, the CCB and the Microbiology Department of the Faculty of Biology of the UB, in co-operation with the Empresa Mixta d'Aigües de la Costa Brava SA and the Health and Environmental Section of the School of Civil Engineering of the UPC, suggested to the Catalan Water Agency (ACA) that an experiment should be carried out with the aim of determining the most suitable doses of ultraviolet light and hypochlorite to achieve broad disinfection at the Blanes water reclamation plant, minimising both operating costs and the costs of the subsequent monitoring to be carried out.

THE BLANES WATER RECLAMATION PLANT

Description of the elements

The Blanes Water Reclamation Plant was designed for a secondary effluent flow of up to 700 m^3/hour and consists of the following elements:

- Header tank: The secondary effluent outlet pipe to the underwater outflow has an interceptor which makes it possible to divert up to 700 m^3/h towards the water reclamation plant header tank. The volume of the tank is 1,500 m^3, which means the time the secondary effluent stays in the tank is approximately 130 minutes, at design flow.

- Coagulation and flocculation: The secondary effluent is pumped from the header tank to physico-chemical treatment, which begins the process of reclamation and which consists of coagulation and flocculation. The addition of reactants (aluminium polychloride – PAX 18 – as a coagulant and anionic polyelectrolyte as a flocculant) leads to the aggregation of the particles in suspension in the form of flakes which are removed from the system in the subsequent reclamation treatment processes. The high quality of the secondary effluent throughout the year (SPM < 10 mg/l and turbidity < 5 NTU) means it is not usually necessary to add these reactants to achieve the desired quality in reclaimed water (SPM < 10 mg/l and turbidity < 2 NTU, in the 90th percentile of the total data for the year) (Costa Brava Consortium, 2006b). Despite this, the existing installations were designed to add a dose of up to 240 mg/l of coagulant and 230 mg/l of flocculant.

- Lamellar settlement: The effluent from the coagulation and flocculation reactors arrives at the lamellar settlement tanks, where the larger flakes are sedimented out. There are two lamellar settlement tanks available, with a total surface area of 110.2 m^2 (55.1 m^2/unit x 2 units). At design flow (700 m^3/h), the ascension speed is 6.4 m/h.

- Filtering: The settled effluent is then brought to the Hydroclear filters, which show a single filtering matrix of fine grained quartz sand up to 25 cm thick and are of the pulsed bed type. The filtering surface is 82.4 m^2 (20.6 m^2/cell x 4 cells), which gives, at design flow, a theoretical filtering speed of 8.5 m/h. These filters retain the smaller particles which lamellar settlement has not been able to eliminate.

- Disinfection with ultraviolet light: The ultraviolet light modules are located in a closed channel positioned after filtration and they are the main disinfection elements of the water reclamation plant. There are four modules, each with 8 lamps, which can be used independently if necessary according to disinfection requirements. At design flow and with transmittance of 70% at 254 nm, the maximum ultraviolet light dose this facility can provide is 189 mJ/cm^2.

- Refining chlorination and exit tank: Finally, the reclaimed water goes into a storage tank and, on entry, sodium hypochlorite is added to complement the disinfectant action of the ultraviolet light equipment. The internal configuration of this tank, in the form of a labyrinth, means the water circulates inside similarly to the way it would in a piston flow reactor. The volume of the tank is 2,500 m^3, so that, at design flow, it ensures that the water is in contact with the chlorine for 210 minutes.

Operational results (January 2003 – April 2006)

Since the Blanes water reclamation plant came into service, the ACA has commissioned the carrying out of extensive, complete monitoring of the physical, chemical and biological characteristics of the reclaimed water produced in order to document the quality achieved and obtain useful information for the gradual improvement of the water reclamation process.

This information has been compiled and presented in summary form in a report published in May 2006 (Costa Brava Consortium, 2006b).



Figures 1 - 3. Pictures of the water reclamation process at Blanes and the reclaimed water produced: on the left, details of the filters; in the centre, disinfection equipment with ultraviolet light; and, on the right, picture of the point where the reclaimed water comes out in the bank of the Tordera.

The conclusions of this report were as follows:

- The Blanes Water Reclamation Plant is capable of producing reclaimed water which meets the quality objectives set by the ACA for replenishing the aquifer of the lower reaches of the River Tordera most of the time. When the reclaimed water does not meet one of the principal criteria (for example, because of nitrogen concentrations above the 10 mg N/l established) it is discharged into the sea through the existing underwater outfall.

- In the three-year period 2003-2005, 8.59 hm^3 (million cubic metres) were used to replenish the aquifer in the lower reaches of the River Tordera, of a total of 10.13 hm^3 of reclaimed water produced (85% reuse), out of a total of 11.83 hm^3 treated (86% reclamation). The volume of water reused to replenish the aquifer represents 73% of the total water treated.

- Disinfection, carried out only with hypochlorite, makes it possible to comply for most of the time with the requirement to have water with undetectable concentrations of *E. coli* in samples of 100 ml. At the same time, this same level of disinfection causes average inactivation of between 1 and 2 logarithms of sulphite-reducing clostridia spores and somatic coliphages in samples of 100 ml.

- No parasite nematode eggs were detected in samples of 50 litres and the presence of *Salmonella* has been detected in only one of the 100 ml samples taken during this period.

- No *Legionella* serotypes were detected in any of the 26 1-litre samples of secondary effluent analysed or in any of the 26 samples of equal volume of reclaimed water analysed.

- No organochlorate or organophosphate pesticides or aromatic polycyclic hydrocarbons have been detected in the reclaimed water.

- The concentration of trihalomethanes has been below the regulatory limit for drinking water (100 µg/l) in 18 of the 21 samples analysed.

- Of all the halogenated solvents analysed, a maximum of 10 have been detected simultaneously, while 15 of them have never been detected. The levels measured are in the region of µg/l.

- The direct cost of producing and monitoring the reclaimed water is around €0.05/m^3.

The bringing into service of ultraviolet light disinfection equipment at the Blanes water reclamation plant comes in the context of an installation that is already operating. The objective of this action is to achieve a double improvement in water quality, both in microbiological terms by improving the disinfection process and in chemical terms because of the lower risk of formation of trihalomethanes through the reduction in the hypochlorite dose.

Results of the performance tests of the ultraviolet light equipment

On 25 October 2005, the company supplying the ultraviolet light equipment, Teqma SL, carried out performance tests in order to determine the level of disinfection achieved by the equipment installed in various operation conditions of the system (flow, modules in operation and levels of power). The results of these tests served for the experimental design of this study (Table 1) (Teqma SL, 2005).

Table 1. Results of the initial performance tests of the ultraviolet light disinfection equipment at the Blanes water reclamation plant carried out by Teqma SL. Analysis carried out at Laboratoris Altimir, Blanes.

UV dose mJ/cm^2	Range of concentrations cfu/100 ml			Range of logarithmic reductions log.u.		
	E. coli	Clostridia spores	Somatic bacteriophages	*E. coli*	Clostridia spores	Somatic bacteriophages
0	75,000	6,100	27,000	-	-	-
30 – 60	1 - 32	570 - 620	1 - 16	3.4 – 4.8	0.99 – 1.03	3.2 – 4.4
60 – 90	0 - 18	28 - 810	1 - 16	3.6 – 4.8	0.88 – 2.34	3.2 – 4.4
> 90	2 - 32	70 - 210	1 - 30	3.4 – 4.6	1.46 – 1.94	3.0 – 4.4

Table 1 shows that relatively low doses of ultraviolet light (between 30 and 60 mJ/cm^2) allow the achievement of reductions of *E. coli* and somatic coliphages to almost zero. This allows the assumption that the equipment installed can normally work quite easily, given the power installed and the reclaimed water quality produced by the Blanes water reclamation plant. At the same time, this data points to the possibility that its operation at full power could be an unnecessary use of energy, as the desired disinfection levels are achieved at intermediate levels of operation of the equipment.

So, as mentioned in the Background section, knowledge of these empirical results and the need to bring into service disinfection with ultraviolet light have led to this study being carried out, with the idea of finding an operating system that maximises the effectiveness of disinfection and minimises energy and reactant consumption.

OBJECTIVES

The general objective of this study is to experimentally determine the doses of disinfectant agents to be applied to the water produced by the Blanes reclamation plant in order to achieve broad spectrum disinfection against bacteria, viruses and protozoa while minimising the operating costs of the disinfection system and the subsequent monitoring of its quality.

The specific objectives of the study are:

- To try different combinations of disinfectant agents and measure their effects on the different groups of bacteria, viruses and pathogenic protozoa (*Cryptosporidium* spp.) chosen for the experiment in controlled conditions.

- To determine the optimum working conditions for the disinfection process of the Blanes water reclamation plant in order to ensure compliance with the microbiological water

quality requirements intended to replenish the aquifer in the lower reaches of the River Tordera.

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

MATERIAL AND METHODS

Reclamation treatment

The tests on the combined action of the ultraviolet light and hypochlorite were carried out between 8 and 31 May 2006 at the Blanes water reclamation plant. During this period, the flow treated was a constant 600 m^3/h, except for 10:00 am on 10 May, when it fell to 200 m^3/hour because of a temporary pumping breakdown at the reclamation treatment intake. The samples at 11:30 am that day were taken with the flow once again at 600 m^3/h.

The treatment applied to the secondary effluent during the study consisted of:

1. Lamellar settlement: Given the high quality of the secondary effluent, during the test period no reactant was added and the effluent went straight into the lamellar settlement tanks. The flow was divided between the two units, so the average ascension speed was 5.4 m/h.

2. Filtering: The settled effluent was divided between the four available cells, with an average filtering speed during this time of 7.3 m/h

3. Disinfection: The working conditions were variable, depending on the proposed experimental design, as the object of this study was to assess the different possibilities of combining the available disinfectant agents (ultraviolet light and hypochlorite). The details of the test conditions are described later.

Determination of the reclaimed water quality

Physico-chemical quality

Table 2 shows the different physico-chemical parameters analysed in the samples collected throughout the study, both of secondary effluent and reclaimed water. These were determined immediately after the collection of samples to ensure that the results were as representative as possible.

Table 2. Description and analysis methods of the physico-chemical parameters determined in samples of water obtained at the Blanes water reclamation plant.

Physico-chemical parameters	Analysis methods
SPM (mg/l)	Standard Methods, 2540-D
Turbidity (NTU)	Nephelometry
Transmittance at 254 nm (%)	Spectrophotometry
Total residual chlorine	Colorimetry kit

Microbiological quality

Microorganisms used in the study

The different nature of the biocide agents means that each acts in a different way – physically in the case of ultraviolet light and chemically in the case of chlorination. This study has used different types of microorganisms to assess the effectiveness of the treatments applied.

The microorganisms analysed were as follows:

- Indicator bacteria
  - *E. coli*
  - Sulphite-reducing clostridia spores
- Bacteriophages
  - Somatic coliphages
- Protozoa
  - *Cryptosporidium*, (total, viable and infectious oocysts)
- Enteroviruses
  - Infectious enteroviruses along the BGM cellular lines

Concentration and counting techniques

Bacteria

- *E. coli*: The selective cultivation medium chosen for cultivating *E. coli* was Chromocult Agar (Merck, Darmastadt, Germany). The detection technique was membrane filtration and incubation in the selective medium at 37 ºC for 24 hours. For taking the reading, only the dark blue colonies which, according to the manufacturer, correspond to *E. coli*, were taken into account.
- Sulphite-reducing clostridia spores: These were counted through mass seeding in the selective medium SPS.

Bacteriophages

- Somatic coliphages: Concentration through filtration following Méndez et al. 2004 and counting according to ISO 10705-2 (Anon., 2000).

Protozoa

- *Cryptosporidium* spp.
  - Concentration of samples following the protocol described in Method 1623 (US EPA, 1999).
  - Detection of oocysts using solid phase cytometry Montemayor et al. (2005).
  - Viability studies following the vital colorant inclusion-exclusion technique described by Campbell et al. (1992).
  - *Cryptosporidium* oocyst infectivity studies on competent HCT-8 cells and detection by indirect immunological techniques (Slifko et al., 1997).

Enteroviruses

- For counting enteroviruses in the secondary effluent samples
  - Decontamination of the samples using GP-type 0.22 μm filters (Mocé-Llivina, 2003).
  - Counting the enteroviruses along BGM cellular lines present in the concentrates. Double-layer plaque assay (Mocé-Llivina, 2004).
- For counting enteroviruses in the tertiary effluent samples
  - Concentration of the enteroviruses present in electropositive Zeta Plus filters and elution of the enteroviruses absorbed by the filter following the protocol described by the US EPA (1996).

- Application of the organic flocculation secondary concentration method (Katzenelson, 1976).
- Decontamination of the concentrates obtained in the secondary concentration process using GP-type 0.22 μm filters (Mocé-Llivina, 2003).
- Counting the enteroviruses along BGM cellular lines present in the concentrates. Double-layer plaque assay (Mocé-Llivina, 2004).

Nomenclature

- EC: *E. coli*, CFU/100 ml
- CSR: sulphite-reducing clostridia spores, CFU/100 ml
- SOM: somatic coliphages, pfu/100 ml
- CRYOT: total *Cryptosporidium* oocysts spp/litre
- CRYOV: viable *Cryptosporidium* oocysts spp/litre
- CRYOI: infectious *Cryptosporidium* oocysts spp/litre
- ENT: enteroviruses, PFU/litre
- FIL: filtered secondary effluent
- 1UV: filtered water disinfected with one ultraviolet light module
- 2UV: filtered water disinfected with two ultraviolet light modules
- 1CL: filtered water disinfected with the addition of 1 mg Cl_2/l
- 2CL: filtered water disinfected with the addition of 2 mg Cl_2/l
- 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
- UVCL: filtered water disinfected with combined ultraviolet light treatment and the addition of hypochlorite

Examples:

- FILSOM: Values for somatic coliphages in PFU/100 ml of filtered secondary effluent.
- 1UV2CLSOM: Values for somatic coliphages in PFU/100 ml of filtered water disinfected with one ultraviolet light module and 2 mg Cl_2/l dose of hypochlorite.
- 0.6CLSOM: Values for somatic coliphages in PFU/100 ml, in filtered water disinfected with a dose of hypochlorite to achieve constant total residual chlorine of 0.6 mg Cl_2/l.

Taking samples

The samples were collected in sterile bottles and kept cold until being analysed at the UB laboratory. The analysis of *E. coli*, of sulphite-reducing clostridia spores and somatic coliphages was carried out during the 12h following their collection, according to the methodology described above.

The *Cryptosporidium* samples were concentrated *in situ* by filtering in Envirocheck (US EPA,1999), capsules at a rate of 2 litres/minute. For the samples of filtered water, volumes of 20 litres were analysed, while for the samples of disinfected reclaimed water, either with ultraviolet light or chlorine, volumes of 50 to 80 litres were analysed, depending on their quality.

The enterovirus samples were concentrated *in situ* by filtering in electropositive MK filters (Cuno, Meriden) at a rate of 1.4 litres/minute. The volume filtered was 100 litres for each and every sample, both those with filtered water and those with disinfected reclaimed water,

whether ultraviolet light or chlorine had been used.

Experimental design

Factors conditioning the study

Given the great variety of possible conditions and considering both the results of the performance tests and those in routine operation carried out to date, the experiments were designed choosing the conditions that were most likely to be applied in subsequent routine operation.

Combinations of disinfectants tested

The combinations tested, for which samples have been taken, are:

- Filtered water (conditions prior to disinfection).
- 1 UV module + addition of 1 mg Cl_2/l of hypochlorite.
- 1 UV module + addition of 2 mg Cl_2/l of hypochlorite.
- 2 UV modules + addition of 1 mg Cl_2/l of hypochlorite.
- Addition of hypochlorite in doses of around 3 mg Cl_2/l to achieve total residual chlorine of 0.6 mg Cl_2/l. This dosing has been automatically regulated using a probe for the continuous measurement of total residual chlorine and it is the dose used to date for disinfecting the reclaimed water.

Based on the results presented in Table 1 corresponding to the performance tests for the disinfection process, the possibility of doing tests with three and four ultraviolet light modules operating has been ruled out, as these are working conditions that are currently unnecessary.

Appendix I includes details of the working conditions for water reclamation treatment during the experiment period, as well as the quality parameters for each of the samples taken.

Micro-organisms analysed

- *E. coli.*
- Sulphite-reducing clostridia spores.
- Somatic coliphages.
- Enteroviruses.
- *Cryptosporidium* spp.: total, viable and infectious oocysts.

Collection of samples and sampling frequency

The structure of the experiment was to test one of the chosen treatments each week, for a total of four weeks. The operational criterion was to collect a sufficient number of samples in each of them so as to be able to obtain results with statistical significance.

The specific operating conditions to be tested were established on the Thursday of the previous week and the sampling process was carried out for three consecutive days of the week in question – specifically Monday, Tuesday and Wednesday. The only exception was in the third week, when the third sample was taken on Thursday, while the new conditions were established the same day, once the sample had been taken. This procedure was chosen in order to ensure the stabilisation of the process, so that the results obtained were truly representative of the chosen conditions. At the same time, the ultraviolet light modules put

into operation were alternated, so that the hours of operation of the lamps were shared and performance of each of them was as equal as possible.

On each sampling day, a sample of filtered water representative of the starting conditions was collected, together with three of reclaimed water obtained from the treatment being tested. As can be seen in Appendix I, a total of 21 samples were generated for each type of test, except in that for disinfection with hypochlorite, in which 18 samples were generated. Because of the complexity of the enterovirus and *Cryptosporidium* analysis, a total of only 12 samples were taken.

Logistics

Week 1

Working conditions: 1 UV module + 1 mg Cl_2/l (start conditions: Thursday of the previous week). Samples at 10:00 and 11.30 am and 1:00 pm.

Monday, Tuesday and Wednesday
10:00 am – Collection of samples of filtered water (fil), after UV (a1UV) and final water (UV + chlorine, a1UV1CL).
11:30 am – Collection of samples after UV (b1UV) and final water (UV + chlorine, b1UV1CL).
1:00 pm – Collection of samples after UV (c1UV) and final water (UV + chlorine, c1UV1CL)

Week 2

Working conditions: 1 UV module + 2 mg Cl_2/l (start conditions: Thursday of the previous week). Samples at 10:00 and 11:30 am and 1:00 pm.

Monday, Tuesday and Wednesday
10:00 am – Collection of samples of filtered water (fil), after UV (a1UV) and final water (UV + chlorine, a1UV1CL).
11:30 am – Collection of samples after UV (b1UV) and final water (UV + chlorine, b1UV2CL).
1:00 pm – Collection of samples after UV (c1UV) and final water (UV + chlorine, c1UV1CL).

Week 3

Working conditions: 2 UV module + 1 mg Cl_2/l (start conditions: Thursday of the previous week). Samples at 10:00 and 11:30 am and 1:00 pm.

Monday, Tuesday and Thursday
10:00 am – Collection of samples of filtered water (fil), after UV (a1UV) and final water (UV + chlorine, a1UV1CL).
11:30 am – Collection of samples after UV (b2UV) and final water (UV + chlorine, b2UV1CL).
1:00 pm – Collection of samples after UV (c1UV) and final water (UV + chlorine, c1UV1CL).

Week 4

Working conditions: Addition of 3 mg Cl_2/l to achieve 0.6 mg total residual Cl_2/l, monitored with continuous probe and with auto-control link (start conditions: Thursday of the previous week). Samples at 10:00 and 11:00 30am and 1:00 pm.

Monday, Tuesday and Wednesday
10:00 am - Collection of samples of filtered water (fil) and final water (chlorinated, a0,6CL).
11:30 am – Collection of samples of final water (chlorinated, b0,6CL).
1:00 pm – Collection of samples of final water (chlorinated, c0,6CL).

RESULTS AND DISCUSSION

Physico-chemical analysis

The requirement for physico-chemical quality in the water produced by the Blanes reclamation plant is very STRICT and its tolerance margins relatively tight, as it is used for replenishing the aquifer in the lower reaches of the River Tordera.

Table 3. Summary of the physico-chemical quality of the reclaimed water in the different stages of the Blanes water reclamation plan during the study period. The results correspond to the mean and standard deviation for each parameter and each type of water.

Parameters	Types of			
	Filtered water	UV	UV+Chlorine	Chl
Period	8-10 May 2006 / 1 module UV + 1 mg Cl_2/l			
Number of samples	3	9	9	-
SPM, mg/l	2.5 ± 0.6	1.5 ± 0.9	2.8 ± 3.7	-
Turbidity, NTU	2.0 ± 1.1	2.2 ± 1.9	1.8 ± 0.6	-
Transmittance at 254 nm, %	71 ± 1	72 ± 2	68 ± 8	-
UV dose, mJ/cm^2 (a)	-	49 ± 26	49 ± 26	-
Total residual chlorine, mg Cl_2/l	-	-	0.2 ± 0.1	-
C·t., mg Cl_2·min/l	-	-	42 ± 18	-
Period	15-17 May 2006 / 1 UV module + 2 mg Cl_2/l			
Number of samples	3	9	9	-
SPM, mg/l	1.7 ± 0.3	2.6 ± 1.4	2.7 ± 1.5	-
Turbidity, NTU	1.3 ± 0.4	1.4 ± 0.4	2.0 ± 1.7	-
Transmittance at 254 nm, %	71 ± 1	71 ± 1	70 ± 3	-
UV dose, mJ/cm^2	-	39 ± 1	39 ± 1	-
Total residual chlorine, mg Cl_2/l	-	-	0.4 ± 0.1	-
C·t, mg Cl_2·min/l	-	-	100 ± 25	-
Period	22-24 May 2006 / 2 UV modules + 1 mg Cl_2/l			
Number of samples	3	9	9	-
SPM, mg/l	2.2 ± 0.7	1.4 ± 0.9	2.5 ± 1.8	-
Turbidity, NTU	1.4 ± 0.1	2.0 ± 1.1	2.8 ± 1.2	-
Transmittance at 254 nm, %	71 ± 1	70 ± 1	69 ± 3	-
UV dose, mJ/cm^2	-	78 ± 1	78 ± 1	-
Total residual chlorine, mg Cl_2/l	-	-	0.3 ± 0.1	-
C·t, mg Cl_2·min/l	-	-	67 ± 13	-
Period	29-31 May 2006 / approx. 3 mg Cl_2/l (0.6 mg Cl_2/l residual)			
Number of samples	9	-	-	9
SPM, mg/l	1.9 ± 0.5	-	-	2.2 ± 0.5
Turbidity, NTU	2.0 ± 0.4	-	-	1.9 ± 0.7
Transmittance at 254 nm, %	71 ± 3	-	-	72 ± 3
UV dose, mJ/cm^2	-	-	-	-
Total residual chlorine, mg Cl_2/l	-	-	-	0.6 ± 0.2
C·t, mg Cl_2·min/l	-	-	-	153 ± 42

(a) The dose of ultraviolet light this week was more variable because of the lower flow of reclaimed water at the time one of the samples was collected.

As can be seen in Table 3, this quality was particularly notable and sustained throughout the 4 weeks the monitoring lasted, with average SPM ranging between 1.4 and 2.8 mg/l. Meanwhile, turbidity averages ranged between 1.3 and 2.8 NTU and transmittance between 68 and 72%. It must be stated, however, that greater variability is almost always detected in the data from the samples taken at the outlet from the reclaimed water tank ("UV+Chlor" in the first three weeks and "Chlor" in the last) than in the samples from places where there is

no water storage ("Filtered water" and "UV"). A hypothesis that could explain these slight increases would be the influence of solids which, despite periodic cleaning, build up as sediment on the bottom of the tank and which can return a certain quantity of SPM or cause turbidity of the water.

Table 4 shows the data collected in May for the other physico-chemical parameters defining the quality of the water produced, such as the pH, electrical conductivity (EC) and the different chemical varieties of nitrogen and phosphorus. All of them show outstanding stability. The comparative analysis of the median values (50th percentile) and those for the 90th percentile show there is a difference of only 0.1 pH units, 0.07 dS/m of EC, 2.8 mg N/l of total nitrogen and 0.4 mg P/l of total phosphorus. It is important to note that the 90th percentile of total nitrogen concentration is 9.2 mg N/l, with clear predominance of nitrate as the dominant chemical type (7.2 mg N/l), and for total phosphorus concentration the figure is 2.4mg P/l. These values are all very low for reclaimed water according to current standards in Catalonia.

Table 4. Statistical summary of various physico-chemical parameters measured in the water produced by the Blanes water reclamation plant during May 2006.

Parameter	pH	EC dS/m	NTK mg N/l	NH4-N mg N/l	NO2-N mg/l	NO3-N mg/l	Total N mg N/l	Total Phosphorus mg P./l
Number samples	29	25	16	16	16	16	16	16
Minimum	7.5	1.18	0.2	0.2	0.1	0.5	2.6	0.8
Mean	7.6	1.32	1.2	0.6	02	4.9	6.4	1.9
Median	7.6	1.33	1.1	0.3	0.2	5.4	6.8	2.0
90th Percentile	7.7	1.40	2.0	1.3	0.3	7.2	9.2	2.4
Maximum	7.8	1.47	4.0	3.9	0.4	7.9	11.1	2.6

Microbiological analysis

Each parameter studied and the water resulting from the different treatments applied is assigned an acronym in order to facilitate the understanding of the tables and the figures. For most of the micro-organisms, there is a significant number of samples based on which the statistical parameters can be calculated and fairly solid conclusions can be drawn (12 samples to document secondary effluent quality, more stable, and between 9 and 18 to document the variations introduced by the different disinfectant agents); by contrast, for the analysis of the different states of *Cryptosporidium* spp. oocysts and enteroviruses, it has been possible to process only 4 samples corresponding to secondary effluent and 7 to evaluate the effects of the disinfection treatments: (Table 5). This fact means the assessments that can be made of the effect of *Cryptosporidium* spp. and the concentrations of enteroviruses are less meaningful than the other parameters.

The differences in concentrations of the different micro-organisms studied have made it necessary to mention the results obtained in the cases of those found in higher concentrations (*E. coli*, sulphite-reducing clostridia spores and somatic coliphages) separately. This makes it possible to better evaluate the effect of the disinfectant agents than those showing lower concentrations (*Cryptosporidium* spp. oocysts and enteroviruses).

E. coli, sulphite-reducing clostridia spores and somatic coliphages

The results corresponding to the concentrations of *E. coli*, sulphite-reducing clostridia spores and somatic coliphages have been expressed with their logarithmic value. Table 5 summarises the results obtained throughout the experiment for each type of water, while Table 6 shows the parameters of the descriptive statistic for each type of microorganism considering all the results obtained. The individual results of the analysis carried out are collected in Appendix II.

Table 5. Descriptive statistical values (minimum, maximum, standard deviation and mean, in logarithmic units) of the parameters studied depending on the type of water for all samples taken between 8 and 31 May 2006 at the Blanes water reclamation plant.

Sample	N	Minimum	Maximum	Mean	Standard deviation
FILEC	12	3.78	4.46	**4.18**	0.19
FILCSR	12	3.00	3.60	**3.30**	0.20
FILSOM	11	4.02	4.61	**4.26**	0.17
1UVEC	18	<1.00	3.90	**< 1.40**	1.03
1UVCSR	18	1.78	3.18	**2.56**	0.39
1UVSOM	18	0.00	3.53	**< 0.89**	0.75
2UVEC	9	< 1.00	1.60	**< 1.10**	0.65
2UVCSR	9	1.48	2.08	**1.80**	0.19
2UVSOM	9	0.45	1.17	**0.85**	0.27
1UV1CLEC	9	< 1.00	1.00	**< 1.00**	0.50
1UV1CLCSR	9	1.95	3.08	**2.59**	0.37
1UV1CLSOM	9	0.00	0.70	**0.32**	0.28
1UV2CLEC	9	< 1.00	< 1.00	**< 1.00**	0.00
1UV2CLCSR	9	1.60	2.90	**2.43**	0.45
1UV2CLSOM	9	-0.40	0.92	**-0.18**	0.43
2UV1CLEC	9	< 1.00	< 1.00	**< 1.00**	0.00
2UV1CLCSR	9	1.70	2.04	**1.89**	0.12
2UV1CLSOM	9	0.00	0.51	**0.22**	0.17
0,6CLEC	9	< 1.00	1.30	**< 1.10**	0.63
0,6CLCSR	9	2.60	3.38	**2.95**	0.22
0,6CLSOM	9	1.26	3.85	**2.24**	1.13

The concentrations of microbes corresponding to conditions prior to disinfection are slightly lower than those normal in a conventional activated sludge WWTP, as in this case the water is not taken directly from the settlement tank but is subjected to an additional filtering process. The geometric means obtained in this study are close to 4 log.u. in the case of *E. coli*, 3 log.u. for sulphite-reducing clostridia spores and 4 log.u. for somatic coliphages (Figure 4a). As happened in the case of physico-chemical analyses, the low values of the standard deviations indicate notable stability of the concentrations of these microorganisms during the study period.

Table 7, Figures 4a-4f and Figure 5 show the logarithmic reductions achieved by the treatments tested for the different microorganisms, while Appendix III includes the probability graphs for this data. The results for the different measured parameters adequately match a normal distribution, and the relative gradients therefore clearly show the different behaviour of the microorganisms in the face of the treatments applied. These graphic representations are a different way of presenting the same results as those given below.

Table 6. Descriptive statistics (mean, standard deviation, variance, minimum, maximum and 25th, 50th, 75th, 90th and 95th percentiles, in logarithmic units) of the parameters studied, considering all samples from all treatments evaluated.

Parameters	Type of microorganism, log.u.		
	E. coli	Sulphite-reducing clostridia spores	Somatic coliphages
Valid samples	63	63	63
Lost samples	0	0	0

Mean	0.52	2.39	0.75
Standard deviation	0.76	0.49	0.94
Variance	0.58	0.24	0.88
Minimum	0.00	1.48	- 0.40
Maximum	3.90	3.38	3.85
25th percentile	0.00	1.95	0.11
50th percentile	0.00	2.48	0.64
75th percentile	1.00	2.85	1.06
90th Percentile	1.48	2.99	1.60
95th percentile	1.57	3.13	3.59

Table 7. Average inactivations, in log.u., of the concentrations of *E. coli*, sulphite-reducing spores and somatic coliphages according to the treatments evaluated in this study.

Treatment means, log.u.	Micro-organism	Inactivation
Disinfection with 1 UV module	EC	≥ 2.78
	CSR	0.74
	SOM	≥ 3.37
Disinfection with 2 UV modules	EC	≥ 3.08
	CSR	1.49
	SOM	3.41
Combination 1 UV module + 1mg Cl_2/l of hypochlorite	EC	≥ 3.18
	CSR	0.71
	SOM	≥ 3.94
Combination 1 UV module + 2mg Cl_2/l of hypochlorite	EC	≥ 3.18
	CSR	0.86
	SOM	≥ 4.44
Combination 2 UV modules + 1mg Cl_2/l of hypochlorite	EC	≥ 3.18
	CSR	1.41
	SOM	≥ 4.04
Disinfection with 3 mg Cl_2/l of hypochlorite (0.6 mg Cl_2/l total residual chlorine)	EC	≥ 3.08
	CSR	0.35
	SOM	2.02

The treatments used inactivate almost all the concentrations of *E. coli* present in filtered water, with logarithmic reductions of around 3 log.u. The stability of these inactivations is the result both of the initial concentrations (of just over 4 log.u.) and that in the reclaimed water, in which the absence is represented by the value <10 cfu/100 ml (Figure 4b). No colonies of *E. coli* have been isolated in any of the water samples collected in the treatment consisting of one module of ultraviolet light with the addition of 2 mg Cl_2/l, nor in that consisting of two modules of ultraviolet light and the addition of 1 mg Cl_2/l. These results indicate that the reclaimed water produced under these conditions is fit for any of the uses established both in the guidelines of the Catalan Water Agency and in the regulations soon due to come into force in Spain on the reuse of water. In addition, all the treatments tested in this study produce reclaimed water with concentrations of *E. coli* lower than 200 cfu/100 ml, the limit established in proposed regulations for watering without restrictions either for agricultural or gardening purposes or on golf courses.

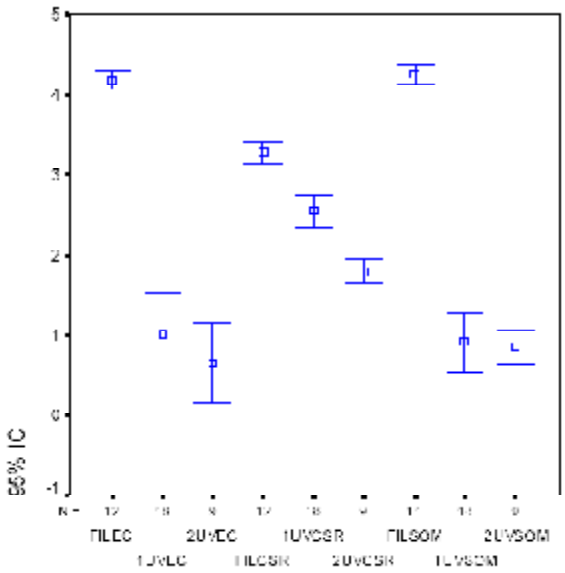


Figure 4a. Mean values and 95% confidence intervals for concentrations of *E. coli*, sulphite-reducing clostridia spores and somatic coliphages (cfu and pfu per 100 ml, in logarithmic units) analysed in the different types of water (filtered water and water treated with one and two disinfection modules with ultraviolet light).

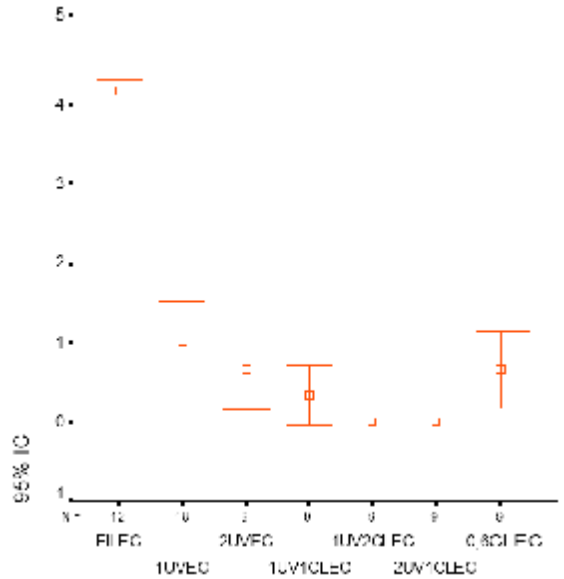


Figure 4b. Mean values and 95% confidence intervals for concentrations of *E. coli* (cfu per 100 ml in logarithmic units) analysed in the different types of water (filtered water, water disinfected with ultraviolet light, water disinfected with hypochlorite and water disinfected with different combinations).

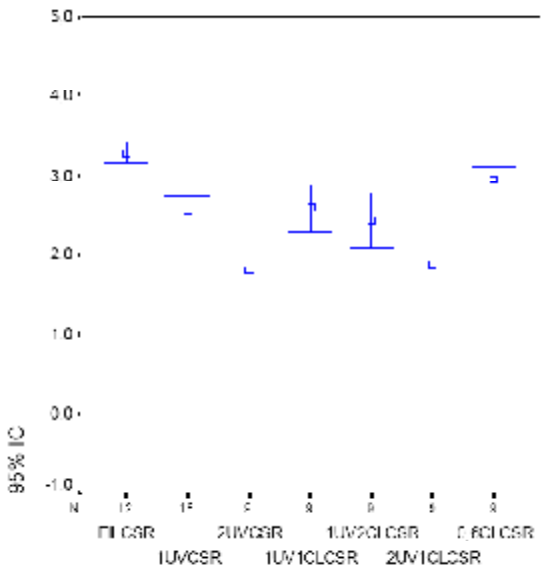


Figure 4c. Mean values and 95% confidence intervals for concentrations of sulphite-reducing clostridia spores (cfu per 100 ml in logarithmic units) analysed in the different types of water (filtered water, water disinfected with ultraviolet light, water disinfected with hypochlorite and water disinfected with different combinations).

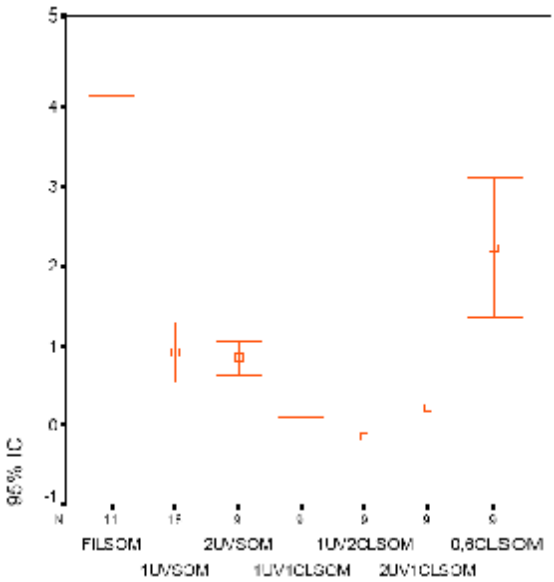


Figure 4d. Mean values and 95% confidence intervals for concentrations of somatic coliphages (cfu per 100 ml in logarithmic units) analysed in the different types of water (filtered water, water disinfected with ultraviolet light, water disinfected with hypochlorite and water disinfected with different combinations).

Figure 4c shows that, by contrast, the sulphite-reducing clostridia spores show high resistance to the different disinfection treatments. The minimum reduction has been achieved with the use of chlorine alone (0.35 log.u.), while the maximum reduction has been produced when disinfection has been carried out with two modules of ultraviolet light (between 1.4 and 1.5 log.u.), regardless of the subsequent use of hypochlorite. Treatments with a single module of ultraviolet light have achieved a medium-level logarithmic reduction of between 0.7 and 0.9 log.u.

Figure 4d shows that somatic coliphages show most clearly the favourable effect of the combination of disinfectants. While the minimum reduction is once again achieved with chlorine used alone (2.0 log.u.), the use of ultraviolet light manages to achieve the elimination of around 3.4 log.u., with practically unnoticeable changes when two modules are used

instead of one. The combination of the two disinfectant agents caused a minimum reduction of 3.9 log.u. (in the case of one ultraviolet light module and a contribution of 1 mg Cl_2/l) and a maximum reduction of more than 4.4 log.u. (in the case of one ultraviolet light module and the addition of 2 mg Cl_2/l). The use of two ultraviolet light modules and the addition of 1 mg Cl_2/l achieved a reduction of more than 4.0 log.u., which puts it between the two previous ones.

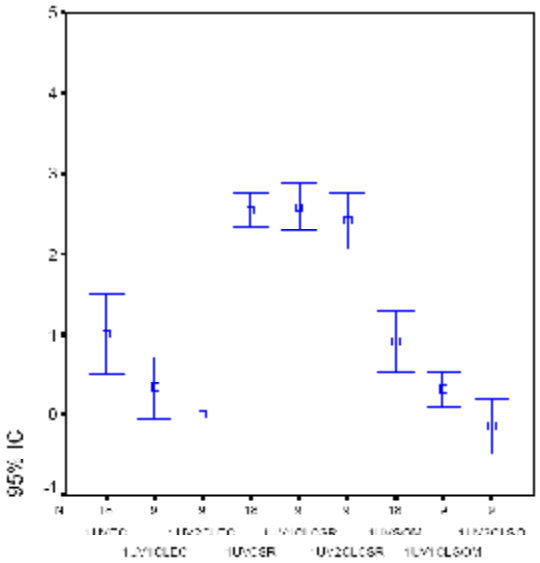


Figure 4e. Mean values and 95% confidence intervals for concentrations of *E. coli*, sulphite-reducing clostridia spores and somatic coliphages (CFU and PFU per 100 ml, in logarithmic units) analysed in the different types of water (water treated with one disinfection module with ultraviolet light, one module and the addition of 1 mg Cl_2/l of hypochlorite, and one module and the addition of 2 mg Cl_2/l hypochlorite).

From the strictly microbiological point of view and given both the individual logarithmic reductions for each of the micro-organisms and the overall inactivations, the most appropriate combination of disinfectant agents is that made up of 2 modules of ultraviolet light (dose of around 80 mJ/cm^2) and the addition of 1mg Cl_2/l in hypochlorite form. This conclusion is based on the total inactivation achieved for *E. coli*, on the greater reduction caused in the concentrations of sulphite-reducing clostridia spores with respect to other treatments and on the high level of reduction achieved in concentrations of somatic coliphages.

Table 8 shows that the disinfectant agents introduce significant modifications in abundance of the different microorganisms compared with the typical proportions shown in secondary effluents before the disinfection process. This effect has already been shown in previous studies of the disinfection of reclaimed water (Costa Brava Consortium, 2006a). While there is a greater abundance of somatic coliphages in the secondary effluent, followed by *E. coli* and sulphite-reducing clostridia spores, the latter come to be the most abundant in all the treatments evaluated because they show greater resistance to disinfection. The second most abundant are the somatic coliphages, which, although present in very low concentrations, are detected more frequently than *E. coli*. Finally, *E. coli* is absent in 62% of the samples analysed for all the disinfection treatments tested in this study.

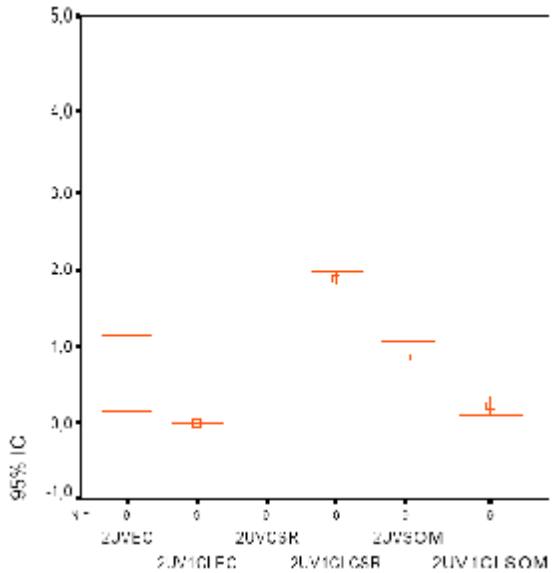


Figure 4f. Mean values and 95% confidence intervals for concentrations of *E. coli*, sulphite-reducing clostridia spores and somatic coliphages (cfu and pfu per 100 ml, in logarithmic units) analysed in the different types of water (water treated with two disinfection modules with ultraviolet light and with two modules and the addition of 1 mg Cl_2/l of hypochlorite).

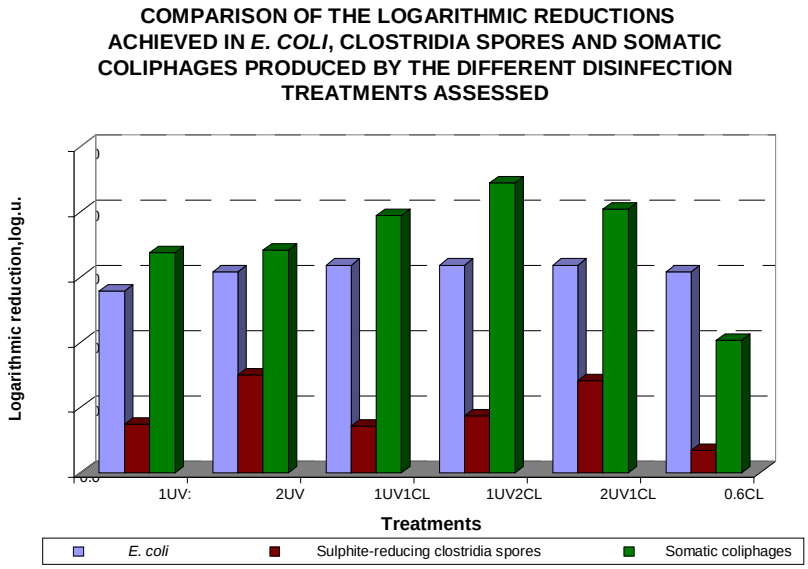


Figure 5. Logarithmic reductions in *E. coli*, sulphite-reducing clostridia spores and somatic coliphages for the disinfection treatments evaluated in the study.

Table 8. Relative abundances of *E. coli*, of sulphite-reducing clostridia spores and somatic coliphages after the different disinfection processes tested at the Blanes water reclamation plant.

Types of treatment	Concentrations, from larger to smaller
Filtered secondary effluent (before treatments)	SOM > EC > CSR
Disinfection with 1 UV module	CSR > EC > SOM (a)
Disinfection with 2 UV modules	CSR > SOM > EC (b)
Combination of 1 UV module + 1 mg Cl_2/l of hypochlorite	CSR > SOM > EC (b)
Combination of 1 UV module + 2 mg Cl_2/l of hypochlorite	CSR > SOM > EC (b)
Combination of 2 UV modules + 1 mg Cl_2/l of hypochlorite	CSR > SOM > EC (b)
Disinfection with 3 mg Cl_2/l (0.6 mg Cl_2/l of total residual chlorine)	CSR > SOM > EC (b)

Notes:

(a) *E. coli* becomes more abundant in average terms than somatic coliphages because of a

single high value that is clearly different from the other values. If it is considered that this is an erroneous value, the resulting abundances for both microorganisms are similar to those for the other treatments.

(b) The concentrations of *E. coli* of under 10 CFU/100 ml in the majority of samples lead us to assume the total elimination of this microorganism. From here it would be established that somatic coliphages were more abundant, as when they appear they do so with higher counts.

Cryptosporidium and enteroviruses

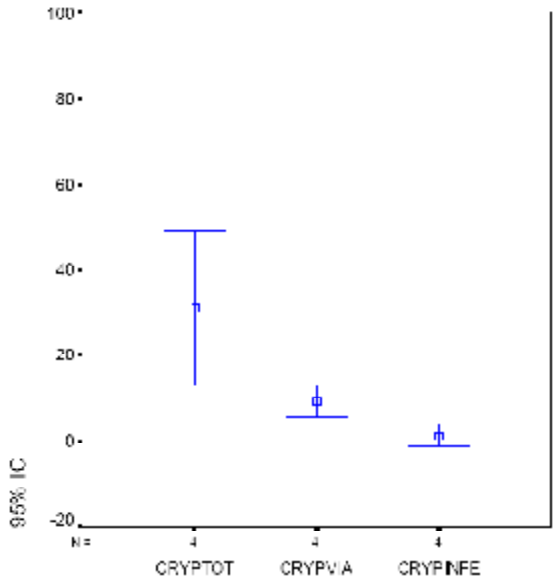
The results of the analyses of *Cryptosporidium* spp. oocysts and enteroviruses is presented in Tables 9a (all data) and 9b (summary). These results show great similarities with the data generated by the same working team in the study "Effect of the Castell-Platja d'Aro water reclamation plant on the ecological, chemical and microbiological quality of the River Ridaura" (Costa Brava Consortium, 2006c). However, the initial concentrations in this study are lower than in the previous study due to the fact that secondary effluent from an extended aeration plant submitted to a subsequent filtration process has been analysed, while in the case of Castell-Platja d'Aro the analysis corresponded to secondary effluent from a conventional, unfiltered activated sludge plant.

Table 9a. Results of the analysis of *Cryptosporidium* spp. and enteroviruses carried out on the different types of water and treatments tested in this study.

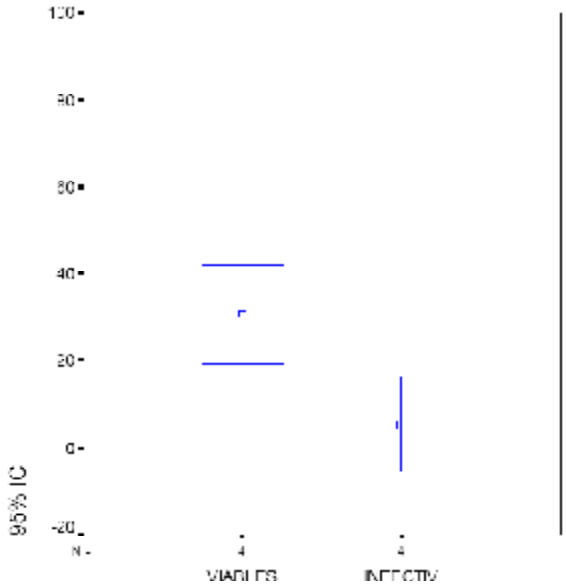
Sample data	Types of water	*Cryptosporidium* spp., oocysts/ 100 litres					Enteroviruses pfu/100 litres
		Totals	Viable	Infectious	Viable %	Infectious %	
10/05/2006	Filtered	3	1	2,5	33	8	2
	A1UV	0	0	<1	40	0	<1
	A1UV1CL	5	2	<1	50	0	<1
15/05/2006	Filtered	4	1	<1	25	0	3
	A1UV	7	2	<1	0	0	<1
	A1UV2CL	<	<	<1	0	0	<1
22/05/2006	Filtered	27.4	6	<1	25	0	1
	A2UV	23.7	8	<1	25	0	<1
	A2UV1CL	6	5	<1	0	0	<1
29/05/2006	Filtered	2	8	2.9	40	14	5
	A0.6CL	0	1	1.4	33	28	<1

Total concentrations of *Cryptosporidium* spp. oocysts ranged between 0 and 50 units samples of 100 litres of water, while viable oocysts ranged between 0 and 20 units in samples of 100 litres of water. The evaluation of infectious forms has given still lower values, ranging between 0 and 2.9 units in 100 litres. These results show clearly that infectious oocysts are a very small percentage (between 0 and 14%) of total oocysts detected, even in filtered water, before the disinfection processes (Table 9a).

Cryptosporidium spp. oocysts (total, viable and infective) in filtered water, oocysts/100 litres



Percentages of oocysts (viable and infectious) of *Cryptosporidium* spp. with respect to the total number, %



Figures 6a and 6b. Mean and 95% confidence interval values for concentrations of *Cryptosporidium* spp. oocysts (total, viable and infectious) (left) and percentages of viable and infectious oocysts (right) in filtered water from the Blanes water reclamation plant.

Table 9b. Summary of the results obtained in the analysis of *Cryptosporidium* spp. and enteroviruses obtained in this study. The data corresponding to filtered water and 1UV treatment is made up of the geometric means of the values presented in Table 9a.

Types of water and/or treatment	Total oocysts		Viable oocysts		Infectious oocysts		Enteroviruses
	in 100 l	%	in	%	in 100 l	%	pfu/100 litres
Filtered water (n=4)	29.6	-	9	30	1.6	5	2.3
1UV (n=2)	7.1	-	0	63	<1	0	< 1
1UV1CL (n=1)	20.0	-	4	50	<1	0	< 1
1UV2CL (n=1)	8.8	-	5	0	<1	0	< 1
2UV (n=1)	23.7	-	10	25	<1	0	< 1
2UV1CL (n=1)	6.0	-	0	0	<1	0	< 1
0.6CL (n=1)	5.0	-	<1	34	1.4	28	< 1

Analysing the summary of data for the different treatments (Table 9b) and taking the example of filtered water, we must observe the way that the (geometric) mean concentration of total oocysts, with an initial value of 29.6 oocysts/100 litres, is reduced to a concentration of viable oocysts of 9.0 oocysts/100 litres and a concentration of infectious oocysts of 1.6 oocysts/100 litres (Figures 6a and 6b). Although it has been possible to detect viable oocysts in samples of 100 litres of water reclaimed through the 1UV, 1UVCL, 2UV and 0.6CL disinfection processes, it has only been possible to determine the presence of infectious oocysts in 0.6CL treatment water (1.4 oocysts/100 litres). As shown in Figure 7, the information generated in this study indicates that treatments with ultraviolet light, either alone or combined with chlorine, have managed to totally inactivate the infectious oocysts.

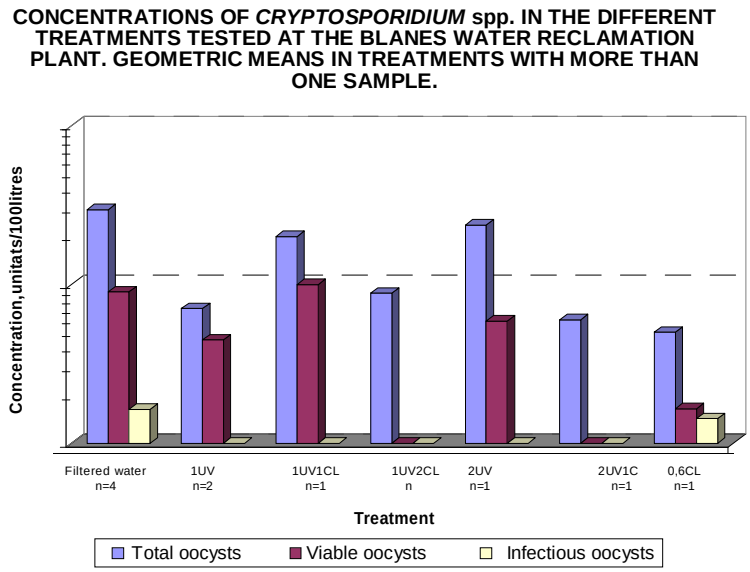


Figure 7. Concentrations of the different forms of *Cryptosporidium* spp. oocysts analysed within this study.

Sulphite-reducing clostridia spores have been considered by some authors (Venczel et al., 1997) as the model microorganism for the elimination of *Cryptosporidium* spp. oocysts. The specific circumstances of this study (small number of samples, low infectious oocyst values found in filtered water and in chlorinated water and total absence in the other treatments) make it impossible to establish a statistically significant relationship between both types of microorganisms. However, an empirical observation can be derived from this study according to which the most effective protection against infectious oocysts of *Cryptosporidium* spp. is offered by the presence of at least one module of ultraviolet light operating in the disinfection process. From this point of view, and combining this criterion with that of using sulphite-reducing clostridia spores as model micro-organisms, it is proposed that the operation of the disinfectant treatment at the Blanes reclamation plant should have at least one ultraviolet light module operating and that the reduction of sulphite-reducing clostridia spores should be at least 1.0 log.u.

Enteroviruses have been detected in very low concentrations (interval of between 1 and 5 pfu/100 litres, geometric mean of 2.3 pfu/100 litres) in all samples of filtered water (4 samples), but they have not been detected in any of the different samples of disinfected water, regardless of the disinfection treatment applied (1 sample of each, except in the case of the use of one ultraviolet light module, for which there are two). Given the circumstances already mentioned in the previous paragraph, the existing data do not allow accurate or statistically significant calculations of the inactivations caused in the concentrations of enteroviruses. Despite this, the specific existing data do make it possible to approach this issue, and, according to them, the inactivation of 2.3 pfu of enteroviruses in 100 litres of sample to the level of absence would require a logarithmic reduction of 0.36 log.u. This reduction is far below that which this study has shown can be achieved for the proposed model microorganisms (somatic coliphages), which is a minimum of 2.0 log.u. in the case of 0.6CL treatment and a maximum of 4.4 log.u. in the case of 1UV2CL treatment.

This data shows that the probability that the Blanes water reclamation plant could become a point source of enterovirus contamination is very low, even assuming that disinfection was carried out only with hypochlorite.

Comparison with the Castell-Platja d'Aro study

The comparison of the results of this study with those obtained a year before at the Castell-Platja d'Aro water reclamation plant make it possible to capture the different disinfection

performance obtained at both installations. This comparison has been made between the treatment normally used at the Castell-Platja d'Aro water reclamation plant (combination of ultraviolet light and hypochlorite) and the two disinfection treatments most likely to be chosen for the operation of the Blanes water reclamation plant, which are the combination of one ultraviolet light module and the addition of 2 mg Cl_2/l, and the combination of two ultraviolet light modules and the addition of 1 mg Cl_2/l.

Table 10. Comparison of the mean logarithmic inactivations achieved for each type of microorganisms at the Castell-Platja d'Aro water reclamation plant between 11-17 and 25-31 July 2005 and in two of the treatments tested at the Blanes water reclamation plant as part of this study between 8 and 31 May 2006.

Micro-organisms	Inactivations according to treatment, log.u.		
	UV + Chlorine (a) Castell-Platja d'Aro	1UV2CL (b) Blanes	2UV1CL (c) Blanes
Bacteria			
Faecal coliforms / *E. coli*	5.06	> 3.18	> 3.18
Faecal enterococci	4.77	-	-
Sulphite-reducing clostridia spores	0.87	0.86	1.41
Viruses			
Somatic coliphages	2.88	> 4.44	> 4.04
F-RNA bacteriophages	0.82	-	-
RYC *B. fragilis* bacteriophages	1.76	-	-
GA17 *B. fragilis* bacteriophages	1.74	-	-
Enteroviruses	- (d)	-	-
Protozoa			
Total *Cryptosporidium* spp. oocysts	0.38	-	-
Viable *Cryptosporidium* spp. oocysts	0.41	-	-
Infectious *Cryptosporidium* spp. oocysts	1.76	-	-

(a) Average doses: UV = approx. 25 mJ/cm^2; chlorine = 5 mg Cl_2/l; C.t = 117 mg Cl_2.min/l
(b.) Average doses: UV = approx. 39 mJ/cm^2; chlorine = 2 mg Cl_2/l; C.t = 100mg Cl_2.min/l
(c) Average doses: UV = approx. 78 mJ/cm^2; chlorine = 1 mg Cl_2/l; C.t = 67 mg Cl_2.min/l
(d) Although data is available on enteroviruses in the study carried out in 2004 and 2005 on the effect of the Castell-Platja d'Aro water reclamation plant on the River Ridaura, the inactivation achieved cannot be precisely quantified because of the uncertainty ("less than" values) both in the secondary effluent and in the reclaimed water (Costa Brava Consortium, 2006c).

Table 10 shows that the logarithmic inactivation of the concentrations of faecal coliforms is higher at Castell-Platja d'Aro than at Blanes, simply because the initial concentrations of this indicator are greater at the former facility. The fact that the inactivations of the two treatments corresponding to Blanes should give unquantifiable inactivations above a certain value indicates that the result achieved by the treatment is the absence of the micro-organism in question, in this case E. coli.

The inactivations achieved in the concentrations of sulphite-reducing clostridia spores are practically identical (0.87 log.u. at Castell-Platja d'Aro and 0.86 log.u. at Blanes) in the two disinfection treatments that are most similar as regards the dose of ultraviolet light and the C.t. parameter. By contrast, the treatment with a double dose of ultraviolet light (two modules of ultraviolet light and the addition of 1 mg Cl_2/l at the Blanes water reclamation plant) allows an inactivation of sulphite-reducing clostridia spores that is almost double (1.41 log.u.), despite the reduction in the value of the C.t. parameter.

The Blanes water reclamation plant treatment process has greater disinfection power than that at Castell-Platja d'Aro concerning the inactivation of somatic coliphages, so that the inactivation levels of 2.88 log.u. at Castell-Platja d'Aro move to minimum levels of 4.04 and 4.44 log.u. at Blanes. As observed in the case of *E. coli*, these inactivation levels cannot be exactly quantified, as the results in reclaimed water are "absences" of microorganisms. This means it is not known whether higher initial concentrations would also be eliminated after the

treatment. In all cases, both the disinfection provided by the Castell-Platja d'Aro water reclamation plant and the Blanes water reclamation plant are enough to inactivate concentrations of enterovirus which, in the secondary effluent at Blanes are found in concentrations that are half those measured in the secondary effluent at Castell-Platja d'Aro. And, while at Blanes the samples for the analysis of enteroviruses have been of 100 litres, at Castell-Platja d'Aro they were only of 1 litre (Costa Brava Consortium, 2006c).

Finally, the low concentration of infectious *Cryptosporidium* spp. oocysts in the effluent from the Blanes water reclamation plant has prevented the precise determination of this facility's inactivation capacity for this type of microorganism. Despite this, the experiments in 2005 at the Castell-Platja d'Aro water reclamation plant made it possible to quantify this inactivation at 1.76 log.u. Given that the Blanes water reclamation plant's disinfection capacity is greater than that at Castell-Platja d'Aro in relation to high-resistance micro-organisms, such as sulphite-reducing clostridia spores, it has to be concluded that it must also offer greater protection against infectious *Cryptosporidium* spp. oocysts.

In summary, a disinfection process applied to water with turbidity values of around 2 NTU and transmittance of more than 70% at 254 nm based on exposure to a dose of ultraviolet light of between 40 and 80 mJ/cm^2, together with a hypochlorite dose of between 1 and 2 mg Cl_2/l, makes it possible to produce reclaimed water without *E. coli*, somatic coliphages, enteroviruses and infectious *Cryptosporidium* spp. oocysts, and at the same time to achieve inactivation of sulphite-reducing clostridia spores of above 1.0 log.u. The combined action of ultraviolet light, particularly effective for inactivating viruses and pathogenic protozoa, and hypochlorite, especially effective for inactivating non-spore producing bacteria, makes it possible to achieve reclaimed water with suitable quality for reuse as non-drinking water in urban areas, for agricultural watering and in gardens.

The results of this study and that carried out in 2005 at the Castell- Platja d'Aro reclamation plant (Costa Brava Consortium, 2006a) have made it possible to establish levels of microbe and virus inactivation of great practical use when it comes to establishing operational and maintenance protocols for water reclamation plants based on secondary effluents of good physico-chemical quality, such as those in the WWTPs at Blanes and Castell-Platja d'Aro.

CONCLUSIONS

The study carried out on the disinfectant capacity of the combined use of ultraviolet light and hypochlorite at the Blanes water reclamation plant makes it possible to draw the following conclusions.

1. The physico-chemical quality of the water produced during the study period (8 to 31 May 2006) by the Blanes water reclamation plant was suitable for the surface replenishment of the lower Tordera aquifer.

2. The average doses of ultraviolet light applied during the experiment ranged between 40 mJ/cm^2 for treatments in which one ultraviolet light module was involved and 80 mJ/cm^2 in those in which two modules were involved. These units worked alone and in combination with doses of chlorine of 1 and 2 mg Cl_2/l, which involved average values of the C.t. parameter of between 40 and 70 mg Cl_2.min/l. At the same time, the disinfectant capacity of the exclusive use of hypochlorite was determined down to achieving constant residual chlorine of around 0.6 mg Cl_2/l, equivalent to an average C.t. parameter of around 150 mg Cl_2.min/l.

3. All the disinfectant treatments tested have achieved absence, or values close to the absence, of *E. coli* in samples of 100ml of water, with logarithmic reductions of more than 3 log.u. No colonies of this micro-organism have been isolated in any of the samples of water collected in treatment consisting of one ultraviolet light model and the addition of 2 mg Cl_2/l, nor in that consisting of two ultraviolet light modules and the addition of 1 mg Cl_2/l, nor in that with hypochlorite dosing to achieve total residual chlorine of 0.6 mg Cl_2/l. The reclaimed water produced in these conditions can be used for any of the uses established both in Catalan guidelines and in the regulations soon to come into force in Spain.

4. The inactivation of sulphite-reducing clostridia spores has been at a minimum when chlorine has been used as a sole disinfectant agent (0.35 log.u.), while it has increased in proportion to the number of ultraviolet light modules operating. While in treatments with a single ultraviolet light module this inactivation has been between 0.7 and 0.9 log.u., in treatments with two ultraviolet light modules, reductions of between 1.4 and 1.5 log.u. have been achieved.

5. The inactivation of somatic coliphages follows similar behaviour to that with sulphite-reducing clostridia spores: the inactivation produced by ultraviolet light, alone or combined with chlorine, has been greater (between >3.3 and >4.4 log.u.) than that obtained when chlorine has been used as a sole disinfectant agent (2.0 log.u.). By contrast, no significant differences of inactivation have been observed between the treatment using ultraviolet light alone, whether one or two modules have been in operation (approximately 3.4 log.u.). Maximum eliminations have been produced in treatments combining the two disinfectant agents, with a complementary effect occurring of the inactivations provided by each one (between >3.9 and > 4.4 log.u.).

6. The disinfection treatments change the relative abundances of the principal microorganisms, depending on their resistance to the different disinfectant agents. While somatic coliphages are most abundant in the filtered water, followed by *E. coli* and sulphite-reducing clostridia spores, all the treatments tested produce a similar alteration of the relative abundances, so sulphite-reducing clostridia spores come to be most abundant, followed by somatic coliphages and *E. coli*.

7. The concentrations of *Cryptosporidium* spp. oocysts and especially enteroviruses were already very low in the filtered water, with values of between 0 and 50 total oocysts and between 1 and 5 pfu in samples of 100 litres in each cases, respectively. The proportion of infectious *Cryptosporidium* spp. oocysts was a maximum of 14% of the total number of oocysts detected in filtered water.

8. No infectious *Cryptosporidium* spp. oocysts have been detected in any of the water samples obtained from the disinfection processes with at least one module of ultraviolet light in operation. Infectious oocysts (1.4 oocysts/100 litres, 28% of total oocysts) have been detected only in water disinfected solely with chlorine.

9. All the disinfection treatments tested have resulted in water without cultivable enteroviruses in 100-litre water samples. The values generated in this study do not allow an accurate estimate of the inactivation of enteroviruses. We only know that this is greater than 0.3 log.u. However, it can be considered that the elimination of enteroviruses must be of the same order of magnitude as that for somatic coliphages.

10. The Blanes water reclamation plant shows a greater inactivation capacity for microorganisms than that of the Castell-Platja d'Aro water reclamation plant because of the greater reductions achieved for the more resistant microorganisms, such as sulphite-reducing clostridia spores and somatic coliphages. Despite this, both reclamation plants effectively eliminate both infectious *Cryptosporidium* spp. oocysts and enteroviruses.

11. In short, having evaluated the inactivation of pathogenic microorganisms as indicators, disinfection combining ultraviolet light and the addition of hypochlorite shows greater efficiency than unitary treatments.

RECOMMENDATIONS

The results of this study enable the drafting of the following recommendations:

1. For maximum performance in the disinfection process, it is necessary to produce a secondary effluent of the highest possible quality (e.g. with values of SPM < 10 mg/l and turbidity < 5 NTU, provided the facilities and working conditions allow). Better quality secondary effluent will mean that the subsequent reclamation process is more reliable due to greater effectiveness in eliminating suspended particles and inactivating bacteria and viruses achieved by this process. Whatever the ultraviolet light emitted or the dose of hypochlorite provided, disinfection performance will be better in water of better physico-chemical quality.

2. To ensure broad spectrum disinfection and therefore maximum protection of public health, it proposed that the operation of the disinfection treatment at the Blanes water reclamation plant should include at least one operating ultraviolet light module and that the reduction of sulphite-reducing clostridia spores, used as a model for micro-organisms, is at least 1.0 log.u. This operating system not only achieves total inactivation of indicator microorganisms like *E. coli* or somatic coliphages, but also offers maximum protection against infectious *Cryptosporidium* spp oocysts and enteroviruses.

3. It is appropriate to continue with the systematic evaluation of the microbiological quality parameters used in this study in order to confirm the preliminary results obtained and to strengthen the proposed operational criteria. The monitoring of the operation of the Blanes water reclamation plant, in accordance with the criteria proposed in this study, should provide a series of data of great practical interest for this purpose.

4. At the same time, it is appropriate to move forward in the interpretation of the utility of sulphite-reducing clostridia spores and somatic coliphages as indicators of the

effectiveness of disinfection and for there determination of the levels of disinfectant agents necessary for eliminating them and the other micro-organisms – both indicators and pathogens – used in this study.

BIBLIOGRAPHY

Anon. 2000. ISO 10705-2: Water quality – Detection and enumeration of bacteriophages. Part 2: Enumeration of somatic Coliphages. Geneva, Switzerland: International Organization for Standardization

Campbell, A.T., Robertson, L.J. and Smith, H.V. (1992). Viability of *Cryptosporidium parvum* oocysts: correlation of in vitro exystation with inclusion or exclusion of fluorogenic vital dyes. Applied *and Environmental Microbiology* 58, 3488-3493.

Consorci de la Costa Brava, 2006a. Technical Report: Acció combinada d'agents desinfectants a la planta de regeneració d'aigua de Castell-Platja d'Aro. Available at: http://www.ccbgi.org/docs/Informe_accio_combinada_desinfectants_Jul_2006.pdf

Consorci de la Costa Brava, 2006b. Report: Resum del seguiment realitzat a la qualitat de l'aigua regenerada produïda en l'EDAR de Blanes (January 2003 - April 2006). Available at: http://www.ccbgi.org/docs/informe_resum_recarrega_blanes_gener_2003_abril_2006.pdf

Consorci de la Costa Brava, 2006c. Technical Report: Efecte de la planta de regeneració d'aigua de Castell-Platja d'Aro en la qualitat ecològica, química i microbiològica del riu Ridaura. (Being prepared)

Katzenelson, E., Fattal, B., & Hostovesky, T. 1976. Organic flocculation: an efficient second step concentration method for the detection of viruses in tap water. *Appl. Environ. Microbiol*. 30: 638-639.

Méndez J., Audicana A., Isern A., Llaneza J, Moreno B, Taracón M.L., Jofre J. & Lucena F. 2004. Standardised evaluation of the performance of a simple membrane filtration-elution method to concentrate bacteriophages from drinking water. *Journal of Virological Methods*. 117, 19-25.

Mocé-Llivina L., Jofre J. & Muniesa M. 2003. Comparison of polyvinylidene fluoride and polyether sulfone membranes in filtering viral suspensions. *Jour. Virol. Meth.*, 109: 99-101.

Mocé-Llivina, L., Lucena, F. & Jofre, J. 2004. Double-layer plaque assay for quantification of enteroviruses. *Appl. Environ. Microbiol*., 70: 2801-2805.

Montemayor, M., Valero, F., Jofre, J. & Lucena, F. 2005. Occurrence of *Cryptosporidium* spp. oocysts in raw and treated sewage and river water in northeastern Spain. *Journal of Applied Microbiology*. 99(6):1455-62.

Slifko,T. R., Friedman, D., Rose, J. & Jabubowski, W. (1997). An In Vitro Method for Detecting Infectious *Cryptosporidium* Oocysts with Cell Culture. *Applied and Environmental Microbiology* 63(9), 3669–3675

US EPA 1996. ICR Microbial Laboratory Manual. Section VIII. Part 1 (VIII-4-VIII-12). U.S. Environmental Protection Agency, Ohio 45268.

US EPA 1999. *Method 1623:* Cryptosporidium *and* Giadia *in water by filtration/IMS/FA. EPA/821/R-99 0~~0~~6.* Office of Water, U.S. Environmental Protection Agency, Washington, DC: Government Printing Office.

Venczel, L.V., Arrowood, M., Hurd, M., & Sobsey, M.D. 1997. Inactivation of *Cryptosporidium parvum* Oocysts and *Clostridium perfringens* Spores by a Mixed-Oxidant Disinfectant and by Free Chlorine. *Applied and Environmental Microbiology* 63(4), 598–1601.

Appendix I

Working conditions during the experiment

Day: Monday 8/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	1 / 8
Useful life of the lamps, hours used	110 –Modules
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	1.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	1.8	0.8	12.4	---
Turbidity, NTU	3.1	0.9	3.1	---
T254, %	72	74	54	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	43.7	43.7 (a)	---
C·t., mg Cl_2·min/l	---	---	75	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	3.2	2.0	---
Turbidity, NTU	---	7.0	1.4	---
T254, %	---	74	74	---
Total residual chlorine, mg Cl_2/l	---	---	0.2	---
UV dose, mJ/cm^2	---	43.7	43.7	---
C·t, mg Cl_2.min/l	---	---	50	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	1.4	2.4	---
Turbidity, NTU	---	1.3	2.3	---
T254, %	---	75	73	---
Total residual chlorine, mg Cl_2/l	---	---	0.2	---
UV dose, mJ/cm^2	---	43.7	43.7 (a)	---
C·t, mg Cl_2.min/l	---	---	50	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Tuesday 9/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	1 / 8
Useful life of the lamps, hours used	110 – Modules A-B
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	1.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	2.8	1.8	1.2	---
Turbidity, NTU	1.0	1.6	1.7	---
T254, %	72	71	55	---
Total residual chlorine, mg Cl_2/l	---	---	0,1	---
UV dose, mJ/cm^2	---	39.0	39.0 (a)	---
C·t, mg Cl_2.min/l	---	---	25	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	0.4	0.7	---
Turbidity, NTU	---	2.3	1.6	---
T254, %	---	70	69	---
Total residual chlorine, mg Cl_2/l	---	---	0.2	---
UV dose, mJ/cm^2	---	37.0	37.0 (a)	---
C·t, mg Cl_2.min/l	---	---	50	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	2.0	2.2	---
Turbidity, NTU	---	1.2	1.4	---
T254, %	---	72	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.1	---
UV dose, mJ/cm^2	---	40.9	40.9	---
C·t, mg Cl_2.min/l	---	---	25	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Wednesday 10/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	1 / 8
Useful life of the lamps, hours used	110 – Modules A-B
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	1.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	2.8	1.8	1.2	---
Turbidity, NTU	1.9	1.0	1.8	---
T254, %	70	71	70	---
Total residual chlorine, mg Cl_2/l	---	---	0.1	---
UV dose, mJ/cm^2	---	118.0	118.0 (a)	---
C·t, mg Cl_2.min/l	---	---	25	---

In certain cases at sample collection at 10am the flow was $200m^3/h$ and not $600m^3/h$.

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	0.4	0.7	---
Turbidity, NTU	---	2.4	1.3	---
T254, %	---	71	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.2	---
UV dose, mJ/cm^2	---	39.0	39.0 (a)	---
C·t, mg Cl_2.min/l	---	---	50	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	2.0	2.2	---
Turbidity, NTU	---	1.9	2.0	---
T254, %	---	70	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.1	---
UV dose, mJ/cm^2	---	38.2	38.2 (a)	---
C·t, mg Cl_2.min/l	---	---	25	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Monday 15/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	1 / 8
Useful life of the lamps, hours used	141 – Modules C-D
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	2.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	1.8	4.6	1.0	---
Turbidity, NTU	1.7	1.5	1.6	---
T254, %	70	70	71	---
Total residual chlorine, mg Cl_2/l	---	---	0.6	---
UV dose, mJ/cm^2	---	38.2	38.2 (a)	---
C·t, mg Cl_2.min/l	---	---	150	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	2.2	2.8	---
Turbidity, NTU	---	1.0	1.2	---
T254, %	---	71	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.5	---
UV dose, mJ/cm^2	---	39.0	39.0 (a)	---
C·t, mg Cl_2.min/l	---	---	125	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	1.6	2.0	---
Turbidity, NTU	---	1.1	1.2	---
T254, %	---	72	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.4	---
UV dose, mJ/cm^2	---	40.9	40.9	---
C·t, mg Cl_2.min/l	---	---	100	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Tuesday 16/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	1 / 8
Useful life of the lamps, hours used	141 – Modules C-D
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	2.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	2.0	3.8	3.0	---
Turbidity, NTU	1.0	1.7	1.5	---
T254, %	71	71	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	39.0	39.0 (a)	---
C·t., mg Cl_2·min/l	---	---	75	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	2.0	2.6	---
Turbidity, NTU	---	2.3	1.1	---
T254, %	---	70	73	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	38.3	38.3 (a)	---
C·t, mg Cl_2.min/l	---	---	75	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	2.0	2.4	---
Turbidity, NTU	---	1.3	2.1	---
T254, %	---	72	70	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	40.9	40.9 (a)	---
C·t, mg Cl_2.min/l	---	---	75	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Wednesday 17/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	1 / 8
Useful life of the lamps, hours used	141 – Modules C-D
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	2.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	1.4	1.4	6.4	---
Turbidity, NTU	1.4	1.4	6.5	---
T254, %	70	70	63	---
Total residual chlorine, mg Cl_2/l	---	---	0.4	---
UV dose, mJ/cm^2	---	38.2	38.2 (a)	---
C·t, mg Cl_2.min/l	---	---	100	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	0.8	2.0	---
Turbidity, NTU	---	0.9	1.1	---
T254, %	---	70	71	---
Total residual chlorine, mg Cl_2/l	---	---	0.4	---
UV dose, mJ/cm^2	---	38,2	38,2 (a)	---
C·t, mg Cl_2.min/l	---	---	100	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	4.6	1.8	---
Turbidity, NTU	---	1.8	1.6	---
T254, %	---	71	68	---
Total residual chlorine, mg Cl_2/l	---	---	0.4	---
UV dose, mJ/cm^2	---	39.0	39.0	---
C·t, mg Cl_2.min/l	---	---	100	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Monday 22/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	2 / 16
Useful life of the lamps, hours used	382 – Modules C-D + D-C
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	1.0
Outlet tank volume, m^3	2.500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	1.4	1.0	6.2	---
Turbidity, NTU	1.5	1.5	4.2	---
T254, %	71	71	66	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	79.0	79.0 (a)	---
C·t., mg Cl_2·min/l	---	---	75	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	0.4	1.6	---
Turbidity, NTU	---	1.2	3.8	---
T254, %	---	70	66	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	76.4	76.4 (a)	---
C·t, mg Cl_2.min/l	---	---	75	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	1.2	1.2	---
Turbidity, NTU	---	3.4	1.4	---
T254, %	---	71	73	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	79.0	79.0 (a)	---
C·t, mg Cl_2.min/l	---	---	75	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Tuesday 23/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	2 / 16
Useful life of the lamps, hours used	382 – Modules C-D + D-C
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	1.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	2.6	1.0	1.4	---
Turbidity, NTU	1.3	1.2	3.0	---
T254, %	70	70	62	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	76.4	76.4 (a)	---
C·t, mg Cl_2.min/l	---	---	75	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	0.8	1.8	---
Turbidity, NTU	---	0.9	2.1	---
T254, %	---	71	69	---
Total residual chlorine, mg Cl_2/l	---	---	0.2	---
UV dose, mJ/cm^2	---	79.0	79.0 (a)	---
C·t, mg Cl_2.min/l	---	---	50	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	0.8	1.6	---
Turbidity, NTU	---	1.5	1.3	---
T254, %	---	71	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.2	---
UV dose, mJ/cm^2	---	79.0	79.0 (a)	---
C·t, mg Cl_2.min/l	---	---	50	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Thursday 25/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	2 / 16
Useful life of the lamps, hours used	382 – Modules C-D + D-C
Hypochlorite dosage for disinfection, mg Cl_2/l	0.0
Hypochlorite dosage for disinfection, mg Cl_2/l	1.0
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	10:00	10:00	---
Physico-chemical results				
SPM, mg/l	2.6	3.4	5.0	---
Turbidity, NTU	1.3	2.3	3.3	---
T254, %	71	70	69	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	76.4	76.4 (a)	---
C·t., mg Cl_2·min/l	---	---	75	---

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	11:30	11:30	---
Physico-chemical results				
SPM, mg/l	---	1.6	2.0	---
Turbidity, NTU	---	4.3	1.8	---
T254, %	---	70	72	---
Total residual chlorine, mg Cl_2/l	---	---	0.3	---
UV dose, mJ/cm^2	---	76.4	76.4 (a)	---
C·t, mg Cl_2.min/l	---	---	75	---

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	---	13:00	13:00	---
Physico-chemical results				
SPM, mg/l	---	2.4	1.8	---
Turbidity, NTU	---	1.5	4.4	---
T254, %	---	71	71	---
Total residual chlorine, mg Cl_2/l	---	---	0.2	---
UV dose, mJ/cm^2	---	79.0	79.0	---
C·t, mg Cl_2.min/l	---	---	50	---

(a) It is considered that the variation in transmittance is caused by the final addition of hypochlorite, so the ultraviolet light dose is maintained.

Day: Monday 29/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	0 / 0
Useful life of the lamps, hours used	-
Hypochlorite dosage for disinfection, mg Cl_2/l	3.0
Hypochlorite dosage for disinfection, mg Cl_2/l	-
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	---	---	10:00
Physico-chemical results				
SPM, mg/l	2.6	---	---	1.6
Turbidity, NTU	1.4	---	---	1.3
T254, %	73	---	---	73
Total residual chlorine, mg Cl_2/l	---	---	---	0.4
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	100

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	11:30	---	---	11:30
Physico-chemical results				
SPM, mg/l	1.6	---	---	2.0
Turbidity, NTU	1.4	---	---	1.4
T254, %	74	---	---	76
Total residual chlorine, mg Cl_2/l	---	---	---	0.6
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	150

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	13:00	---	---	13:00
Physico-chemical results				
SPM, mg/l	1.4	---	---	2.0
Turbidity, NTU	1.9	---	---	1.2
T254, %	74	---	---	76
Total residual chlorine, mg Cl_2/l	---	---	---	0.5
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	125

Day: Tuesday 30/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	0 / 0
Useful life of the lamps, hours used	-
Hypochlorite dosage for disinfection, mg Cl_2/l	3.0
Hypochlorite dosage for disinfection, mg Cl_2/l	-
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	---	---	10:00
Physico-chemical results				
SPM, mg/l	2.2	---	---	2.6
Turbidity, NTU	2.1	---	---	2.7
T254, %	72	---	---	71
Total residual chlorine, mg Cl_2/l	---	---	---	0.4
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	100

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	11:30	---	---	11:30
Physico-chemical results				
SPM, mg/l	2.0	---	---	3.2
Turbidity, NTU	2.5	---	---	3.2
T254, %	71	---	---	72
Total residual chlorine, mg Cl_2/l	---	---	---	0.6
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	150

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	13:00	---	---	13:00
Physico-chemical results				
SPM, mg/l	1.8	---	---	2.0
Turbidity, NTU	2.1	---	---	2.0
T254, %	71	---	---	71
Total residual chlorine, mg Cl_2/l	---	---	---	0.6
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	150

Day: Wednesday 31/05/2006

Working conditions	
Production of reclaimed water, m^3/h	600
Filtered water pumps in operation, number	3
Number of modules/lamps in operation	0 / 0
Useful life of the lamps, hours used	-
Hypochlorite dosage for disinfection, mg Cl_2/l	3.0
Hypochlorite dosage for disinfection, mg Cl_2/l	-
Outlet tank volume, m^3	2,500
Chlorine contact time, min	250

	Samples			
First sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	10:00	---	---	10:00
Physico-chemical results				
SPM, mg/l	2.8	---	---	2.2
Turbidity, NTU	2.3	---	---	1.8
T254, %	65	---	---	67
Total residual chlorine, mg Cl_2/l	---	---	---	0.8
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	200

	Samples			
Second sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	11:30	---	---	11:30
Physico-chemical results				
SPM, mg/l	1.6	---	---	1.8
Turbidity, NTU	2.1	---	---	2.1
T254, %	71	---	---	71
Total residual chlorine, mg Cl_2/l	---	---	---	0.9
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	225

	Samples			
Third sample	Filtered water	UV	UV+Chlorine	Chlorine
Sampling times	13:00	---	---	13:00
Physico-chemical results				
SPM, mg/l	1.4	---	---	2.6
Turbidity, NTU	2.4	---	---	1.2
T254, %	64	---	---	71
Total residual chlorine, mg Cl_2/l	---	---	---	0.7
UV dose, mJ/cm^2	---	---	---	---
C·t, mg Cl_2.min/l	---	---	---	175

Appendix II

Results of the microbiological analysis carried out at the Blanes water reclamation plant in the study of the combined action of disinfectant agents. May 2006. Samples in chronological order.

1st week										
Sampling conditions		**Bacteria, cfu/100 ml**		**Somatic coliphages, pfu/100 ml**	***Cryptosporidium* spp.**					**Enteroviruses pfu/l**
Date	**Sample**	***E. coli***	**Sulphite reducing clostridia spores**		**Total oocysts/l**	**Viable oocysts/l**	**Infectious oocysts/l**	**Viability %**	**Infectivity %**	
08/05/2006	Filtered	25,000	1,050	41,000	n	nt	nt	nt	nt	nt
08/05/2006	A1UV	< 10	400	<0.4	n	nt	nt	nt	nt	nt
08/05/2006	A1UV1CL	< 10	200	1.6	n	nt	nt	nt	nt	nt
08/05/2006	B1UV	< 10	700	10	n	nt	nt	nt	nt	nt
08/05/2006	B1UV1CL	< 10	300	4.4	n	nt	nt	nt	nt	nt
08/05/2006	C1UV	< 10	400	9.6	n	nt	nt	nt	nt	nt
08/05/2006	C1UV1CL	10	300	4.8	n	nt	nt	nt	nt	nt
09/05/2006	Filtered	6,000	1,000	19,200	n	nt	nt	nt	nt	nt
09/05/2006	A1UV	< 10	100	<1	n	nt	nt	nt	nt	nt
09/05/2006	A1UV1CL	< 10	90	<1	n	nt	nt	nt	nt	nt
09/05/2006	B1UV	< 10	600	4	n	nt	nt	nt	nt	nt
09/05/2006	B1UV1CL	< 10	800	<1	n	nt	nt	nt	nt	nt
09/05/2006	C1UV	< 10	100	2	n	nt	nt	nt	nt	nt
09/05/2006	C1UV1CL	10	200	5	n	nt	nt	nt	nt	nt
10/05/2006	Filtered	18,000	3,000	19,000	0	0.1	0.025	33.3	8.3	0.02
10/05/2006	A1UV	20	1,500	7	0	0.2	<0.025	40.0	< 5	< 0.01
10/05/2006	A1UV1CL	< 10	700	1.6	0	0.1	<0.025	50.0	< 12.5	< 0.01
10/05/2006	B1UV	20	800	8	n	nt	nt	nt	nt	nt
10/05/2006	B1UV1CL	10	1,200	1.3	n	nt	nt	nt	nt	nt
10/05/2006	C1UV	< 10	600	2.3	n	nt	nt	nt	nt	nt
10/05/2006	C1UV1CL	< 10	900	2.2	n	nt	nt	nt	nt	nt

2nd week										
Sampling conditions		**Bacteria, cfu/100 ml**		**Somatic coliphages, pfu/100 ml**	***Cryptosporidium* spp.**					**Enteroviruses pfu/l**
Date	**Sample**	***E. coli***	**Sulphite-reducing clostridia**		**Total oocysts/l**	**Viable oocysts/l**	**Infectious oocysts/l**	**Viability %**	**Infectivity %**	
15/05/2006	Filtered	22,000	1,500	21,500	0.47	0.12	< 0.02	25.0	< 4.3	0.03
15/05/2006	A1UV	10	200	9.6	< 0.12	-	-	-	-	< 0.01
15/05/2006	A1UV2CL	< 10	120	0.4	0.088	0	< 0.015	0.0	< 5	< 0.01
15/05/2006	B1UV	30	100	5.2	n	nt	nt	nt	nt	nt
15/05/2006	B1UV2CL	<10	200	0.8	n	nt	nt	nt	nt	nt
15/05/2006	C1UV	20	300	10	n	nt	nt	nt	nt	nt
15/05/2006	C1UV2CL	< 10	100	0.4	n	nt	nt	nt	nt	nt
16/05/2006	Filtered	14,000	3,200	20,500	n	nt	nt	nt	nt	nt
16/05/2006	A1UV	20	400	16.2	n	nt	nt	nt	nt	nt
16/05/2006	A1UV2CL	< 10	800	0.4	n	nt	nt	nt	nt	nt
16/05/2006	B1UV	8,000	960	3,420	n	nt	nt	nt	nt	nt
16/05/2006	B1UV2CL	< 10	550	< 0.4	n	nt	nt	nt	nt	nt
16/05/2006	C1UV	30	800	17.2	n	nt	nt	nt	nt	nt
16/05/2006	C1UV2CL	< 10	700	8.4	n	nt	nt	nt	nt	nt
17/05/2006	Filtered	12,000	4,000	14,000	n	nt	nt	nt	nt	nt
17/05/2006	A1UV	30	700	9.6	n	nt	nt	nt	nt	nt
17/05/2006	A1UV2CL	< 10	500	0.4	n	nt	nt	nt	nt	nt
17/05/2006	B1UV	150	300	16.4	n	nt	nt	nt	nt	nt
17/05/2006	B1UV2CL	<1 0	500	0.8	n	nt	nt	nt	nt	nt
17/05/2006	C1UV	30	60	4	n	nt	nt	nt	nt	nt
17/05/2006	C1UV2CL	< 10	40	0.4	n	nt	nt	nt	nt	nt

3rd week										
Sampling conditions		**Bacteria, cfu/100 ml**		**Somatic coliphages, pfu/100 ml**	***Cryptosporidium* spp.**					**Enteroviruses pfu/l**
Date	**Sample**	***E. coli***	**Sulphite-reducing clostridia**		**Total oocysts/l**	**Viable oocysts/l**	**Infectious oocysts/l**	**viability %**	**infectivity %**	
22/05/2006	Filtered	20,000	1.	24,500	0.274	0.068	< 0.016	25.0	< 5.84	0.01
22/05/2006	A2UV	1	5	14.8	0.237	0.059	< 0.014	25.0	< 5.91	< 0.01
22/05/2006	A2UV1CL	<1	1	3.2	0.06	0	< 0.014	0.0	< 23.3	< 0.01
22/05/2006	B2UV	<1	7	10.8	nt	n	n	nt	n	nt
22/05/2006	B2UV1CL	<1	1	1.6	nt	n	n	nt	n	nt
22/05/2006	C2UV	<1	1	14.8	nt	n	n	nt	n	nt
22/05/2006	C2UV1CL	<1	9	1.2	nt	n	n	nt	n	nt
23/05/2006	Filtered	13,000	2.	11,000	nt	n	n	nt	n	nt
23/05/2006	A2UV	1	9	5.2	nt	n	n	nt	n	nt
23/05/2006	A2UV1CL	<1	7	2	nt	n	n	nt	n	nt
23/05/2006	B2UV	2	6	11.6	nt	n	n	nt	n	nt
23/05/2006	B2UV1CL	<1	8	1.6	nt	n	n	nt	n	nt
23/05/2006	C2UV	<1	1	2.8	nt	n	n	nt	n	nt
23/05/2006	C2UV1CL	<1	9	2.4	nt	n	n	nt	n	nt
25/05/2006	Filtered	29,000	2.	22,500	nt	n	n	nt	n	nt
25/05/2006	A2UV	4	3	7	nt	n	n	nt	n	nt
25/05/2006	A2UV1CL	<1	5	1	nt	n	n	nt	n	nt
25/05/2006	B2UV	<1	6	5	nt	n	n	nt	n	nt
25/05/2006	B2UV1CL	<1	5	2	nt	n	n	nt	n	nt
25/05/2006	C2UV	1	4	3	nt	n	n	nt	n	nt
25/05/2006	C2UV1CL	<1	8	<1	nt	n	n	nt	n	nt

4th week										
Sampling conditions		**Bacteria, cfu/100 ml**		**Somatic coliphages, pfu/100 ml**	***Cryptosporidium* spp.**					**Enteroviruses pfu/l**
Date	**Sample**	***E. coli***	**Sulphite-reducing clostridia**		**Total oocysts/l**	**Viable oocysts/l**	**Infectious oocysts/l**	**Viability %**	**Infectivity %**	
29/05/2006	Filtered	19,000	3,000	12,500	0.2	0.08	0.0286	40.0	14.3	0.05
29/05/2006	A0.6CL	20	800	51	0.05	0.0165	0.0143	33.0	28.6	< 0.01
29/05/2006	B0.6CL	<10	700	44.8	nt	nt	nt	nt	nt	nt
29/05/2006	C0.6CL	20	1,000	34.8	nt	nt	nt	nt	nt	nt
30/05/2006	Filtered	12,000	2,500	10,500	nt	nt	nt	nt	nt	nt
30/05/2006	A0.6CL	<10	700	23	nt	nt	nt	nt	nt	nt
30/05/2006	B0.6CL	<10	400	18	nt	nt	nt	nt	nt	nt
30/05/2006	C0.6CL	<10	600	24	nt	nt	nt	nt	nt	nt
31/05/2006	Filtered	9,000	2,000	nt	nt	nt	nt	nt	nt	nt
31/05/2006	A0.6CL	10	1,400	4,050	nt	nt	nt	nt	nt	nt
31/05/2006	B0.6CL	10	1,200	5,800	nt	nt	nt	nt	nt	nt
31/05/2006	C0.6CL	20	2,400	7,100	nt	nt	nt	nt	nt	nt

Results of the microbiological analysis carried out at the Blanes water reclamation plant in the study of the combined action of disinfectant agents. May 2006. Samples ordered by type of water.

Sampling conditions		Bacteria, cfu/100 ml		Somatic coliphages, pfu/100 ml	*Cryptosporidium* spp.					Enteroviruses pfu/l
Date	Sample	*E. coli*	Sulphite-reducing clostridia spores		Total oocysts/l	Viable oocysts/l	Infectious oocysts/l	Viability %	Infectivity %	
08/05/2006	Filtered	25,000	1,050	41,000						
09/05/2006	Filtered	6,000	1,000	19,200						
10/05/2006	Filtered	18,000	3,000	19,000	0.3	0.1	0.025	33.3	8.3	0.02
15/05/2006	Filtered	22,000	1,500	21,500	0.47	0.12	< 0.02	25.0	< 4.3	0.03
16/05/2006	Filtered	14,000	3,200	20,500						
17/05/2006	Filtered	12,000	4,000	14,000						
22/05/2006	Filtered	20,000	1,000	24,500	0.274	0.068	< 0.016	25.0	< 5.8	0.01
23/05/2006	Filtered	13,000	2,000	11,000						
25/05/2006	Filtered	29,000	2,000	22,500						
29/05/2006	Filtered	19,000	3,000	12,500	0.2	0.08	0.0286	40.0	14.3	0.05
30/05/2006	Filtered	12,000	2,500	10,500						
31/05/2006	Filtered	9,000	2,000							
08/05/2006	A1UV	< 10	400	< 0.4						
09/05/2006	A1UV	< 10	100	< 1						
10/05/2006	A1UV	20	1,500	7	0.5	0.2	< 0.025	40.0	< 5.0	< 0.01
15/05/2006	A1UV	10	200	9.6	< 0.12	<0.12	< 0.02	0	0	< 0.01
16/05/2006	A1UV	20	400	16.2						
17/05/2006	A1UV	30	700	9.6						

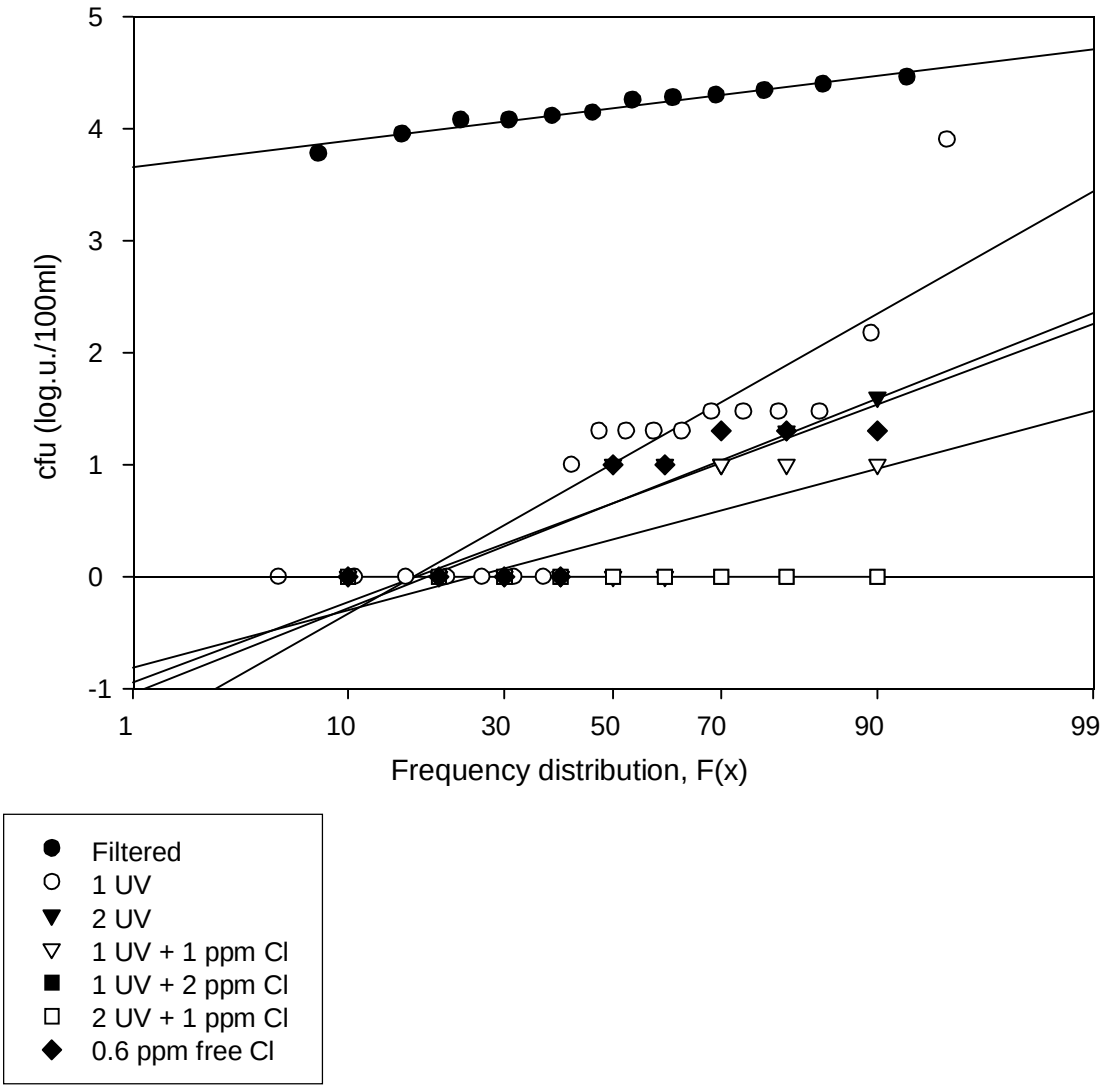
Sampling conditions		Bacteria, cfu/100 ml		Somatic coliphages, pfu/100 ml	*Cryptosporidium* spp.					Enteroviruses pfu/l
Date	Sample	*E. coli*	Sulphite-reducing clostridia		Total oocysts/l	Viable oocysts/l	Infectious oocysts/l	Viability %	Infectivity %	
08/05/2006	B1UV	< 10	700	10						
09/05/2006	B1UV	< 10	600	4						
10/05/2006	B1UV	20	800	8						
15/05/2006	B1UV	30	100	5,2						
16/05/2006	B1UV	8,000	960	3420						
17/05/2006	B1UV	150	300	16.4						
08/05/2006	C1UV	< 10	400	9.6						
09/05/2006	C1UV	< 10	100	2						
10/05/2006	C1UV	< 10	600	2.3						
15/05/2006	C1UV	20	300	10						
16/05/2006	C1UV	30	800	17.2						
17/05/2006	C1UV	30	60	4						
22/05/2006	A2UV	10	50	14.8	0.237	0.059	< 0.014	25.0	< 5.9	< 0.01
23/05/2006	A2UV	10	90	5,2						
25/05/2006	A2UV	40	30	7						
22/05/2006	B2UV	< 10	70	10.8						
23/05/2006	B2UV	20	60	11.6						
25/05/2006	B2UV	< 10	60	5						
22/05/2006	C2UV	< 10	100	14.8						
23/05/2006	C2UV	< 10	120	2.8						
25/05/2006	C2UV	10	40	3						

Sampling conditions		Bacteria, cfu/100 ml		Somatic coliphages, pfu/100 ml	Cryptosporidium spp.					Enteroviruses pfu/l
Date	**Sample**	***E. coli***	**Sulphite-reducing clostridia spores**		**Total oocysts/l**	**Viable oocysts/l**	**Infectious oocysts/l**	**Viability %**	**Infectivity %**	
08/05/2006	A1UV1CL	< 10	200	1.6						
09/05/2006	A1UV1CL	< 10	90	< 1						
10/05/2006	A1UV1CL	< 10	700	1.6	0.2	0.1	< 0.025	50.0	< 12.5	< 0.01
08/05/2006	B1UV1CL	< 10	300	4.4						
09/05/2006	B1UV1CL	< 10	800	< 1						
10/05/2006	B1UV1CL	10	1200	1.3						
08/05/2006	C1UV1CL	10	300	4.8						
09/05/2006	C1UV1CL	10	200	5						
10/05/2006	C1UV1CL	< 10	900	2.2						
15/05/2006	A1UV2CL	< 10	120	0.4	0.088	0	< 0.015	0.0	< 5	< 0.01
16/05/2006	A1UV2CL	< 10	800	0.4						
17/05/2006	A1UV2CL	< 10	500	0.4						
15/05/2006	B1UV2CL	< 10	200	0.8						
16/05/2006	B1UV2CL	< 10	550	< 0.4						
17/05/2006	B1UV2CL	< 10	500	0.8						
15/05/2006	C1UV2CL	< 10	100	0.4						
16/05/2006	C1UV2CL	< 10	700	8.4						
17/05/2006	C1UV2CL	< 10	40	0.4						

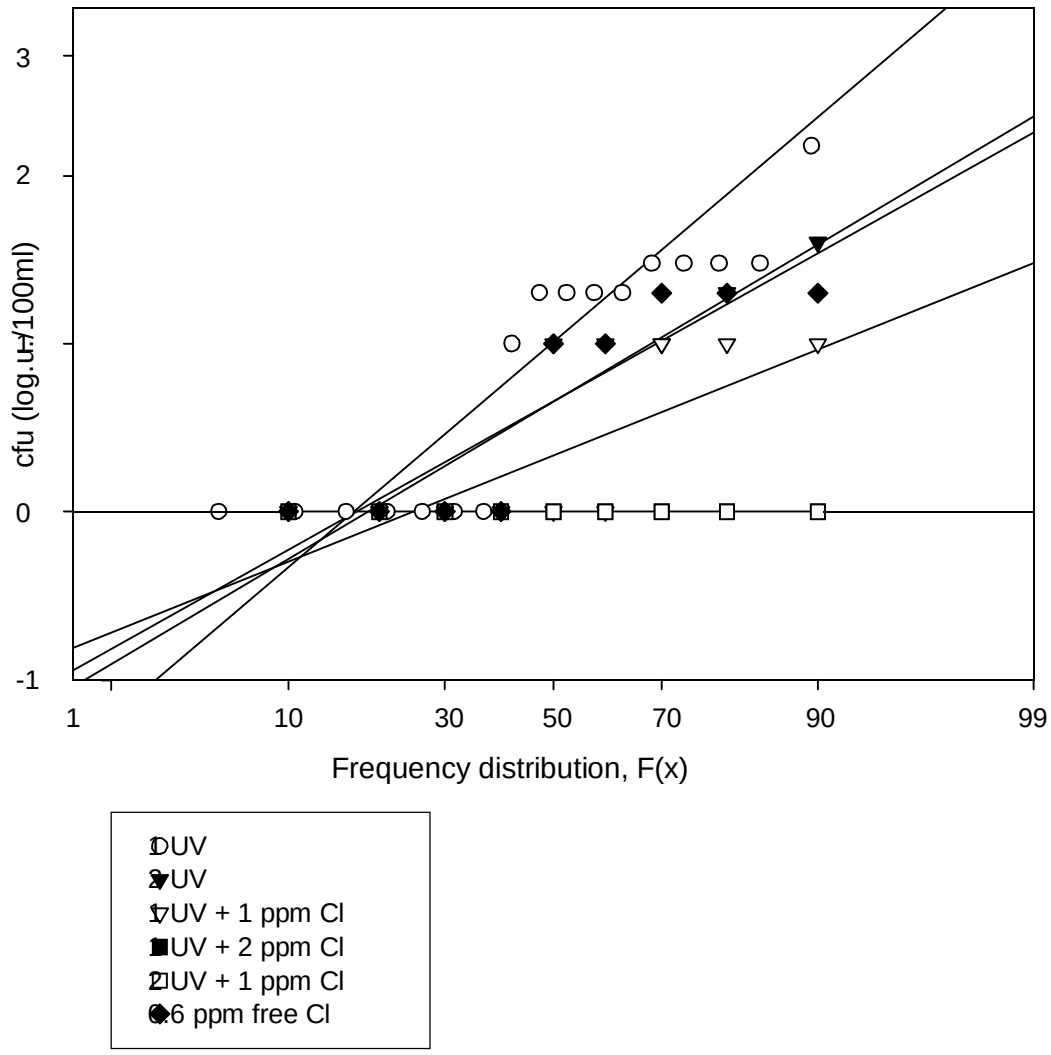
Sampling conditions		Bacteria, cfu/100 ml		Somatic coliphages, pfu/100 ml	*Cryptosporidium* spp.					Enteroviruses pfu/l
Date	Sample	*E. coli*	Sulphite-reducing clostridia spores		Total oocysts/l	Viable oocysts/l	Infectious oocysts/l	Viability %	Infectivity %	
22/05/2006	A2UV1CL	< 10	100	3.2	0.06	0	<0.014	0.0	<23.3	<0.01
23/05/2006	A2UV1CL	< 10	70	2						
25/05/2006	A2UV1CL	< 10	50	1						
22/05/2006	B2UV1CL	< 10	110	1.6						
23/05/2006	B2UV1CL	< 10	80	1.6						
25/05/2006	B2UV1CL	< 10	50	2						
22/05/2006	C2UV1CL	< 10	90	1.2						
23/05/2006	C2UV1CL	< 10	90	2.4						
25/05/2006	C2UV1CL	< 10	80	<1						
29/05/2006	A0.6CL	20	800	51	0.05	0.0165	0.0143	33.0	28.6	< 0.01
30/05/2006	A0.6CL	< 10	700	23						
31/05/2006	A0.6CL	10	1,400	4,050						
29/05/2006	B0.6CL	< 10	700	44.8						
30/05/2006	B0.6CL	< 10	400	18						
31/05/2006	B0.6CL	10	1,200	5,800						
29/05/2006	C0.6CL	20	1,000	34.8						
30/05/2006	C0.6CL	< 10	600	24						
31/05/2006	C0.6CL	20	2,400	7,100						

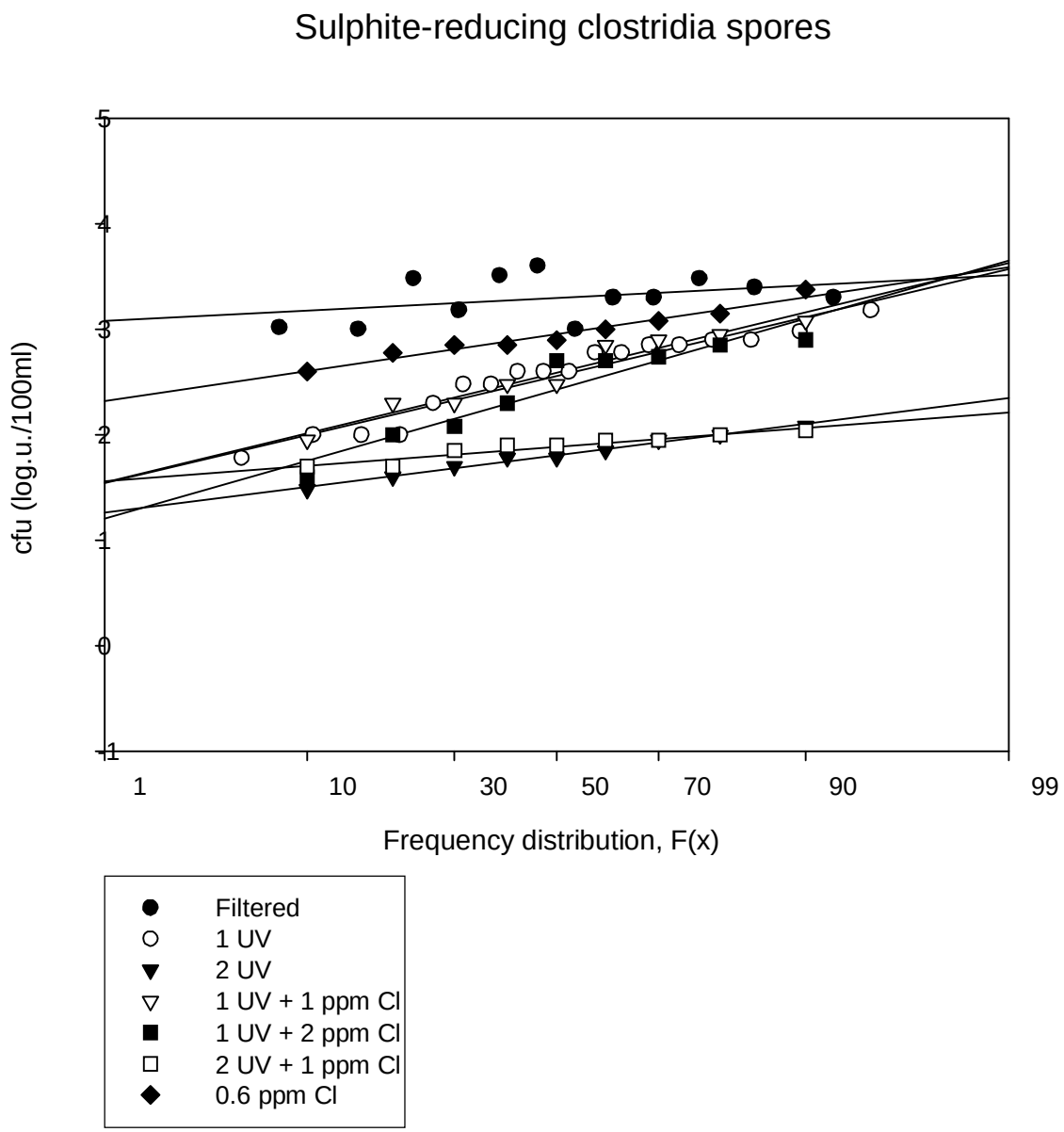
Appendix III

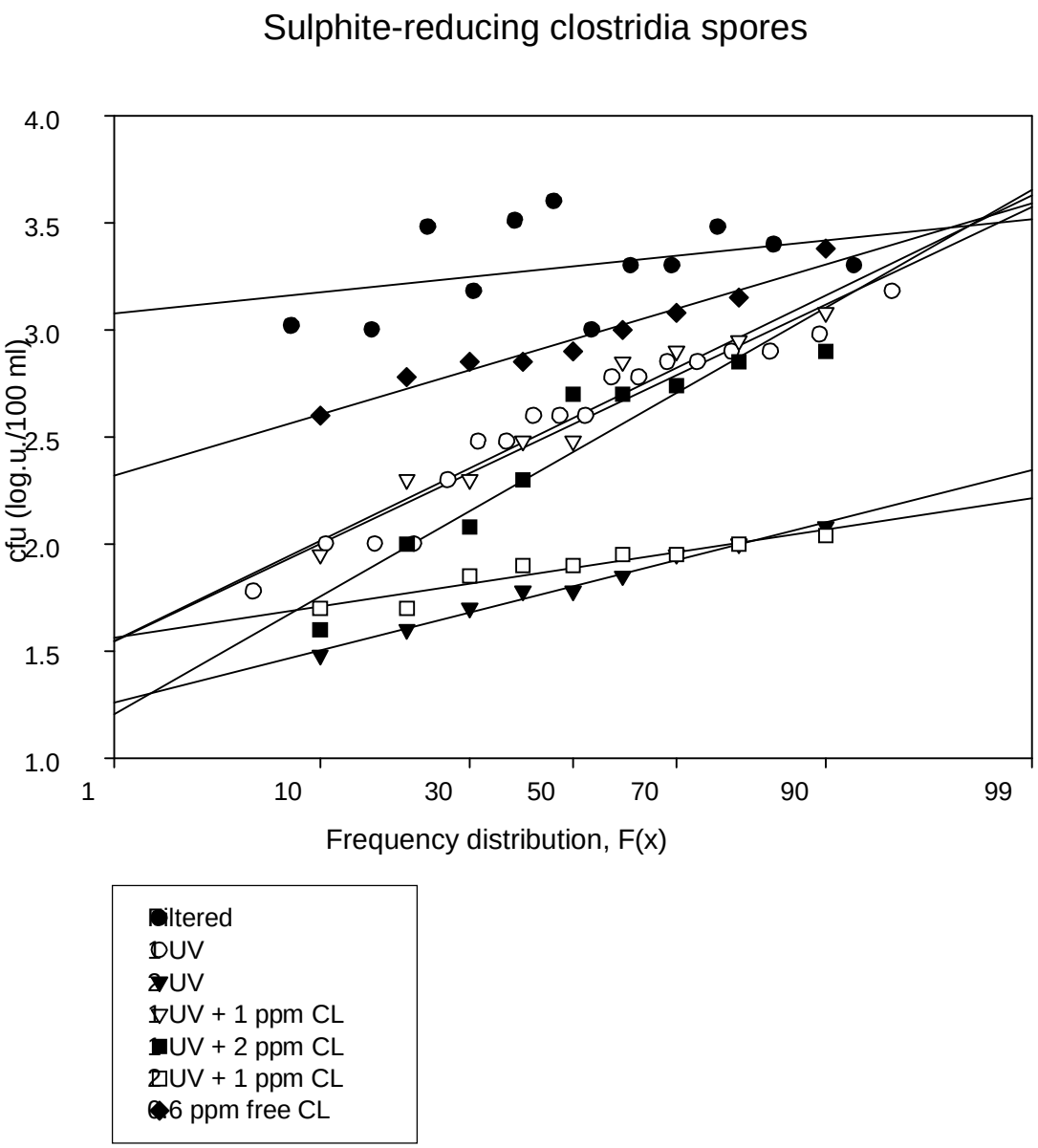
E. coli

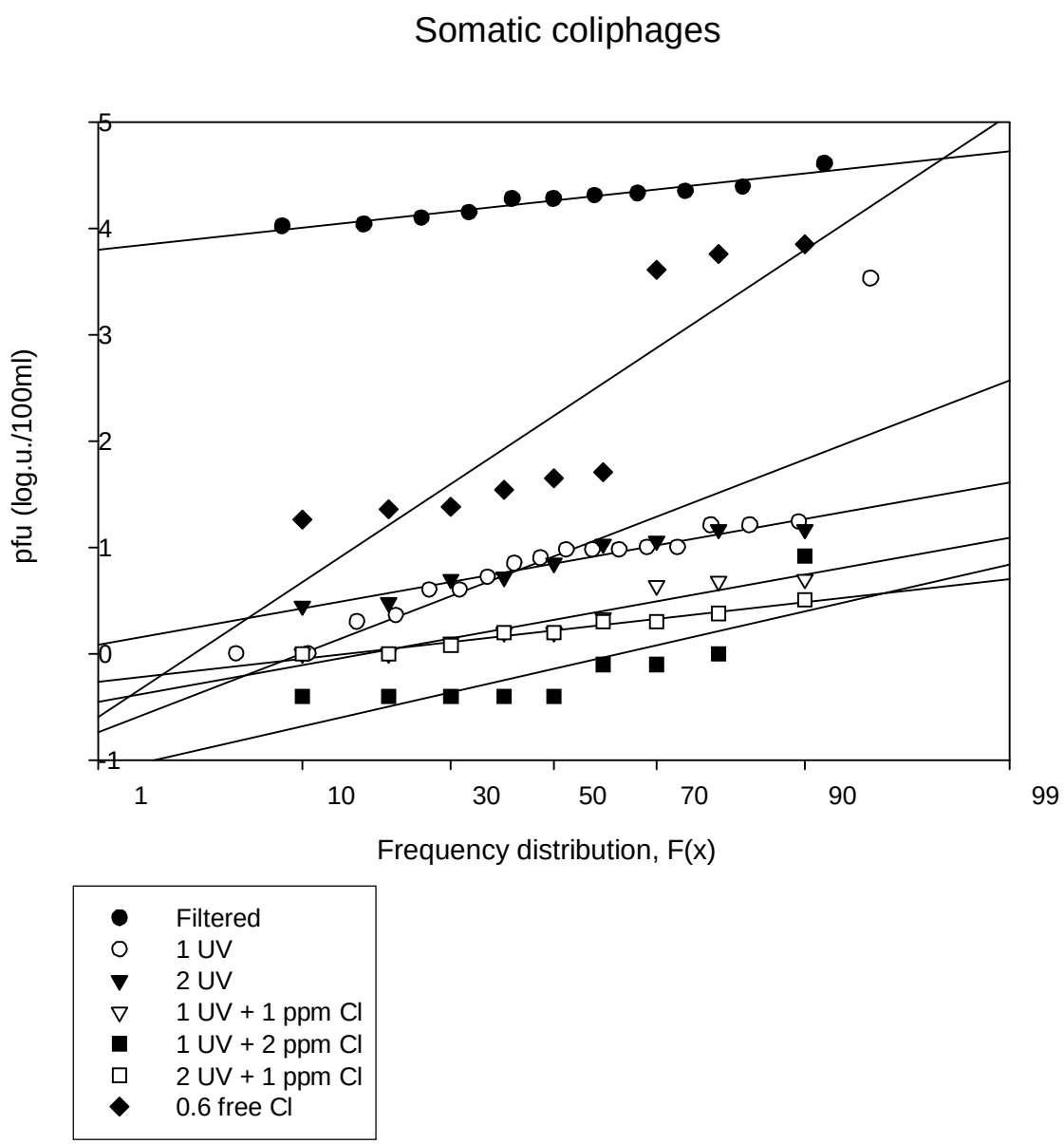


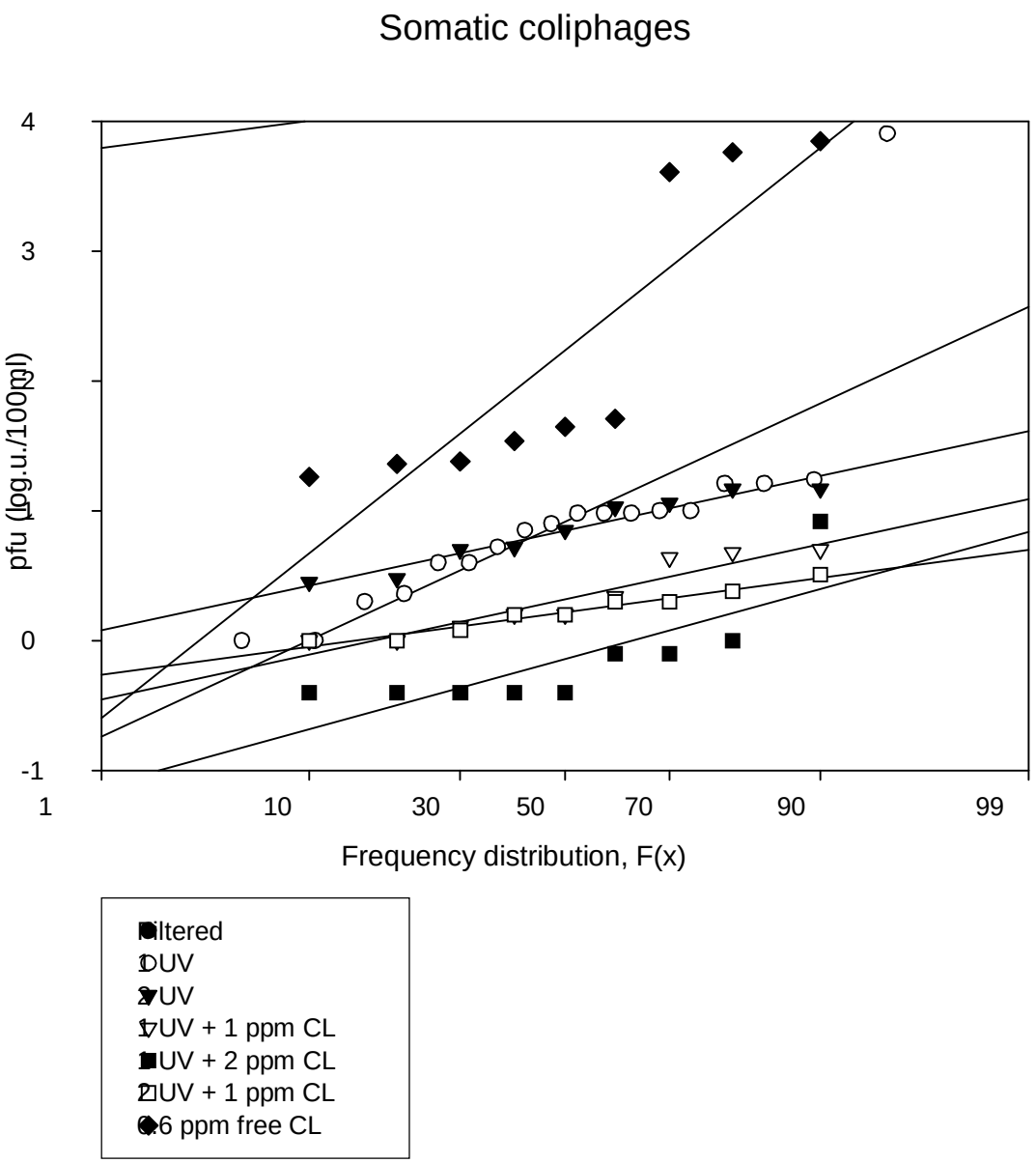
E. coli


3
2
0
-1
cfu (log.u.f./100ml)
1
10
30
50
70
90
99
Frequency distribution, F(x)
1 UV
2 UV
17 UV + 1 ppm Cl
1 UV + 2 ppm Cl
2 UV + 1 ppm Cl
6 ppm free Cl


Sulphite-reducing clostridia spores
cfu (log.u./100ml)
5
4
3
2
1
0
-1
1
10
30
50
70
90
99
Frequency distribution, F(x)
Filtered
1 UV
2 UV
1 UV + 1 ppm Cl
1 UV + 2 ppm Cl
2 UV + 1 ppm Cl
0.6 ppm Cl


Sulphite-reducing clostridia spores
4.0
3.5
3.0
2.5
2.0
1.5
1.0
cfu (log.u./100 ml)
1
10
30
50
70
90
99
Frequency distribution, F(x)
Filtered
UV
UV
UV + 1 ppm CL
UV + 2 ppm CL
UV + 1 ppm CL
6 ppm free CL


Somatic coliphages
pfu (log.u./100ml)
5
4
3
2
1
0
-1
1
10
30
50
70
90
99
Frequency distribution, F(x)
Filtered
1 UV
2 UV
1 UV + 1 ppm Cl
1 UV + 2 ppm Cl
2 UV + 1 ppm Cl
0.6 free Cl


Somatic coliphages
4
3
2
1
0
-1
pfu (log.u./100ml)
1
10
30
50
70
90
99
Frequency distribution, F(x)
Filtered
UV
UV
UV + 1 ppm CL
UV + 2 ppm CL
UV + 1 ppm CL
6 ppm free CL