The use of fluorescence to monitor groundwater microbiological quality

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The driver

- 2 billion people consume drinking water contaminated with faeces (WHO, 2018)
- 500,000 deaths per year from diarrhoea alone
- Children under five
The driver – developed world

• USA, 750k – 6 million cases waterborne illness per year from consuming groundwater (Maclean and Merkle, 2000)

• Private groundwater supply surprisingly common
  - USA (12%), Ireland (17%)
  - Effective treatment?
  
    • 33% show evidence of faecal contamination in Ireland 1998-2008 (EPA)

• Monitoring?
  - Contamination is episodic
The driver – developed world

- Municipal supplies

- Contamination is episodic, microbial monitoring is infrequent and off-site – online approach?
Fluorescence

Light → Filter → Water sample → Filter → Light detector
Tryptophan-like fluorescence (TLF)

- What is TLF?
  - Tryptophan – essential amino acid
  - Quantified using field fluorimeters
  - Simple, instant, reagentless, online

- Why TLF?
  - Linked to microbial activity in freshwater environments
Is TLF an indicator of thermolerant coliforms?

- Best predictor of thermotolerant coliform (TTC) presence/absence and enumeration in drinking water in Zambia (Sorensen et al. 2015)
Is TLF an indicator of thermolerant coliforms?

- Significant predictor of TTC presence/absence and enumeration in India; turbidity was not (Sorensen et al. 2016)
2018 - Defining TLF thresholds

• Roaming survey of drinking water sources in Africa/India ($n = 564$)

Instant result

Result within >18hr
Predicting presence/absence of TTCs

Plate counts (>18 h)

Predicting plate counts (real-time)

False negatives 4%

Fluorescence > 1.3 ppb?

False positives 18%

Limit of detection ~10 cfu/100mL

Sorensen et al. 2018a
Predicting number of TTCs

- Very strong correlation ($\rho = 0.80$, p-value <0.001)
2018 - TLF online UK public water supplies

• Four public water supplies
• Fissured limestone
• Setup fluorimeters on raw water
TLF online UK public water supplies

- Online TLF (2 min) UK comparison with:
  - online turbidity
  - *E. coli*
  - total bacterial cell counts by flow cytometry

Sorensen *et al.* 2018b
Online indicators and *E. coli*

\[ \rho = 0.71^{***} \]

\[ \rho = 0.48^{***} \]
Online indicators and total bacteria

\[ \rho = 0.73^{***} \]

\[ \rho = 0.40^{***} \]

TLF (ppb) vs. Total bacterial cell counts (1000 cells/mL)
Continuous TLF data

TLF (ppb)

E. coli (cfu/100mL)

Total bacterial (1000 cells/mL)

Rainfall (mm)

Feb  Apr  Jun
Adding turbidity data

- Turbidity

TLF
- Total bacteria
- E. coli

Rainfall (mm)

Feb  Mar  Apr  May  Jun  Jul

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Causation?

- *E. coli* fluoresce at TLF wavelengths
- *E. coli* used for the industrial production of tryptophan

- Laboratory TLF - *E. coli* correlation $R^2 = 0.98$
- Majority intracellular

Fox et al. 2017
Overcoming limitations

- Environmental - temperature, turbidity, inner-filtering effect

- Uniqueness of TLF to *E. coli*

- Fluorescence interference
Current work

- Improving sensor technology
- Expanding beyond raw water
- Understanding false-positives
Conclusions

- Tryptophan-like fluorescence (TLF) is:

- Indicative of the presence/absence and number of TTCs/E. coli in drinking water

- Superior to turbidity as an online indicator of microbial water quality

- Quantified using in-situ/portable existing, commercially available sensors

Instant result
Referenced papers


Any questions?

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