Process Reliability and Significance of Reclaimed Water Quality Parameters

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Introduction

- Water quality evaluation is a necessary step to determine compliance with applicable criteria and standards
- Statistical methods have become common tools
  - To assess process performance
  - To assess process reliability
- That information is also very useful for developing simulation studies on the public health risks of using reclaimed water

Objectives

- To statistically quantify microbial
  - Inactivation efficiency
  - Performance reliability
- Several water reclamation processes
- At 3 different water reclamation facilities
- During a 2-year follow-up study
- To determine
  - The extent and significance of bacterial inactivation
  - Changes in process reliability

Study Program

- A field study, under normal operating conditions
- Of 3 water reclamation facilities in Catalonia:
  - WRP Castell Platja d'Aro
  - WRP Empuriabrava
  - WRP Mataró
- Sampling points for each individual process
- 40 samples at each sampling point:
  - 2-year study: March 2003 to January 2005
  - 4 sampling seasons, one week each
  - 5 working days per weak
- Interpretation with lognormal probability distribution

Bacterial Indicators

- Common faecal indicators:
  - Total coliforms
  - Faecal coliforms
  - E. Coli
  - Faecal enterococci
- Membrane filtration method
- Detection limits
  - 1 cfu/100ml in secondary effluents
  - 1 cfu/litre in disinfected reclaimed water

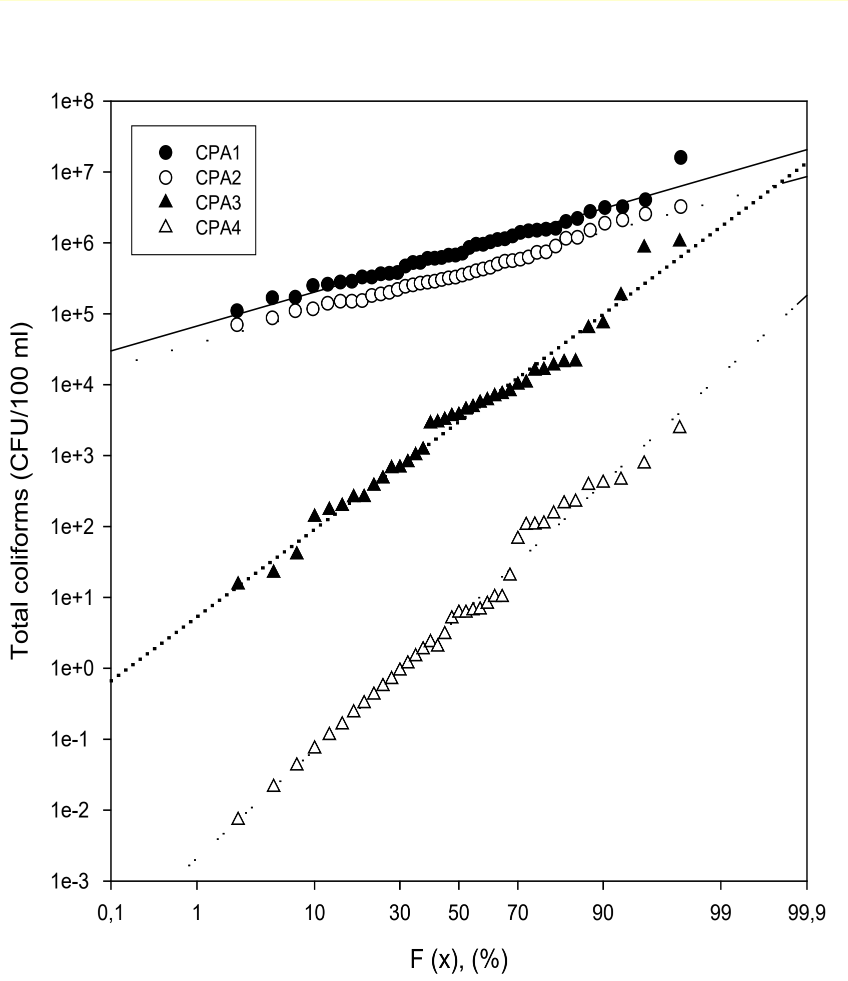
Statistical Methods

- Graphical adjustment to lognormal probability distribution
- Kolmogorov-Smirnov goodness-of-fit test
- Standard deviation: $s = \log X84 - \log X50$
- ANOVA test
- SPSS 14.0 for Windows for statistical analysis
  - F test and T-student test for equality of means
  - Levene test for equality of variances
  - Student-Newman-Keuls for equal variances
  - Tamhane test for different variances

WRP Castell Platja d'Aro

- 600 m^3/hr
- Coagulation (optional)
- Rapid sand filtration
- UV light disinfection with 25 to 35 mJ/cm^2
- Chlorine disinfection with 5 mg Cl_2/l, and Cxt = 80 - 135 mg Cl_2.min/l

WRP Castell Platja d'Aro



- Filtration and coagulation achieve insignificant inactivation
- Inactivation occurs during UV light exposure
- UV disinfection is affected by transmittance (%)
- Subsequent chlorine improves performance, but not reliability

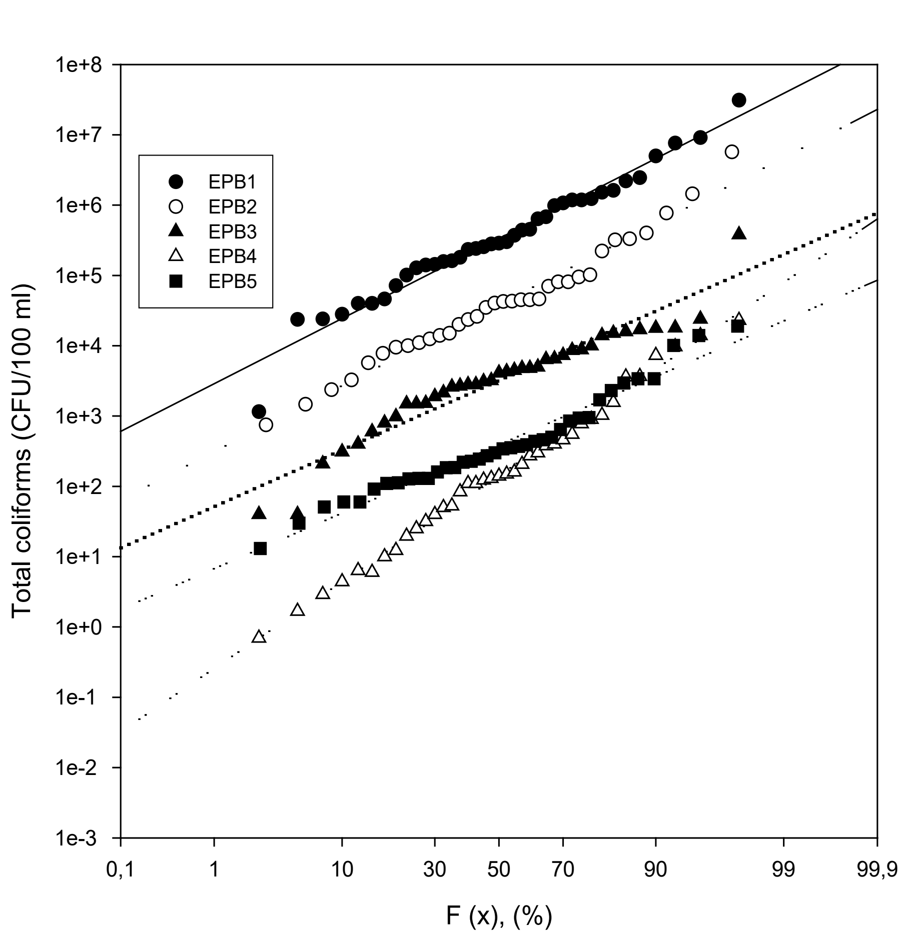
UV Light and Chlorine Disinfection

Microorg.	No.	Inactivation ulog/100 ml	Stand. Dev. (ulog)
TC	118	2.115 + 2.745 = 4.860	CPA2: 0.409; CPA3: 1.113; CPA4: 1.374
FC	118	2.149 + 3.594 = 5.743	CPA2: 0.621; CPA3: 1.289; CPA4: 1.602
EC	118	2.141 + 2.674 = 4.825	CPA2: 0.652; CPA3: 1.216; CPA4: 1.099
FE	117	1.926 + 2.518 = 4.444	CPA2: 0.515; CPA3: 1.228; CPA4: 1.316

WRP Empuriabrava

- Up to 8,750 m3/day
- 1,800 to 5,600 m^3/day
- Secondary sedimentation
- Stabilization pond
- Polishing pond
- 7,0 ha constructed wetland
- 2,5 ha vegetated cells
- 4,5 ha shallow lagoon

WRP Empuriabrava



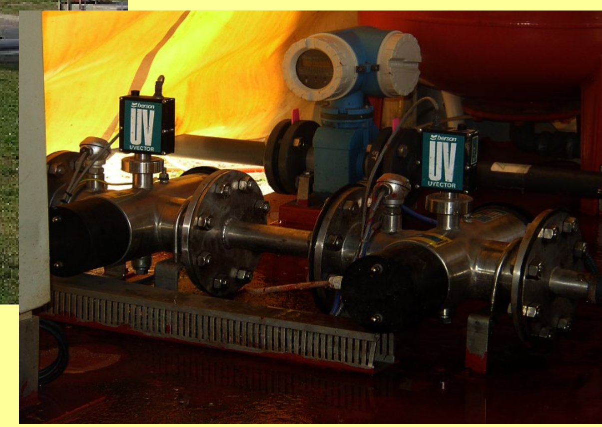
- Inactivation increases steadily as water flows
- Quality deteriorates at storage lagoon
- Time variability remains stable through the processes, including storage lagoon

Stabilization and polishing pond, wetland and storage lagoon

Microorg.	No.	Inactivation (ulog/100ml)	Stand. Dev. (ulog)
TC	151	0.941+1.080+1.348= 3.369	EPB1: 0.841; EBP2: 0.841 EPB3: 0.747; EPB4: 1.103
FC	151	1.077+0.923+1.602= 3.602	EPB1: 0.682; EBP2: 0.809 EPB3: 0.687; EPB4: 1.040
EC	151	0.943+1.141+0.974= 3.058	EPB1: 0.719; EBP2: 0.750 EPB3: 0.732; EPB4: 0.792
FE	151	0.701+0.859+0.665= 2.225	EPB1: 0.590; EBP2: 0.716 EPB3: 0.636: EPB4: 1.045

WRP Mataró

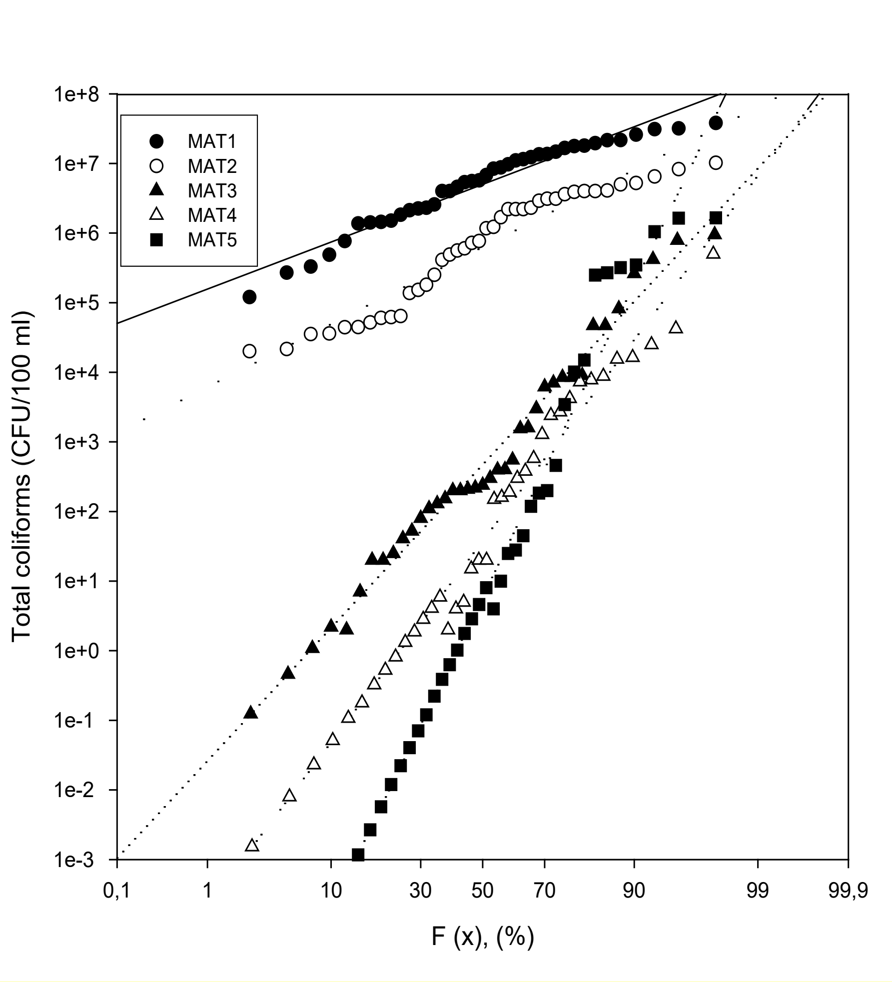
20 m^3/day



Full physico-chemical treatment

Disinfection:
UV light 35 to 45 mJ/cm^2
Chlorine 3-6 mg Cl_2/l 90 min

WRP Mataró



- Significant inactivation by physico-chemical
- UV light and chlorine: main inactivation
- UV light is affected by water transmittance
- Chlorine improves efficiency, with slight change of reliability
- Need for closer control of disinfection process

Phys-Chem, UV and Chlorine

Microorg.	No.	Inactivation (ulog/100ml)	Stand. Dev. (ulog/100 ml)
TC	159	0.900+3.123+1.899= 5.922	MAT1: 0.619; MAT2: 0.835 MAT3: 1.717; MAT5: 3.300
FC	159	1.061+2.953+2.258= 6.272	MAT1: 0.586; MAT2: 1.005 MAT3: 1.535; MAT5: 3.324
EC	159	0.945+3.106+2.756= 6.807	MAT1: 0.662; MAT2: 0.957 MAT3: 1.903; MAT5: 3.832
FE	160	1.573+2.246+2.435= 6.254	MAT1: 0.550; MAT2: 1.194 MAT3: 1.592; MAT5: 2.949

Indicators Evaluation

- A comparative analysis:
  - Total coliforms
  - Faecal coliforms
  - *E. coli*
  - Faecal enterococci
- Ranging in 0 – 100 cfu/100 ml
- *E. coli* values were higher than total coliforms
  - Only 4 out of 40 at WRP Castell Platja d'Aro and Empuriabrava
  - Only 3 out of 20 at WRP Mataró
- TC could be preferred indicators for simplicity

Conclusions

- Evaluation using a lognormal distribution helps to verify conformity and to estimate reliability
- The method provides basic references for:
  - Defining consistent regulatory limits
  - Determining regulatory compliance
  - Controlling reclamation processes and facilities
  - Evaluating new processes performance and reliability
  - Elaborating risk simulation methods
- Full physico-chemical treatment inactivates 1.0 ulog/100ml, with reliability < 1.0 (ulog)
- Inactivation is insignificant without coagulant

Conclusions

- Sand filtration followed by disinfection, and 3-step natural process effectively inactivate faecal indicators
- Dissolved organic matter significantly affects performance and reliability of UV light
- Although processes may reach up to 6.0 ulog inactivation, reliability deteriorates to 3.0 (ulog)
- Natural processes (6 days in summer and 17 days in winter) provide 3.0 – 3.5 ulog inactivation, with high reliability, 0.65-1.0 (ulog)

Thank you

for your attention