QMRA of an indoor swimming pool

Chlorination versus UV-based treatment (PPT)

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QMRA of an indoor swimming pool

Chlorination versus UV-based treatment

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Alternative disinfection

- Good microbial water quality with UV-based treatment
- What are the risks of infection compared to chlorination?

Quantitative Microbial Risk Assessment (QMRA)

QMRA parameters (swimming pool)

- Competition pool: 25x10x2 m^3
- Turnover time:
  - Chlorinated: 4 h
  - UV-based treatment: 30 min
- bathing load: 40 bathers /h
- Swimming: 12h /day

QMRA parameters (micro-organisms)

- *Campylobacter jejuni*
- *Escherichia coli* O157:H7
- *Salmonella enterica*
- *Cryptosporidium parvum*

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Micro-organism release

- Enterobacter release bathers: 9% (Peters et al. 2016)
- Intact cell release distribution (Keuten et al. 2013)
  - 0-5 min: 3.0×10^9 intact cells → 1.06 g faecal matter
  - 6-10 min: 2.7×10^9 intact cells → 979 mg faecal matter
  - 11-15 min: 1.4×10^9 intact cells → 518 mg faecal matter
  - 16-20 min: 1.3×10^9 intact cells → 473 mg faecal matter
  - 21-25 min: 0.4×10^9 intact cells → 158 mg faecal matter
  - 26-30 min: 0.4×10^9 intact cells → 143 mg faecal

Pathogen release

- Faecal matter: 10^8 pathogens /g
- Pathogens within (de Wit et al. 2001):
  - *Campylobacter jejuni*: 1.3%
  - *Escherichia coli* O157:H7: 0.3%
  - *Salmonella enterica*: 0.4%
  - *Cryptosporidium parvum*: 0.1%
- Pool basin is homogeneously mixed

QMRA parameters (bathers)

- Swim duration: 1h
- 59 swimming events per year
- 100% pre-swim shower
- Only continual release (no incidental)
- Water ingestion: 13,7 mL / bather (Suppes et al. 2014)
- Infection probability NL: 283/1000 (de Wit et al. 2001)

Treatment

- Chlorination;
  - 3 log reduction in 1 minute (Blaser 1986)
    for *C. jejuni*, *E. coli* and *S. enterica*
  - *Cryptosporidium* removal by filtration
    1 log reduction per filter passage (Amburgey 2011)

- UV-based treatment
  - 5 log removal / inactivation per treatment

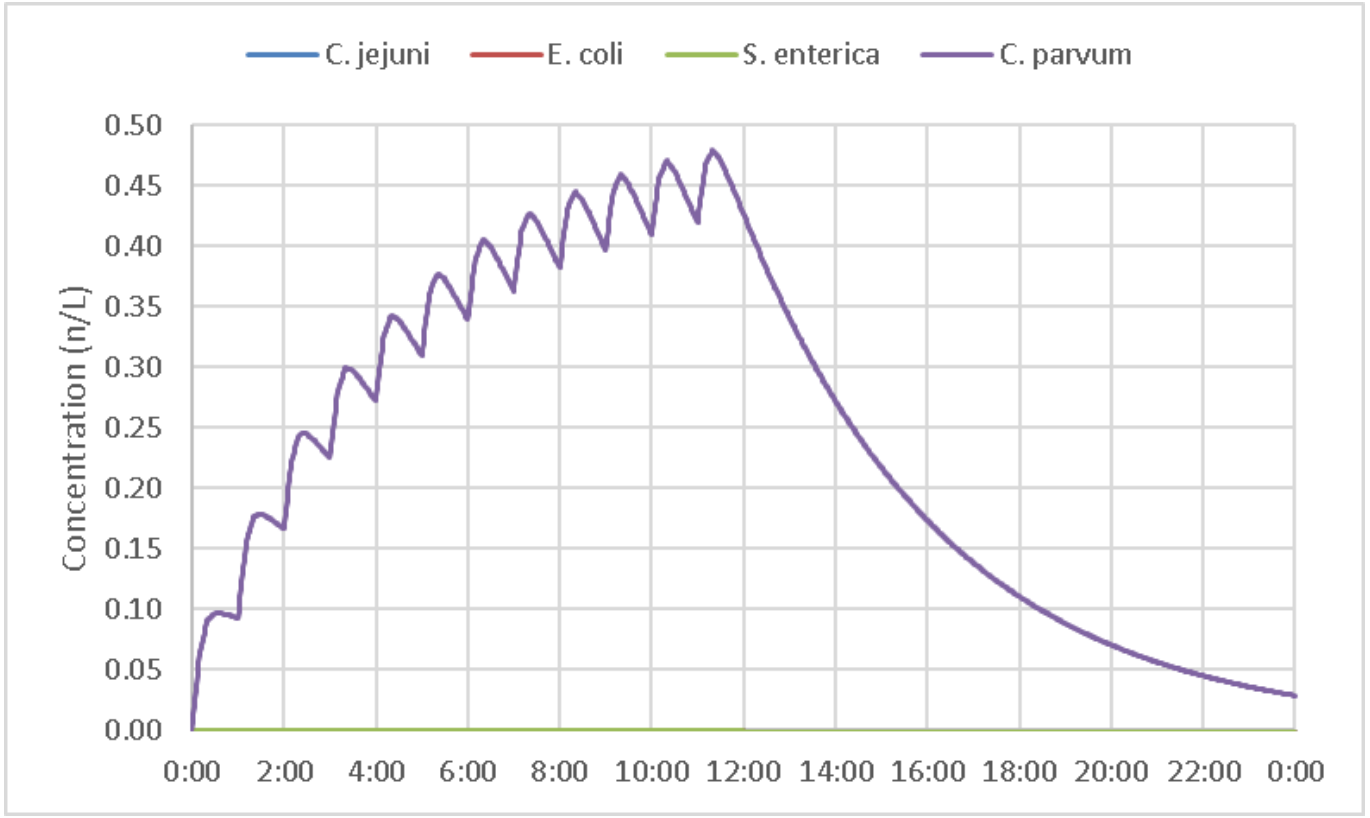
Dose response models

- Beta-Poisson model:

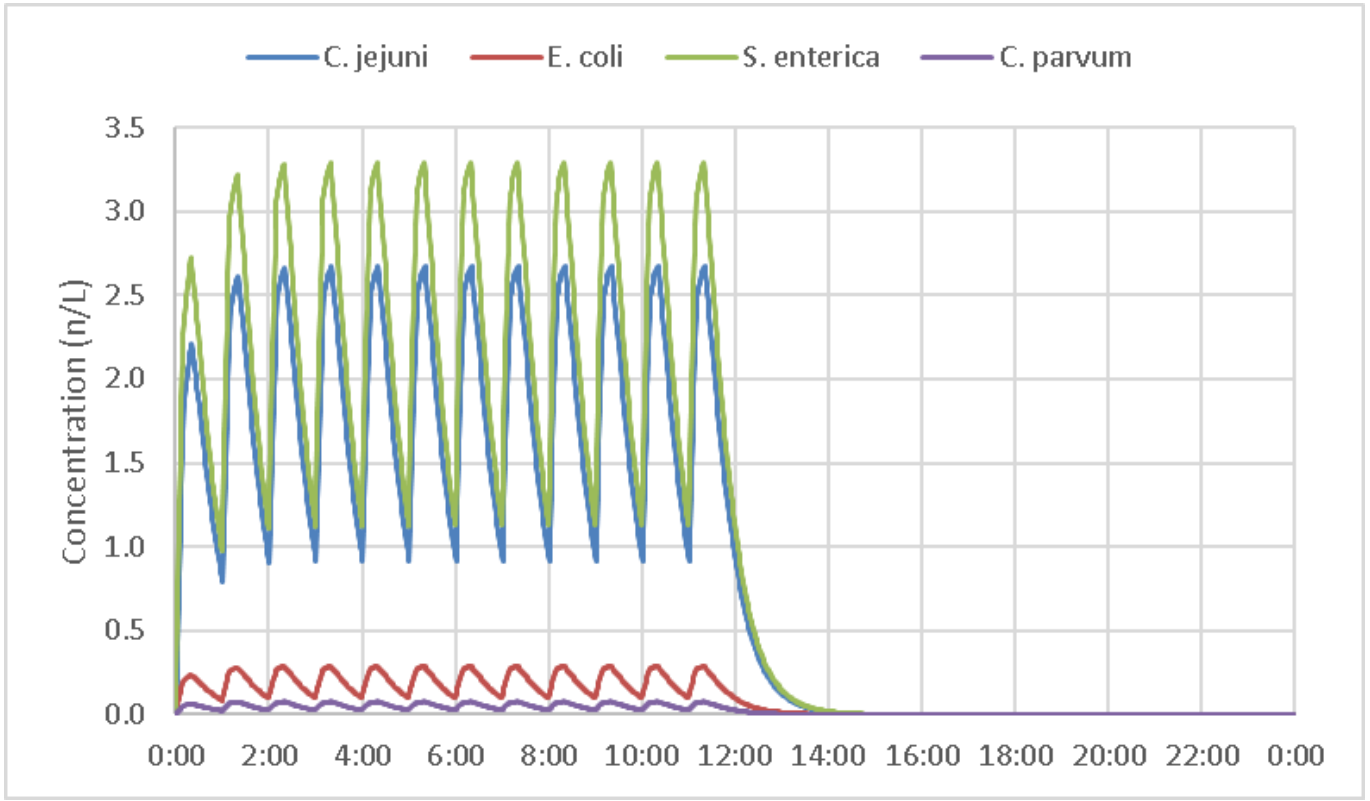
	α	β	
Campylobacter jejuni	0.144	7285	(Black et al. 1988)
Escherichia coli O157:H7	0.155	24386	(DuPont et al. 1971)
Salmonella enterica	0.175	10776	(Hornick 1966, 1970)

- Exponential model:
  - *Cryptosporidium*; k = 0.057 (Messner et al. 2011)

Results chlorination



Results UV-based treatment



Results

		Average concentration (n/L)	Dose (n/swim)	Infection risk	Yearly infection risk
C. jejuni	Chlorination	6.4×10^{-5}	8.8×10^{-7}	1.7×10^{-11}	1.0×10^{-9}
	UV-based	1.8	2.5×10^{-2}	4.8×10^{-7}	2.8×10^{-5}
E. coli	Chlorination	6.9×10^{-6}	9.5×10^{-8}	6.0×10^{-13}	3.6×10^{-11}
	UV-based	2.0×10^{-1}	2.7×10^{-3}	1.7×10^{-8}	1.0×10^{-6}
S. enterica	Chlorination	7.9×10^{-5}	1.1×10^{-6}	1.8×10^{-11}	1.0×10^{-9}
	UV-based	2.2	3.1×10^{-2}	5.0×10^{-7}	3.0×10^{-5}
C. parvum	Chlorination	3.3×10^{-1}	4.6×10^{-3}	4.3×10^{-3}	1.5×10^{-2}
	UV-based	5.2×10^{-2}	7.2×10^{-4}	6.9×10^{-4}	2.4×10^{-3}

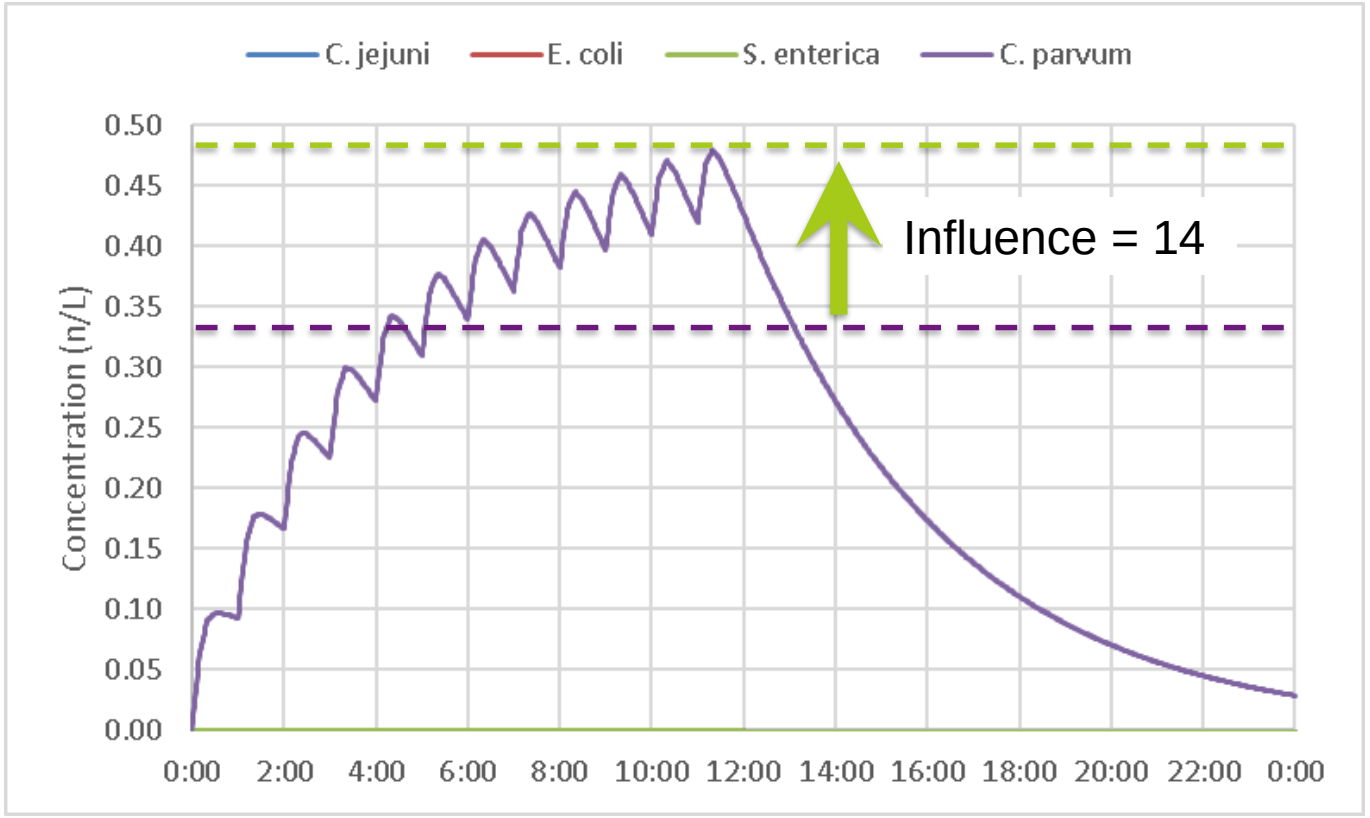
Sensitivity analysis for *E. coli* (UV-based treatment)

- Bathers / m^3: 40/500 → 10/5 (toddler or hwp)
- Turnover time: 30 → 240 min
- Treatment: 5-log → 1-log reduction
- Swimming events: 59 → 260 /year (5/wk)
- Simultaneous bathers: 40 → 108
- Infected bathers: 2/40 → 11/40
- Ingested pool water: 13.7 → 51 mL
- *E. coli* in faecal matter: 0.3% → 10%
- Pathogens in faeces: 10^8 → 10^{10}

Sensitivity analysis for *E. coli*

	Value Ref.	Value worst case	P[inf] ref	P[inf] max	Value max/ref	P[inf] max/ref	Influence
Bathers / m^3	12.5	0.5	$1.0x10^{-6}$	$2.5x10^{-5}$	0.04	25	625
Turnover time	30	240	$1.0x10^{-6}$	$6.0x10^{-6}$	8	5.95	0.7
Treatment eff.	0.99999	0.9	$1.0x10^{-6}$	$1.1x10^{-6}$	0.9	1.11	1.2
Swim events	59	260	$1.0x10^{-6}$	$4.5x10^{-6}$	4.4	4.4	1.0
Bathers	40	108	$1.0x10^{-6}$	$2.7x10^{-6}$	2.7	2.7	1.0
Infected bathers	5%	28%	$1.0x10^{-6}$	$5.6x10^{-6}$	5.56	5.56	1.0
Ingested water	13.7	51	$1.0x10^{-6}$	$3.8x10^{-6}$	3.72	3.7	1.0
***E.coli*% pathogens**	0.3%	10%	$1.0x10^{-6}$	$3.4x10^{-5}$	33.3	33.4	1.0
Path.in faeces	10^{8}	10^{10}	$1.0x10^{-6}$	$1.0x10^{-4}$	100	100	1.0

Moment of exposure



Conclusions

- Yearly risk of infection with UV-based treatment higher than treatment with chlorination
- All risks $<10^{-4}$, except for *Cryptosporidium*
- For *Cryptosporidium*, best removal with UV-based treatment

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Thanks for your attention

Questions ?

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