Microbial quality of swimming pool water

Treatment without disinfection, with ultrafiltration, with UV-based treatment and chlorination (PPT)

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Van Remmen UV Techniek

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Microbial quality of swimming pool water

Treatment without disinfection, with ultrafiltration, with UV-based treatment and chlorination

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Alternative disinfection

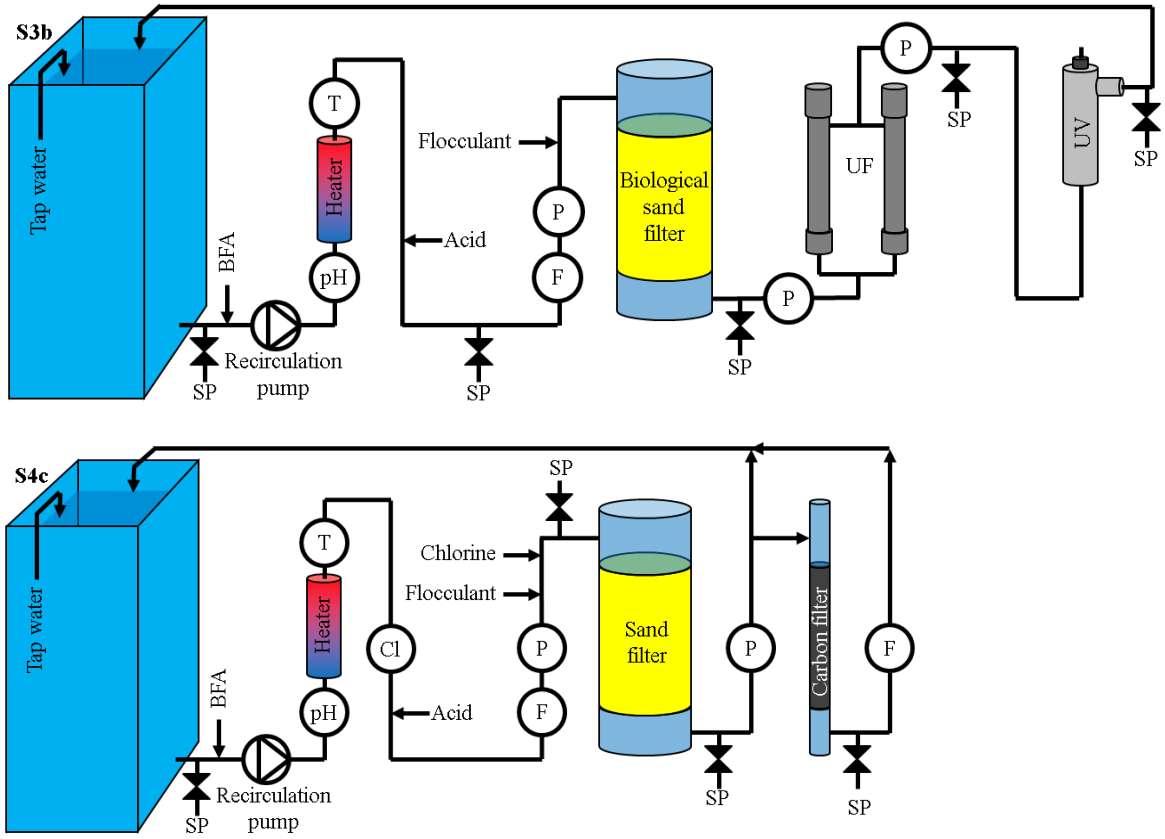
- $UV+H_2O_2$ (Crandall ‘86, Dingman ‘90, Savino et al. ‘93)
- UV in drinking water treatment (Hijnen 2006)
- Ultrafiltration (van der Bruggen et al. 2003)
- UV in pool water (Caramello and Amisano 2001, Sobótka and Krysztofik 1984)
- Ultrafiltration (DIN 19643-4)
- Natural waters (Giampaoli eo al. 2014)

DIPool project

- Disinfection with ultrafiltration and UV-treatment every 30 minutes
- Reduction of nutrients with biological filtration

Goal: Investigate microbial water quality with UV-based treatment and influence of individual treatment steps

Experimental setup



Microbial water quality

- Intact cell count (iCC) with flow cytometry
- Intracellular ATP (cATP)
- 2x per week in duplo

- iCC + cATP → metabolic state
- Tendency for overestimated results

Main design specifications

- Turnover: 30 min
- (re)circulation: 1 m^3/h
- Setup volume: 500L
- Pool tank hydraulics:
  - Chlorination → well mixed
  - UV-based treatment → plug flow

Specific design specifications

- Biological sand filtration: 14-17 m/h
- Ultrafiltration:
  - 86 l/m2/h
  - 100-150 kD MWCO
- UV dose: 400 J/m^2

- Sand filtration: 14 m/h
- Biological activated carbon filtration:
  - 10% side stream
  - 19 m/h
  - Norit PK1-3

Experiments

Without recirculation:

- Maximum concentration of nutrients
- Investigate influence treatment steps

With recirculation:

- Influence repetitive treatment and accumulation

Experiments without recirculation

- Biological sand filtration (BSF)
- BSF + ultrafiltration (UF)
- UV + BSF + UF
- UV + BSF + UF (25% BFA)
- Sand filtr. (SF) + chlorination

NPOC (mg/L)	TN (mg/L)	PO_4 (mg/L)
2.0	4.0	0.5
2.0	4.0	0.5
2.0	4.0	0.5
0.5	1.0	0.5
2.0	4.0	0.5

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Experiments with recirculation

- BSF + UF + UV
- SF + chlorination

	NPOC (µg/L)	TN (µg/L)	PO_4 (µg/L)
With PO_4	32	64	2.4
Without PO_4	32	64	0.0

- 10 h/d (continual + accidental) → BFA

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Body Fluid Analogue (BFA)

Components

- Urea (95% of all N)
- Creatine monohydrate (5% of all N)
- Sodium citrate (all remaining C)
- Potassium hydrogen phosphate

- Cold stored, refreshed weekly

Settings

- Water temperature: 30-32 °C
- pH: 7.4

- Free chlorine: 0.3-0.5 mg/L

- Duration of each experiment: 23 days

Equipment preparation

Before each experiment:

- Chemical cleaning sampling tubes
- Chemical cleaning UF
- Backwash filters (SF, BSF BACF)

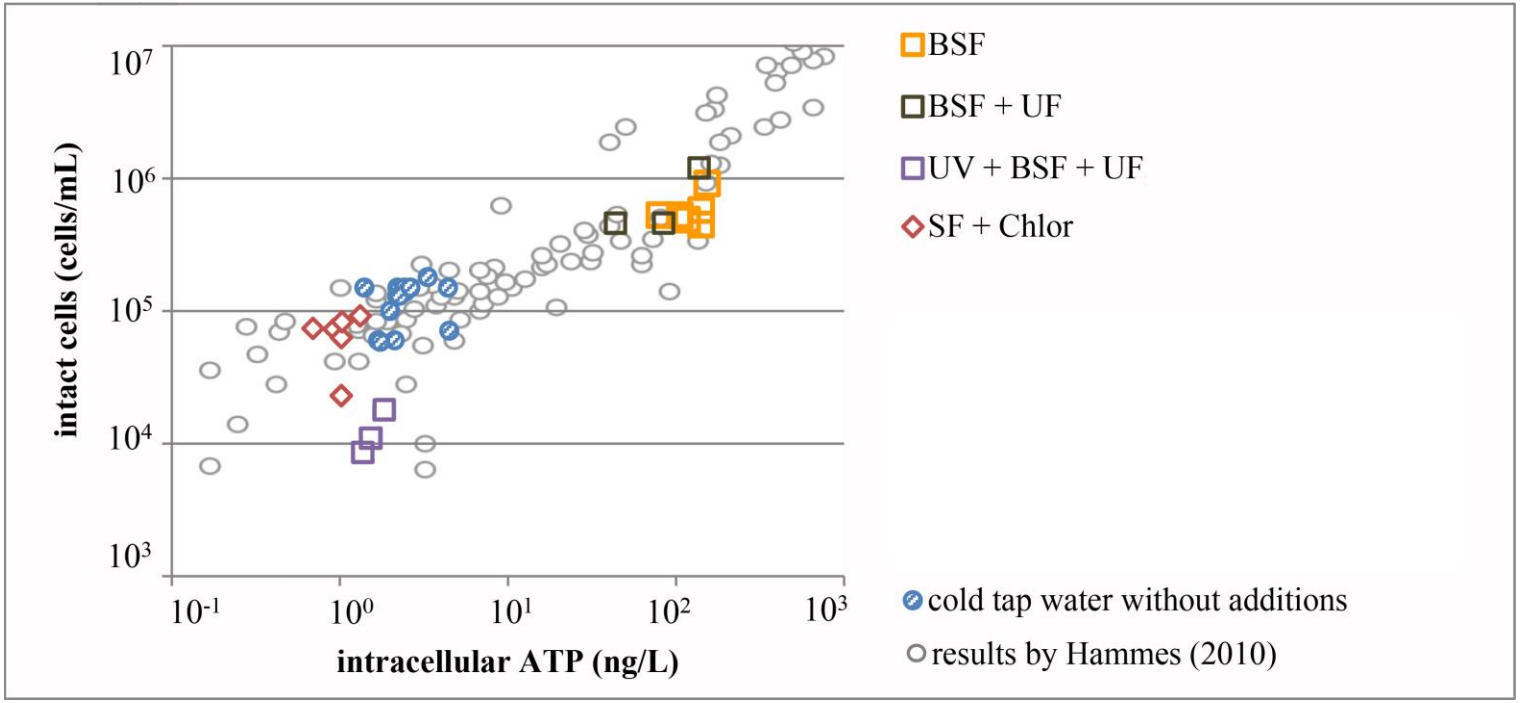
Sampling + analysis

- Constantly running sampling points
- Sampling 2x per week

Analysis in duplo:

- iCC (BD Accuri C6® fow cytometer)
- cATP (Junior LB 9509 Luminometer, Aquatools)

Results (without recirculation)



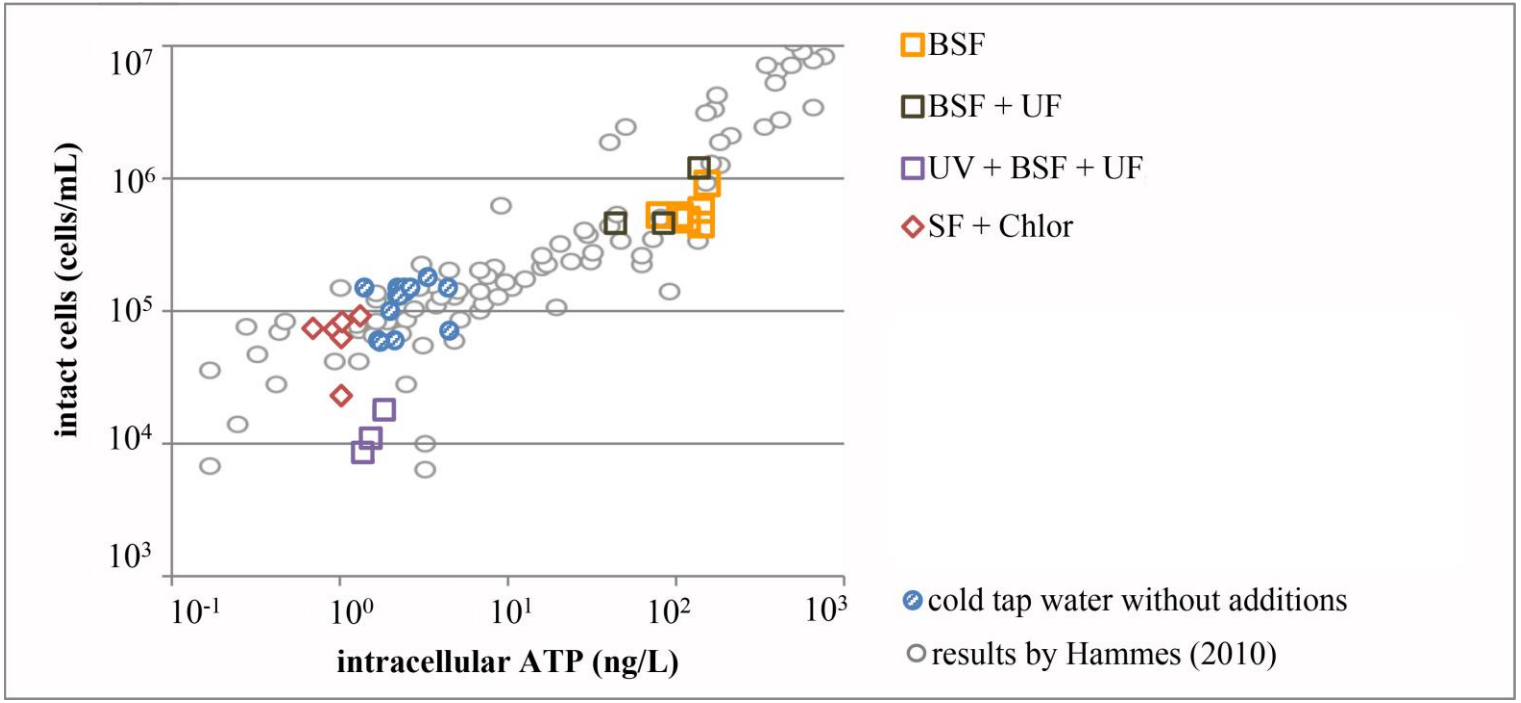
Results (exp. without recirculation)

Results after 16, 21 and 23 days min-max (average)	cATP ng/L	iCC Mcells/L	ATP/cell ag/cell
UV + BSF + UF 100% BFA	1.4-1.8 (1.6)	8.6-18 (12.5)	102-159 (133)
UV + BSF + UF 25% BFA	0.8-1.4 (1.1)	9.3-13 (11.1)	58-148 (102)

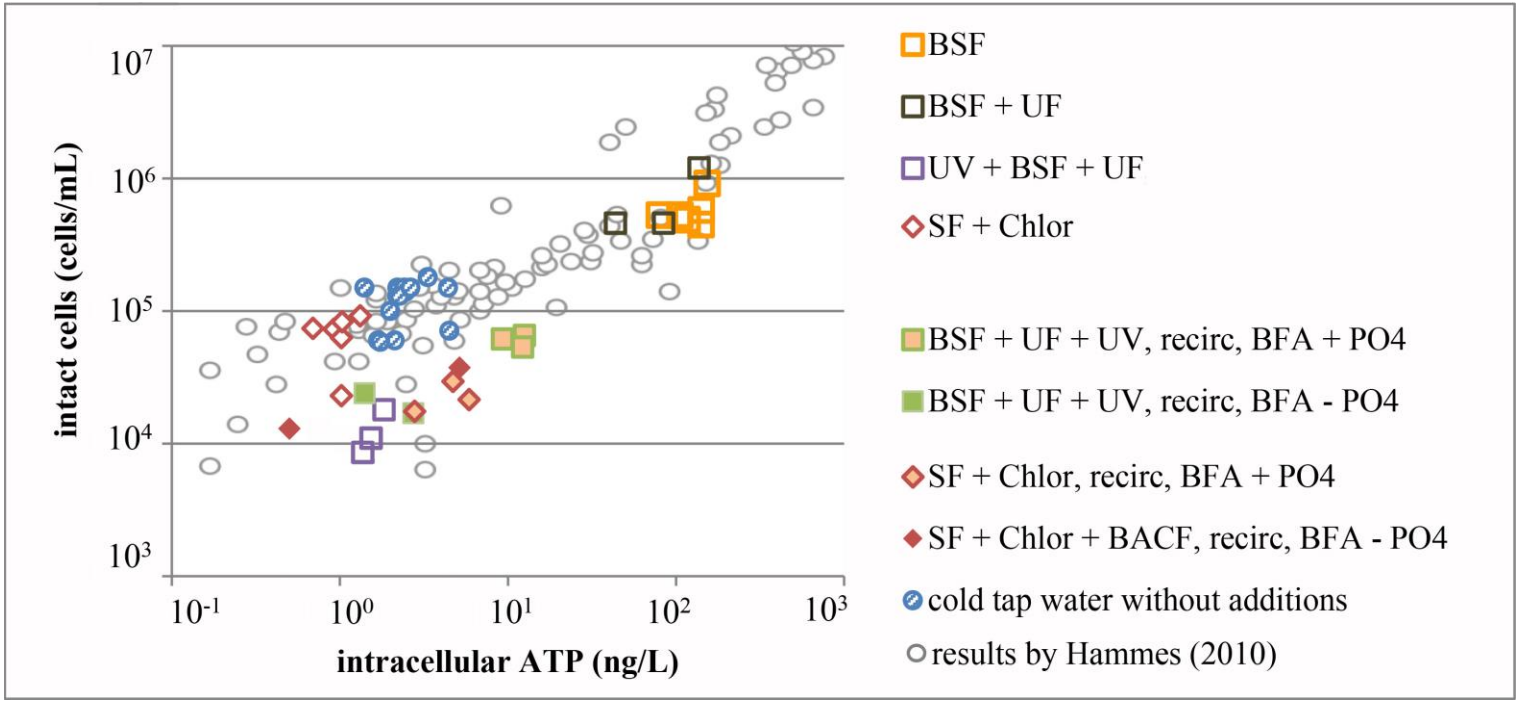
Influence treatment steps
(with recirculation)

		-log (C/C_0)	cATP	iCC
BSF (no disinfection)	BSF	0.17	-0.21
BSF + UF	BSF	-0.03	-0.03
	UF	0.16	-0.09
UV + BSF + UF	UV	0.19	-0.04
	BSF	0.22	0.08
	UF	1.40	1.47
SF + Chlorination	SF (without flocculation)	-0.28	0.27

Results (without recirculation)



Results (with recirculation)



Results (exp. with recirculation)

Results after 16, 21 and 23 days min – max (average)	cATP ng/L	iCC Mcells/L	ATP/cell ag/cell
BSF + UF + UV (BFA + PO_4)	9.3-13 (11)	54-66 (60)	151-228 (190)
BSF + UF + UV (BFA – PO_4)	1.4-2.7 (2.1)	17-24 (21)	58-161 (109)
SF + chlorination (BFA + PO_4)	2.8-5.9 (4.5)	18-30 (23)	159-273 (197)
SF + chlorination (BFA – PO_4)	0.5-5.1 (2.8)	13-38 (25)	38-137 (88)
Cold tap water	1.4-4.5 (2.4)	59-150 (98)	15-35 (21)

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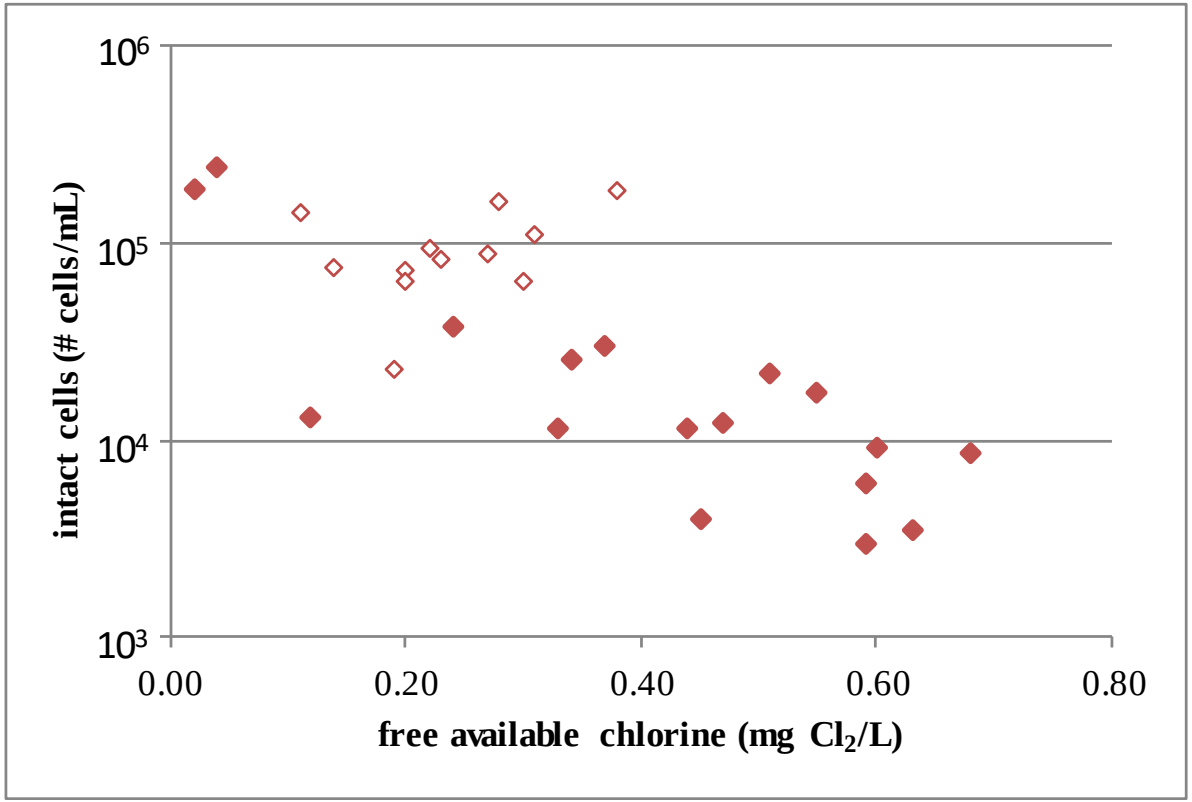
Influence treatment steps
(with recirculation)

		-log (C/C_0)	cATP	iCC
UV-based treatment	Pool tank residence	-0.93	-0.82
	Chemical addition	0.20	0.05
	BSF	0.10	0.29
	UF	0.50	0.60
	UV	0.13	-0.12
Chlorination-based treatment	Pool tank residence	-0.31	-0.44
	Chemical addition	0.33	0.26
	SF (with flocculation)	0.21	0.39

Influence FAC concentration



Conclusions to microbial water quality

- UV-based pool water similar to chlorinated pool water
- UF is important treatment step
- SF + flocculation improves water quality
- C-limitation is not likely in pool water
- P-limitation can be additional restrain

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Thanks for your attention

Questions ?

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