The implementation of fluorescence based sensors for remote water quality monitoring.
A new Indo/UK initiative.

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Researchers:
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Water Quality – TEST
Technology Enabled Sensing and Treatment of water

Grant: NE/R003106/1
The development and implementation of sensors and treatment technologies for freshwater systems in India

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Water Quality – TEST

Technology Enabled Sensing and Treatment of water
Development & implementation of sensors & treatment technologies for freshwater systems in India

To implement sensors for biological contamination in freshwater sources.

To develop sensors for chemical water pollutants (EDCs) in urban and rural aquatic environments.

To implement ‘off-grid’ treatment technology for production of drinking water in freshwater catchments.

To develop bioreactor-based processes for the remediation of EDCs in wastewaters and/or industrial effluents to reduce chemical burden in freshwater systems.
UK Consortium lead: The deployment and adaption of a recently UK developed “off-grid” treatment technology for the removal of bacterial contaminants in Indian freshwater systems to produce clean drinking water.

The deployment, adaption and networking of a recently UK developed in-situ fluorescence sensor for the rapid detection of microbial contamination of Indian freshwater sources.
India Consortium to lead:

The development of **whole-cell bioreporter strains for the detection of Endocrine Disrupting Chemicals (EDCs)** in freshwaters and wastewaters based on the exploitation of the relevant inducible catabolic operon of EDC-degrading bacteria.

Development of **bioreactor-based processes for the remediation of EDCs** in wastewaters and/or industrial effluents.
Indo-UK collaboration

This project will **develop and implement robust technology platforms capable of delivering improved water quality**, through real-world application.

Co-creation of solutions to tackle existing and emerging water quality problems by bringing together interdisciplinary expertise.

Knowledge and skill transfer between Indian and UK researchers, via international exchange **secondments**, and **industrial partnerships**.

**Water Quality – TEST**

Technology Enabled Sensing and Treatment of water
What is Organic Matter?

- Organic matter (OM), or natural organic matter (NOM), is the pool of carbon-based compounds within the environment.
- Comprised of organic compounds derived from plants and animals and their waste - composition is highly variable and dependent upon origin, transformation and age.
- OM is ubiquitous in natural waters.
- OM origin can be either allochthonous or autochthonous, input varies cyclically:
  - **allochthonous** OM is derived from the surrounding environment and so is influenced by the hydrology, geology and land-use of its source.
  - **autochthonous** OM is created *in situ* via microbial processes, either in recycling or formation.
Importance of Organic Matter

- Influences the transport of nutrients, impacting
  - ecosystems and underpinning ecological health
  - global biogeochemical and carbon cycles
- Contribution of various carbon stores and sinks to carbon cycling is important for climatic modelling
- Conceptual carbon “pumps” mainly focus on long-term marine carbon cycling:
  - largest reservoir and mechanism for movement of carbon globally
- Carbon mechanisms are important within all aquatic environments throughout the hydrological continuum
- “Organic matter” (or “organic carbon”) pump:
  - DIC > POC & DOC
  - DOC utilised in the “microbial carbon” pump
“Microbial Carbon” Pump

- Biological pump processes OM > DOC

- Key for climatic modelling and predictions
  - any change in this DOC consumption, degradation and transformation could have a large impact of atmospheric CO₂

- Not well represented within current model as inputs, interactions and outputs very complex
  - many of the present day models use a “black box” element to represent the “microbial carbon” pump
  - major element of uncertainty within predictions
  - improving understanding of the mechanisms and function of microbial-OM interactions is vital
Aquatic Fluorescent OM (AFOM)

- Autochthonous
  - Protein-like
    - Tryptophan-like
    - Tyrosine-like

- Allochthonous
  - Humic-like
  - Fulvic-like
Why Monitor AFOM?

Real-time monitoring of water and wastewater quality using a fluorescence technique

Optical Spectroscopy in the Aquatic Environment

Elsholt Works, Yorkshire Water (May 1998)
Why Monitor AFOM?

The characterisation of sewage using fluorescence

Effluent and Sewage Network Management

Inst. Mech. Engineers (February 2000)
Why Monitor AFOM?

Real-time monitoring of river water quality using in-line continuous acquisition of fluorescence excitation and emission matrices.

Future Water Sensing Technologies

Warrington, (February, 2010)
<table>
<thead>
<tr>
<th>TRL</th>
<th>Stage</th>
<th>Description of alignment of TRL with our sensor technology development</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL9</td>
<td>Operations</td>
<td><strong>V-Lux</strong> sensing network deployed operationally as part of catchment water quality monitoring programme [WP6] Risk management = WP5</td>
</tr>
<tr>
<td>TRL8</td>
<td>Active Commissioning</td>
<td><strong>V-Lux</strong> to undergo active commissioning in an identified catchment site [WP4]. Risk Management = WP3</td>
</tr>
<tr>
<td>TRL7</td>
<td>Inactive Commissioning</td>
<td>The manufacture of the <strong>V-Lux</strong>, has undergone inactive commissioning including works testing and factory trials culminating in a final design that has been tested using simulated waters between 2014 and 2017 (CTG &amp; NE/K007572/1).</td>
</tr>
<tr>
<td>TRL6</td>
<td>Large Scale</td>
<td>The sensor technology (Uvi-Lux version) tested at or near full-scale sensor size. The design was not finalised and the sensor underwent major modifications. Limited testing of a small range of water simulants was undertaken, with limited sensing time between 2014 and 2017 (NE/K007572/1).</td>
</tr>
<tr>
<td>TRL5</td>
<td>Pilot Scale</td>
<td>The sensor technology underwent testing at a small basic scale (Uvi-Lux version 2) to demonstrate specific aspects of the design between 2014 and 2017 (NE/K007572/1).</td>
</tr>
<tr>
<td>TRL4</td>
<td>Bench Scale</td>
<td>The technology sensor (Uvi-Lux) was developed in partnership with CTG and UWE using laboratory/research facilities, funded by CTG (2012-13).</td>
</tr>
<tr>
<td>TRL3</td>
<td>Proof of Concept</td>
<td>Demonstration, in principle, that the phenomenon could be translated into a small sensing device and that it has the potential to work was conducted by UWE and CTG under a SEEDA business voucher (2011-12).</td>
</tr>
<tr>
<td>TRL2</td>
<td>Invention &amp; Research</td>
<td>Further investigation of the phenomena, was undertaken by the PI through acquisition of new knowledge, or correction and integration of previous knowledge NERC grant, NER/S/C/2004/12659 (held from 2004 – 2010).</td>
</tr>
<tr>
<td>TRL1</td>
<td>Basic Principles</td>
<td>The basic phenomenon was established and shown by the PI and others during SERC grant GR/G18858 (1992) and EPSRC Grant GR/H51620 (1991-1994).</td>
</tr>
</tbody>
</table>
Why Monitor AFOM?

- Technological developments – *in situ*, real-time
- Associated with specific OM compounds
- Can monitor baseline AFOM and identify changes
- Can be used to trace AFOM origin and transportation throughout hydrological continuum.

- Peak T fluorescence associated with microbial activity
  - Infer ecosystem health
  - Monitor activity
Urban Kolkata water courses

- Hooghly River (Ganga)
- Adi Ganga (tributary)
- Wetland
- Canal
Initial scoping – Urban Kolkata
### Site “type” summary

#### Hooghly River (Ganga)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Peak Type</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>pH</td>
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<td>T</td>
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<tr>
<td>EC</td>
<td>230</td>
<td>C</td>
<td>15</td>
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<td>DO</td>
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<tr>
<td>NO$_3$</td>
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<td>$3 \times 10^4$</td>
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<tr>
<td>PO$_4$</td>
<td>0.3</td>
<td><em>E. coli</em></td>
<td>$4 \times 10^3$</td>
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</tbody>
</table>

#### Adi Ganga (tributary)

<table>
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<tr>
<td>PO$_4$</td>
<td>5.5</td>
<td><em>E. coli</em></td>
<td>$1 \times 10^5$</td>
</tr>
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#### Wetland

<table>
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<tr>
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<tbody>
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<tr>
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<td>Temp</td>
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<tr>
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<td>PO$_4$</td>
<td>0.7</td>
<td><em>E. coli</em></td>
<td>$3 \times 10^3$</td>
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</table>

#### Canal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Peak Type</th>
<th>Value</th>
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<td>EC</td>
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<td>1.4</td>
<td>TTCs</td>
<td>$2 \times 10^6$</td>
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<tr>
<td>PO$_4$</td>
<td>4.9</td>
<td><em>E. coli</em></td>
<td>$4 \times 10^5$</td>
</tr>
</tbody>
</table>
Sensing - Next steps

V-Lux (5 channel fluorimeter):
- TLF (280nm ex LED, 360nm em)
- CDOM (280nm ex LED, 450nm em)
- Chlorophyll -a & -c
- Turbidity
- Absorbance

Field work in India (January 2019)
- Sensor trials, optimisation and deployment
- Twinned with laboratory testing
Sensing - Next steps

Catchment scale monitoring of freshwater systems

Six V-Lux sensors

~ 0.5 km RTU

Long-term

Stake holders
UK Case Study

To implement a fluorescence-based sensing network to inform our understanding of river catchment quality as a function of land-use.

1. Further understand underpinning science
2. Optimization of sensor
3. Implementation of catchment monitoring scheme
Microbial DOM Processing

- *Algae*?
- *Biofilms*?
- *Land-use*?

Advancing our understanding of the underpinning science will facilitate effective implementation of the technology.
To Demonstrate fluorescence monitoring of microbial FDOM processing as an effective water quality parameter

- Implement at a catchment-scale, long-term, with continuous ground-truthing

- Augment with historical data from existing catchment monitoring schemes
India Relevance

• Simultaneous deployment in UK and India will provide a comparison case-study to support India data

• Beneficial to have a UK and international contrast which tests the robustness of sensors along a wide breadth of WQ scenarios
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  - Dr Robin Thorn
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  - Professor Tapan K Dutta
  - Researchers: Suman Basu & Rinita Dhar
- Project funders
  - RCUK: EPSRC & NERC
  - Department of Science and Technology
  - Newton-Bhabha Fund

References

- Coble et al., 2014. Aquatic Organic Matter Fluorescence
- Fox et al., 2018. Water, https://doi.org/10.3390/w11010010
Get Involved

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Water Quality – TEST
Technology Enabled Sensing and Treatment of water
Thanks for listening
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