Risk based analysis for cyanobacteria in waste stabilisation ponds

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Waste stabilisation ponds (WSP)

- Treatment of sewage by natural processes
  → relies on healthy bacterial and algal communities
Cyanobacteria in waste stabilisation ponds
Cyanobacteria in waste stabilisation ponds

- Cyanobacteria can change pond ecology
- Cyanobacteria: cause or symptom of low performing ponds?
- Cyanobacteria are a risk to humans and the environment, especially where the effluent of WSP is reused
- Currently, in the presence of a bloom, the *precautionary principle* is followed, leading to potential losses in revenues
  → instigation of algal monitoring programs
- Problem: costs related to monitoring; limited budget; limited man-hours
- Therefore an optimised distribution of monitoring resources reduces risk and costs
Aim

To identify an optimum monitoring strategy for cyanobacteria and their toxins in waste stabilisation ponds across WA.
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Development of a new risk-based framework to guide investment in water quality monitoring

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Abstract An innovative framework for optimising investments in water quality monitoring has been developed for use by water and environmental agencies. By utilising historical data, investigating the accuracy of monitoring methods and considering the risk tolerance of the management agency, this new methodology calculates optimum water quality monitoring frequencies for individual water bodies. Such information can be particularly useful in prioritising a monitoring framework to optimise the allocation of both monitoring and mitigation resources. When applied to cyanobacterial blooms in the Swan Coastal Plain of Western Australia, we determined that optimising the monitoring regime at individual lakes could greatly alter the overall monitoring schedule for the region, rendering it more risk averse without increasing the amount of monitoring resources required. For water resources with high cyanobacterial activity, this represents an efficient strategy for optimising monitoring resources.
Aim

To identify an optimum monitoring strategy for cyanobacteria and their toxins in waste stabilisation ponds across WA.

By achieving this aim, we can then identify general patterns about monitoring frequencies in WSPs.

• Do monitoring frequencies differ between two related constituents of concern (biomass, toxins)?
  ✓ Do monitoring frequencies differ between two related constituents of concern (biomass, toxins)?
• Are monitoring frequencies similar within a climatic region (climate versus internal processes)?
• Compare monitoring frequencies of WWTPs with different final treatment methods (e.g., UV; filter)
  ✓ Seasonal changes of monitoring frequencies.
Main components of this probability based framework:

- **Hazard frequency (HF)**
  - Identification of the constituent of concern (cyanobacterial biomass; toxins)
  - Identification of hazard level that poses a risk
Risk-based framework to identify optimised monitoring frequencies (MF) (Barrington et al. 2014)

Main components of this probability based framework:

• Hazard frequency ($HF$)
  – *Identification of the constituent of concern (cyanobacterial biomass; toxins)*
  – *Identification of hazard level that poses a risk*

• Tolerance ($To$)
  – $To$ is the probability that we are willing to accept that our monitoring regime will fail to identify a hazard when one is present.
Risk-based framework to identify optimised monitoring frequencies (MF) (Barrington et al. 2014)

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\[
MF = \frac{1}{HF} \times 1 - \frac{1 - HF}{1 - To}
\]
Main components of this probability based framework:

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- **Tolerance** ($To$)
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Mathematically, the formula for the monitor frequency ($MF$) is given by:

$$MF = \frac{1}{HF} \times 1 - \frac{1 - HF}{1 - To}$$

CB biomass: 10 µg chl-a/L
Microcystins: 4 µg MC/L
Experimental design

- Monthly profiling of final reuse effluent for cyanobacterial biomass and microcystin concentration;
- 12 plants from across Western Australia (4 climate regions);
- Duration: 6-8 months;
Results - Range and dominance of CB biomass
Results - Range and dominance of CB biomass
Results - Monitoring frequency for CB biomass

• Using the Recreational Water Guidance Level 1 (10 µg chl-a L⁻¹) (WHO 2003)
Results - Monitoring frequency for CB biomass

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Results - Monitoring frequency for CB biomass

- Using the Recreational Water Guidance Level 1 (10 µg chl-a L⁻¹) (WHO 2003)
Results - Monitoring frequency for microcystins

- Using the Recreational Water Guidance Level 1 (4 µg MC L⁻¹) (WHO 2003)
Results - Comparison of monitoring frequencies

- Using the Recreational Water Guidance Level 1 (WHO 2003):
  
  Comparing monitoring frequency for cyanobacterial biomass (10 µg chl-a L⁻¹) with microcystin concentration (4 µg MC L⁻¹)
Results - Seasonal monitoring frequency for microcystins

- Using the Recreational Water Guidance Level 1 (4 µg MC L$^{-1}$) (WHO 2003)
Results - Seasonal monitoring frequency for microcystins

- Using the Recreational Water Guidance Level 1 (4 µg MC L⁻¹) (WHO 2003)
Results - Seasonal monitoring frequency for microcystins

- Using the Recreational Water Guidance Level 1 (4 µg MC L⁻¹) (WHO 2003)
Summary and conclusions (I)

• Optimum monitoring frequencies for each WWTP can be determined with a framework that is based on the assessment of the risk posed by cyanobacteria and their toxins to the environment and humans.

• An important component of the framework is the accepted tolerance ($T_o$), which is the probability (risk) that a Water Authority is willing to take to miss an occurring hazardous event due to their chosen monitoring regime.

• The tolerance should be based on guidelines, the reuse purpose and also take into account that microcystins are potentially more harmful than cyanobacterial biomass, suggesting using a lower tolerance level for toxins than for biomass.
Summary and conclusions (II)

- In our study, the monitoring regime depended on
  - the WWTP;
  - the constituent of concern;
  - the season for some WWTPs

- Monitoring frequencies were different within a climate region, indicating that in-pond processes rather than climate is the main driver for cyanobacterial blooms in WSP.

Using this framework allows determining flexible and optimized monitoring regimes for each WWTP.