



British  
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

# Gateway to the Earth

## 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 (Maclear 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



## Lancashire boiled water 'safe' amid cryptosporidium alert - officials

8 August 2015 | Lancashire

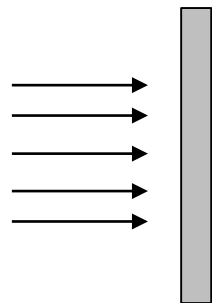


- Contamination is episodic, microbial monitoring is infrequent and off-site – online approach?

# Fluorescence



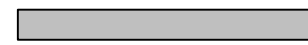
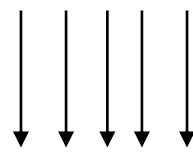
Light



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



Instant results

- 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)

Public supply



Private supply



# 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 ( $n = 564$ )



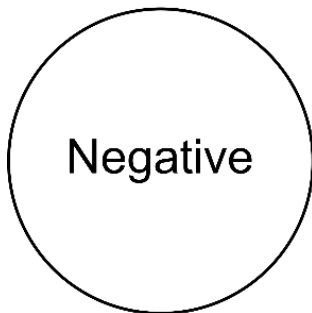
Instant result



Result within >18hr

# Predicting presence/absence of TTCs

Plate counts  
(>18 h)



Predicting plate counts (real-time)

False negatives  
4%



Fluorescence > 1.3 ppb?



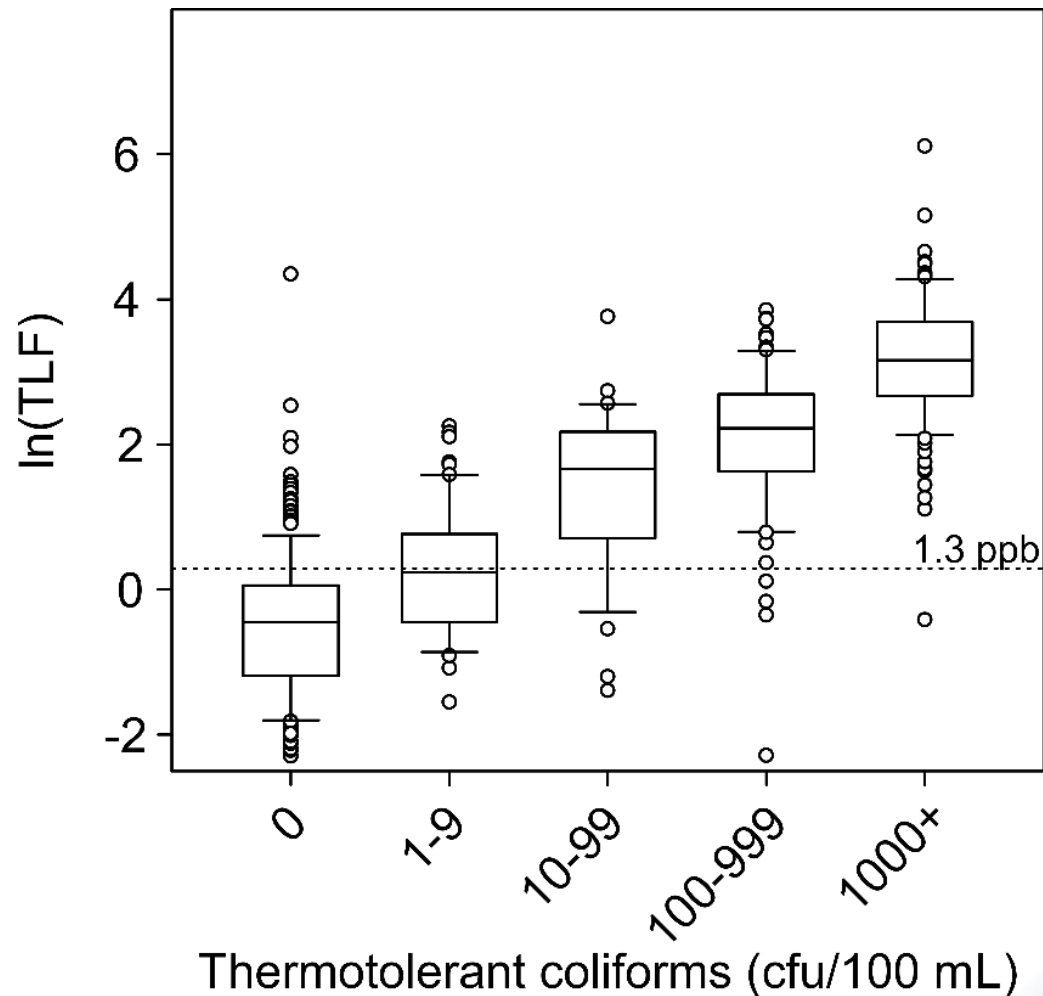
False positives  
18%

Limit of detection  
~10 cfu/100mL

Sorensen *et al.* 2018a

# Predicting number of TTCs

- Very strong correlation ( $\rho = 0.80$ , p-value  $< 0.001$ )



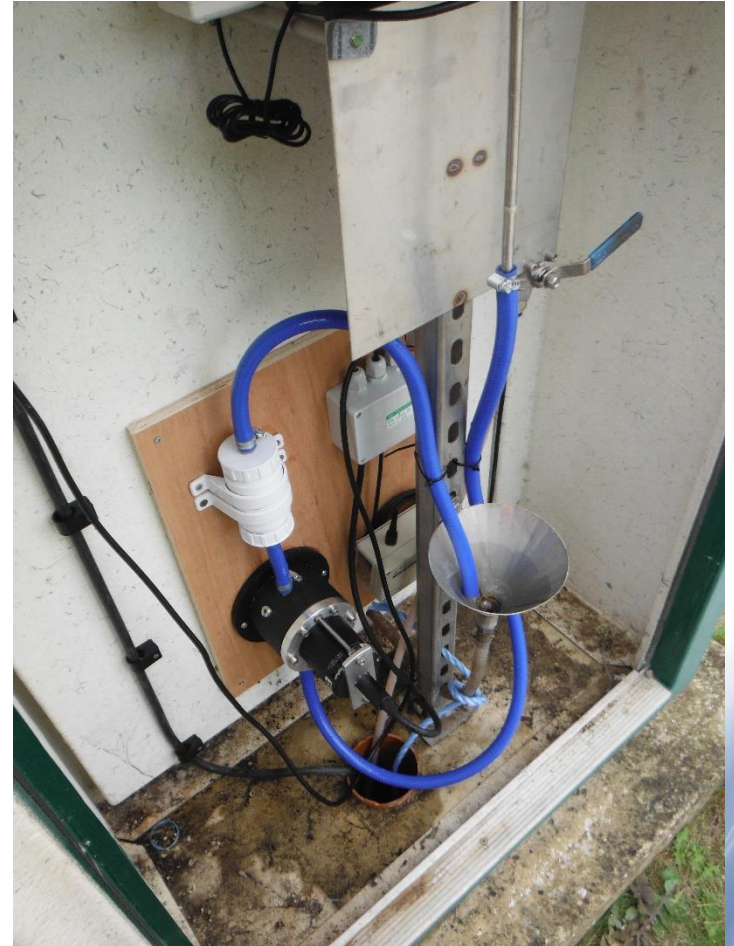
# 2018 - TLF online UK public water supplies

- Four public water supplies
- Fissured limestone
- Setup fluorimeters on raw water

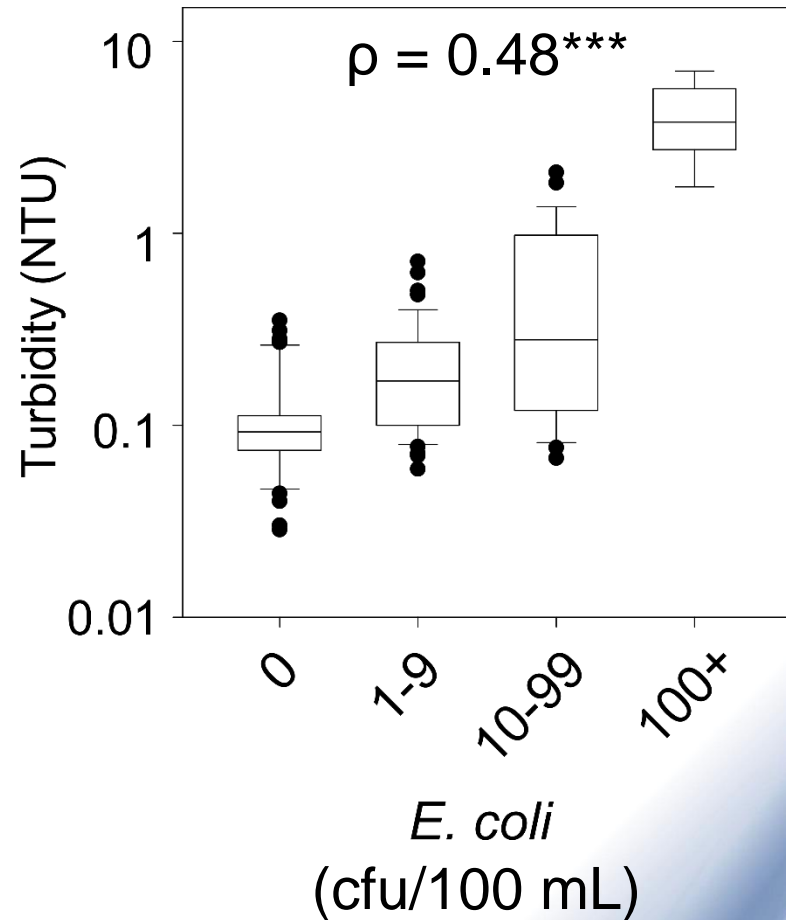
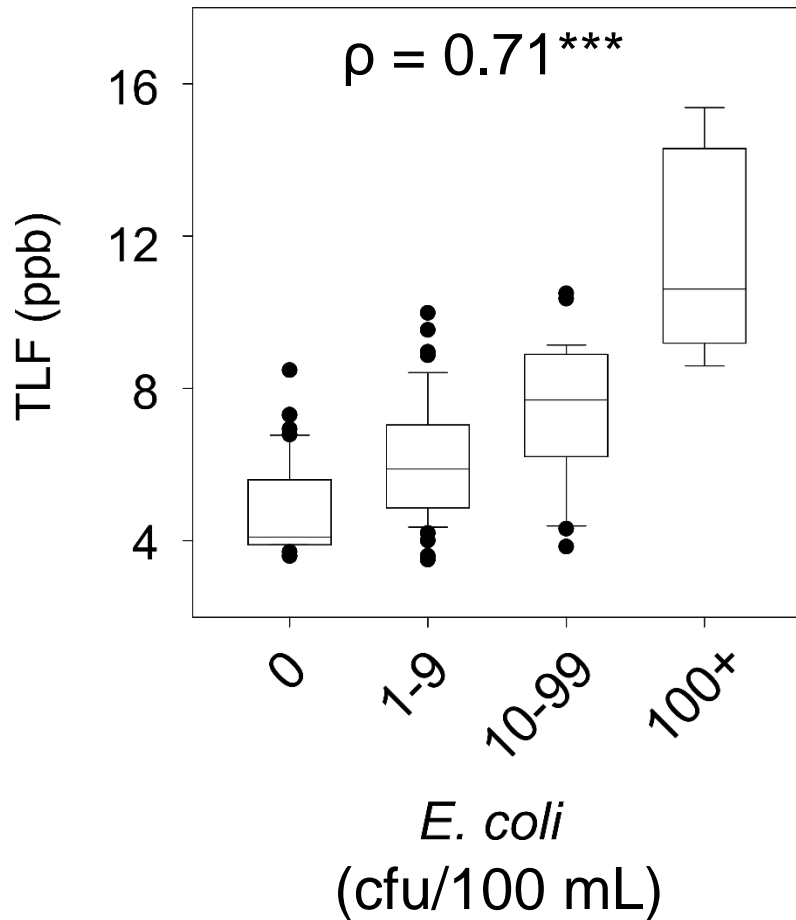


# TLF online UK public water supplies

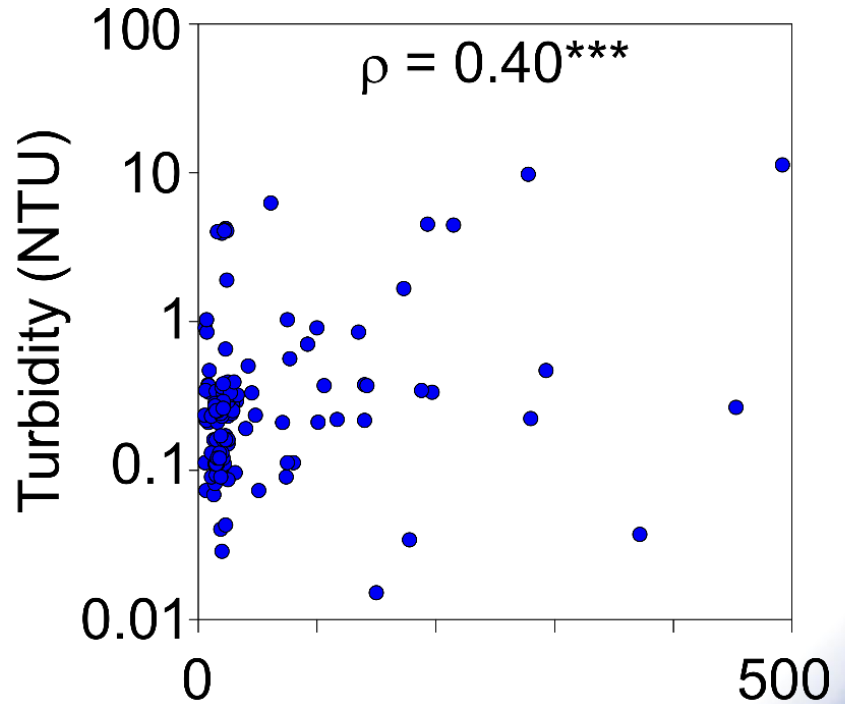
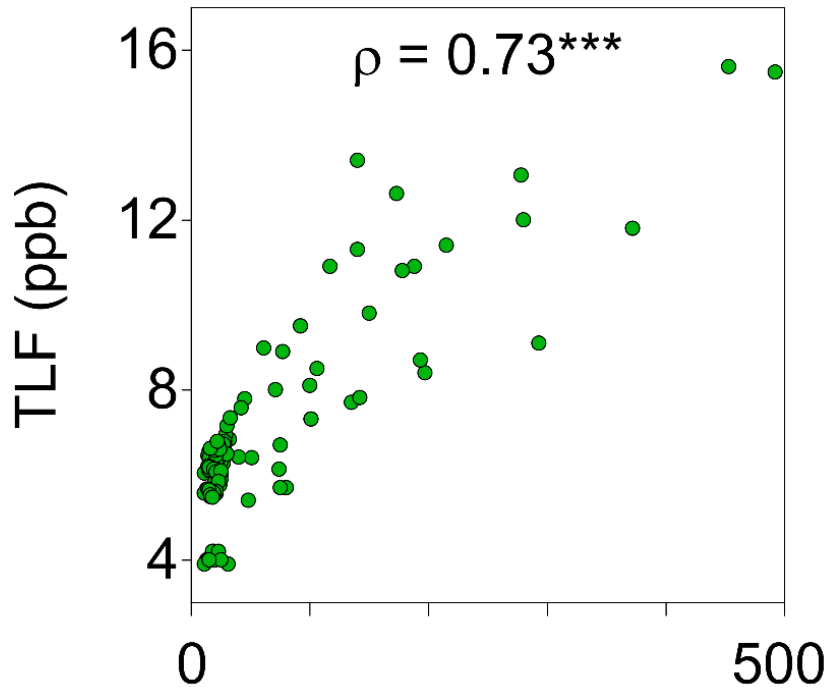
- Online TLF (2 min) UK comparison with:
  - online turbidity
  - *E. coli*
  - total bacterial cell counts by flow cytometry



# Online indicators and *E. coli*

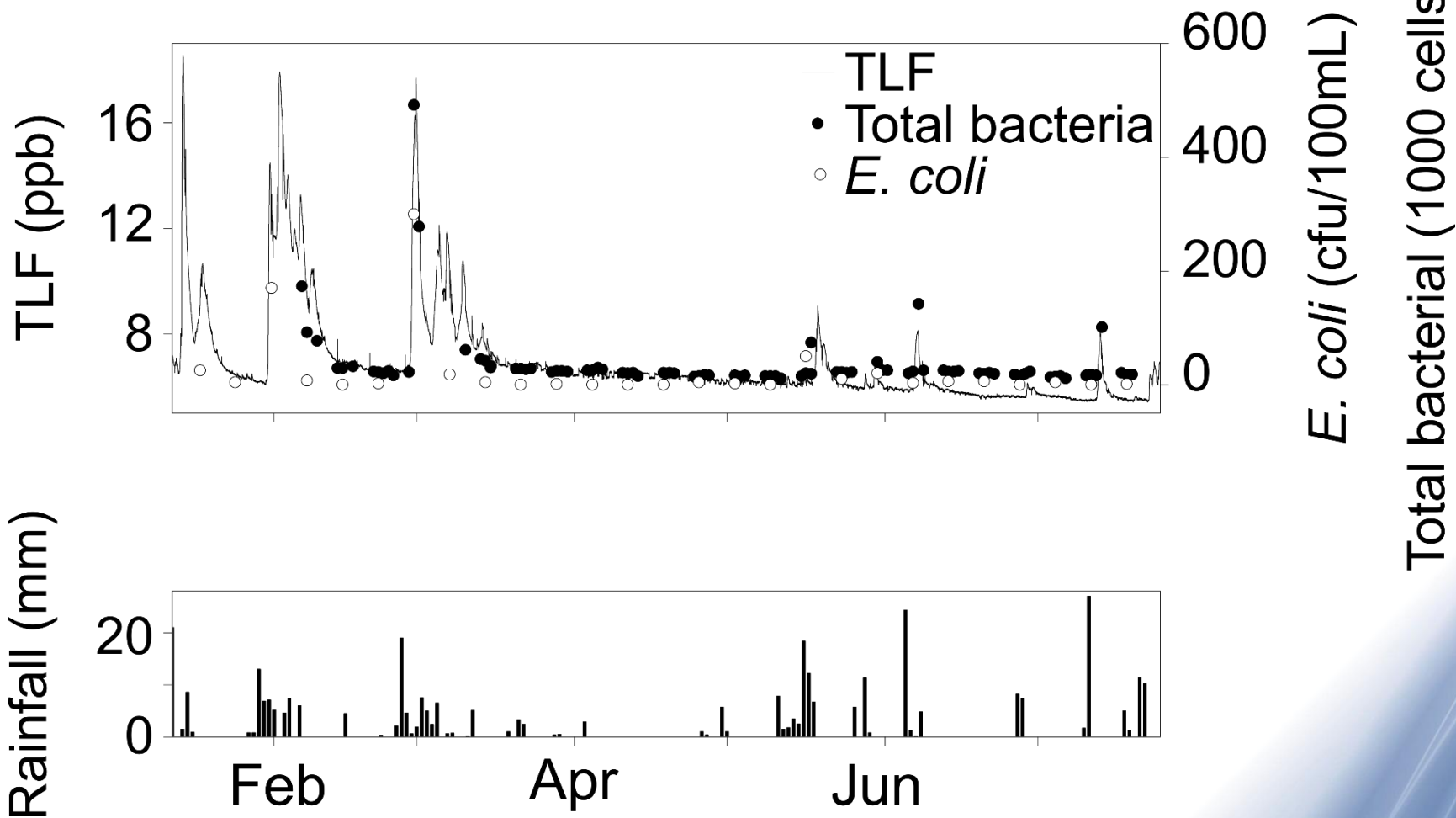


# Online indicators and total bacteria



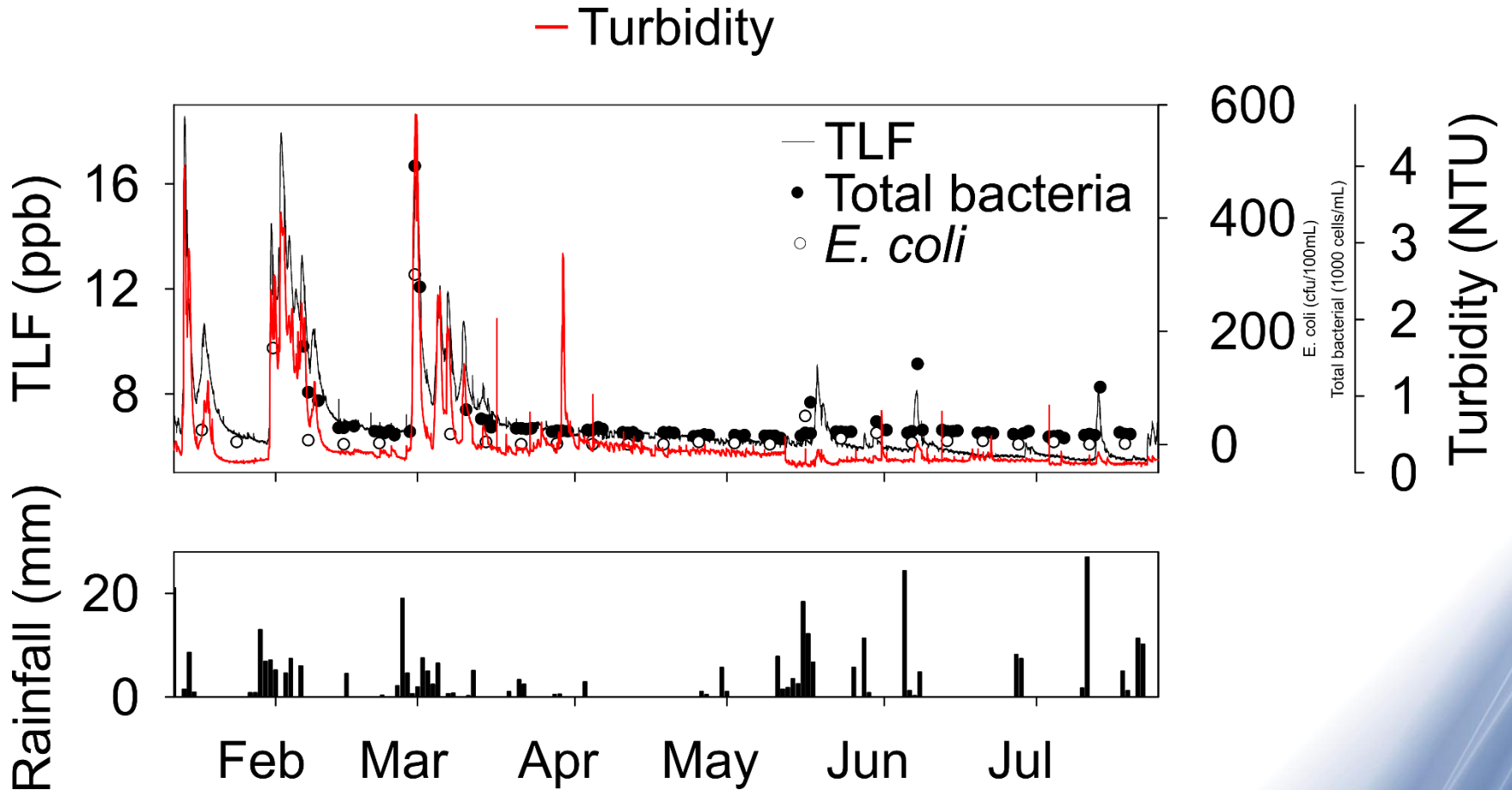
Total bacterial cell counts (1000 cells/mL)

# Continuous TLF data





# Adding turbidity data

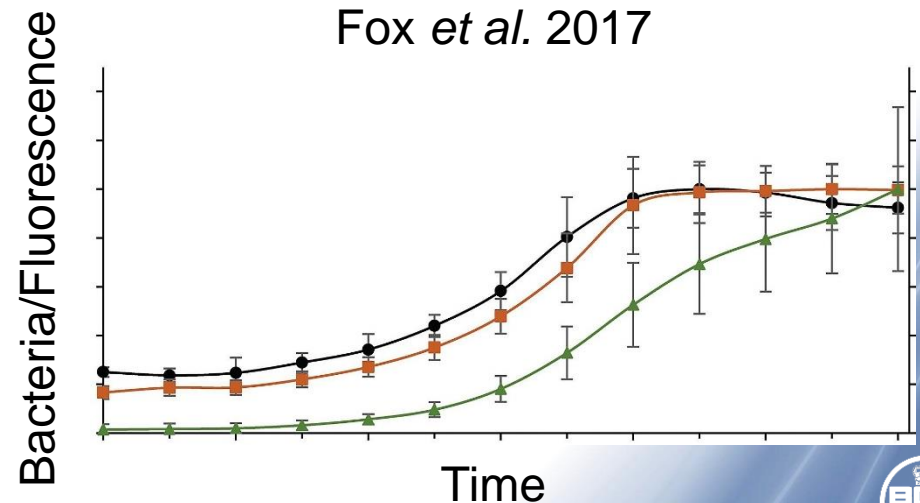


# Causation?



- *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



# Overcoming limitations

- Environmental
  - temperature, turbidity, inner-filtering effect
- Uniqueness of TLF to *E. coli*
- Fluorescence interference

Instant advice to consumers



# Current work

Innovate UK



Trace<sub>2</sub>o

- 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

Sorensen, J.P.R., Lapworth, D., Marchant, B., *et al.* (2015). In-situ tryptophan-like fluorescence: a real-time indicator of faecal contamination in drinking water supplies. *Water Research*, 81, 38-46.

Sorensen, J.P.R., Sadhu, A., Sampath, G., *et al.* (2016). Are sanitation interventions a threat to drinking water supplies in rural India? An application of tryptophan-like fluorescence. *Water Research*, 88, 923-932.

Sorensen, J.P.R., Baker, A., Cumberland, S., *et al.* (2018a). Real-time detection of faecally contaminated drinking water with tryptophan-like fluorescence: defining threshold values. *Science of the Total Environment*, 622, 1250-1257.

Sorensen, J.P.R., Vivanco, A., Ascott, M.J., *et al.* (2018b). Online fluorescence spectroscopy for the real-time evaluation of the microbial quality of drinking water. *Water Research*, 137, 301-309.

Fox, B. G., Thorn, R. M. S., Anesio, A. M., & Reynolds, D. M. (2017). The in situ bacterial production of fluorescent organic matter; an investigation at a species level. *Water Research*, 125, 350-359.



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## Any questions?

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