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Bioelectrochemical Biosensors for Organic Load Monitoring in Sewage Treatment

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Better Water Quality for Wales 2023

Professor Richard Dinsdale

Royal Academy of Engineering Chair in Emerging
Technologies

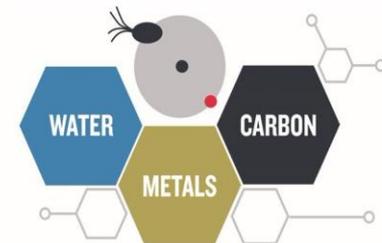
Sustainable Environment Research Centre

University of South Wales

28th June 2023



**Royal Academy
of Engineering**



Measurement of Organic Water Pollution

- Main goal of water resource protection has been the treatment of organic content of wastewater to prevent oxygen depletion.
- Requires significant investment in infrastructure plus ongoing energy cost of approx. 2% of UK electrical usage and biosolids production.
- Typically measured by the use of the 5 day Biochemical Oxygen Demand (BOD_5) test BUT also chemical oxygen demand, total organic carbon et al.

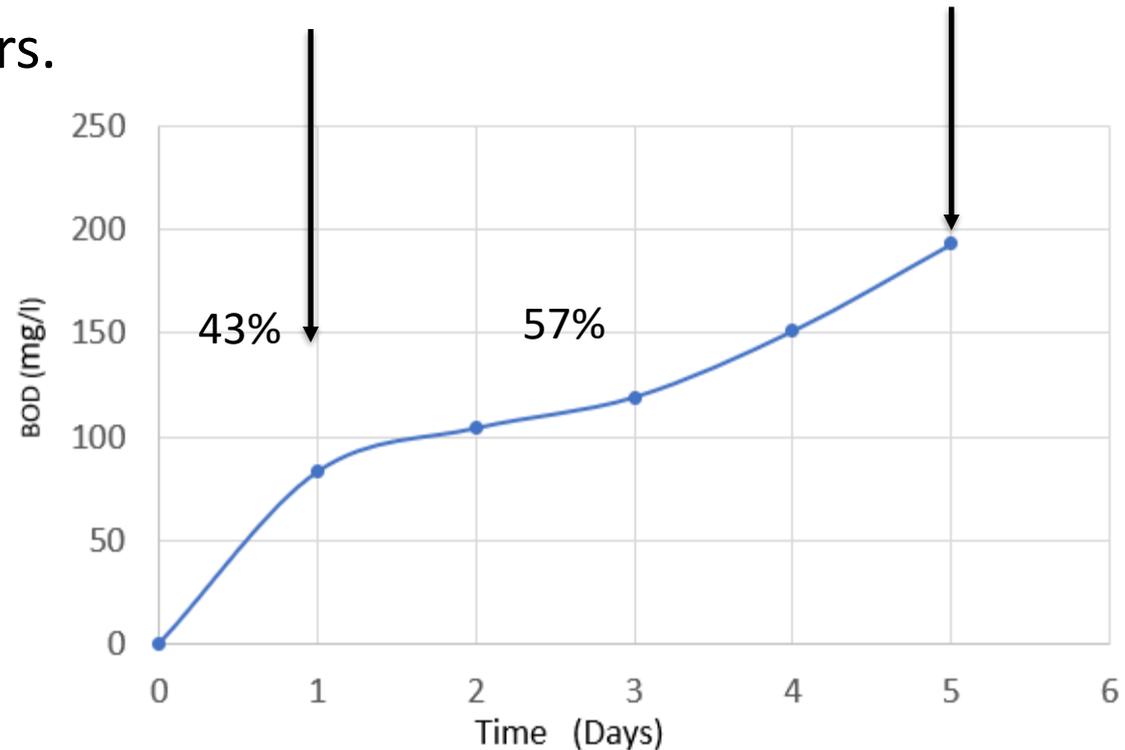
Traditional & More Modern BOD Measurement



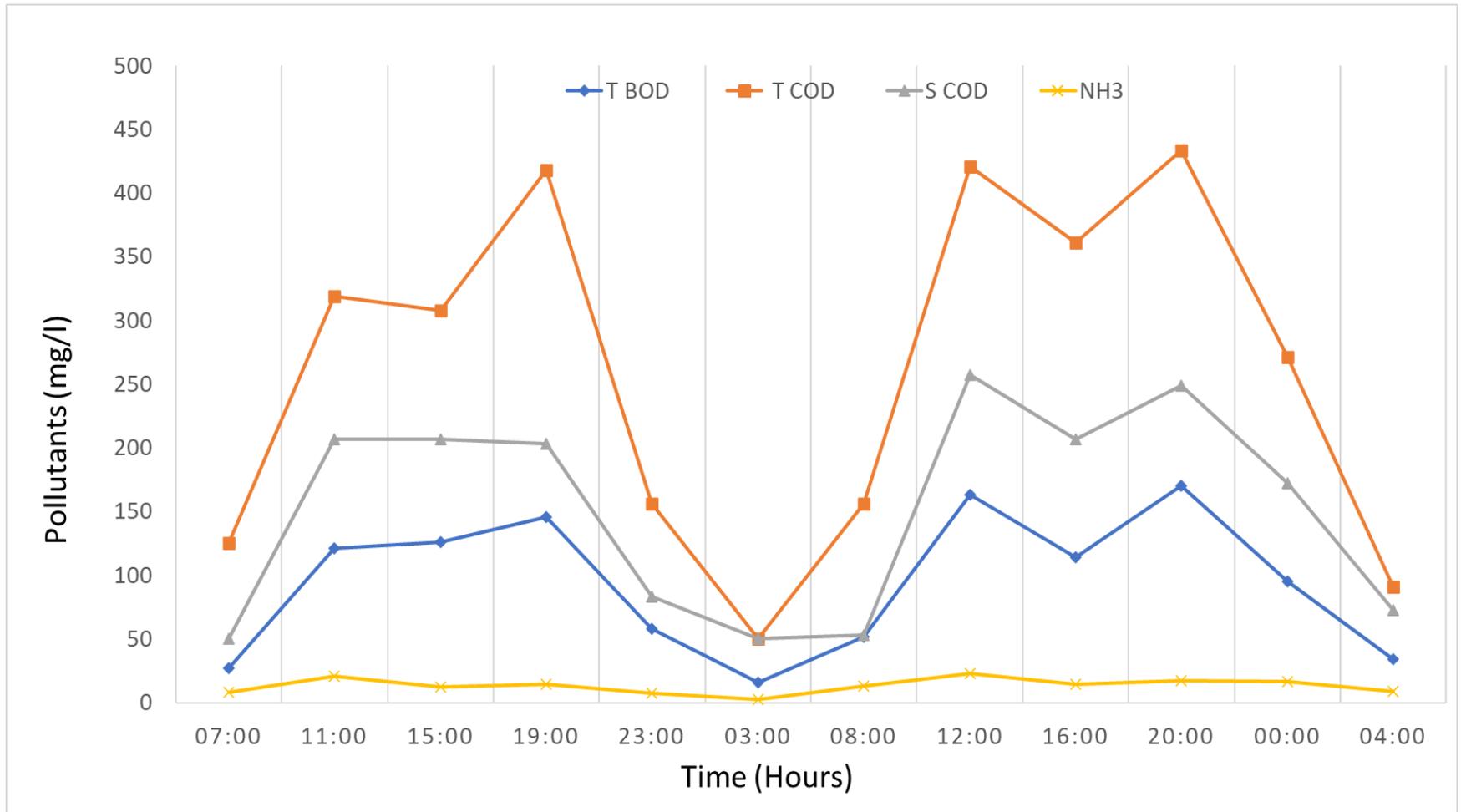
Dissolved oxygen electrode vs manometric

Problems with BOD & COD

1. Takes 5 days (at least) for BOD, COD quicker (2-3 hours)
2. Typically done at a central laboratory
3. Depends on microbes working (BOD) OR hazardous chemicals for COD.
4. Prone to dilution errors.
5. Difficult to automate for continuous plant monitoring.
6. Could be missing important information.



Variation in Pollution Load to a WWTW



Development and Testing of BOD (Organic Load) Sensor

- Test bioelectrochemical sensor developed 2012 in a industrial context to measure the organic load to WWTP continuously, use no chemicals, be low maintenance and have a biological basis of measurement.
- Joint proposal with Newcastle University, Welsh Water, Chivas Brothers and Northumbria Water.
- Three tests sites which tested to March 2024

What are Bioelectrochemical Microbial Systems?

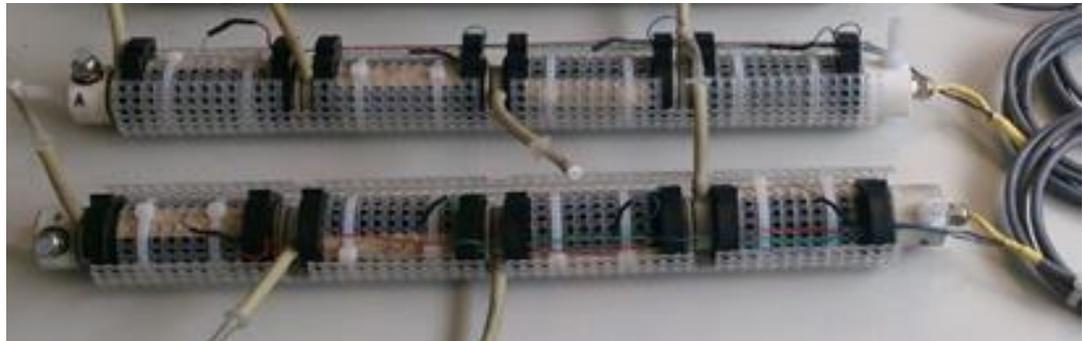
- They use a novel group of bacteria which are found in anaerobic sediments which have the ability to generate and transfer electrons.
- In classical biochemical engineering terms they would be classified as fixed film anaerobic processes.
- Typically used in what is termed a microbial fuel cell as they convert organic matter to electrons (a voltage)

Bioelectrochemical Systems as Sensors

- Using the increase in electrical response in BES to the presence of biodegradable organic matter has been widely proposed for use as BOD sensor and more recently to measure volatile fatty acids.
- BOD Sensor- see link to work at USW and Newcastle <https://www.youtube.com/watch?v=39WPEiuA8Bg>
- VFA Sensor

Kaur, A., Kim, J.R., Dinsdale, R.M., Guwy, A.J. (2013). Microbial fuel cell type biosensor for volatile fatty acid with an acclimated bacterial community. *Biosensors and Bioelectronics*, 47, 50-55.

What does it look like?



Testing at DCWW Ponthir

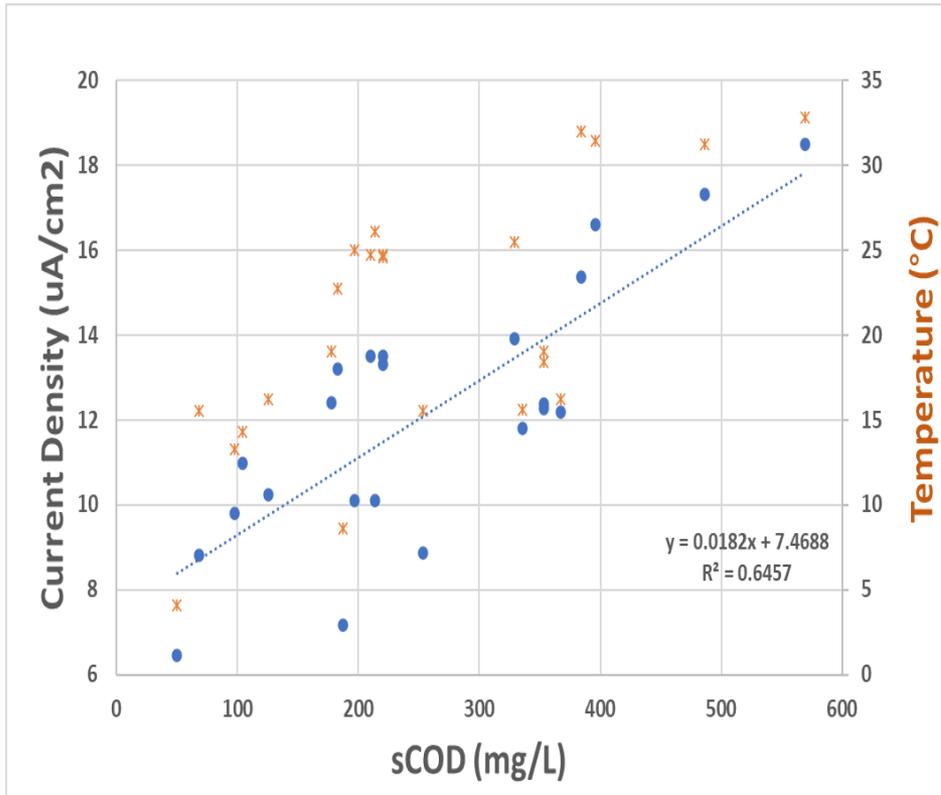
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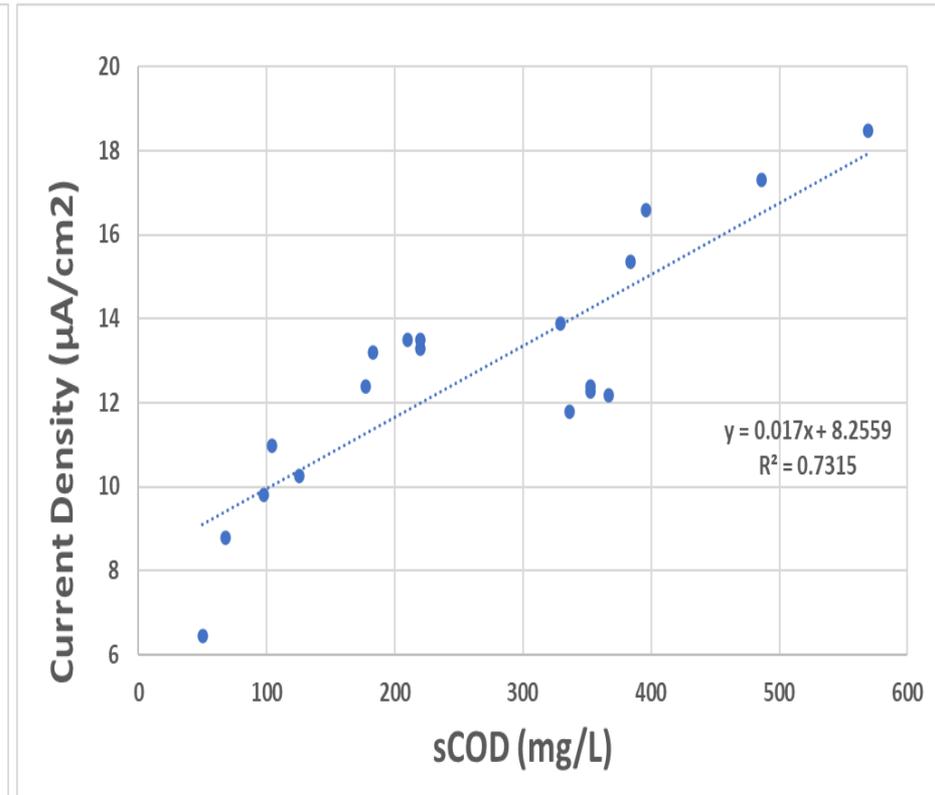
Can we improve sewage treatment performance and energy efficiency?



Comparison of Soluble COD against Sensor Signal and Effect of Temperature



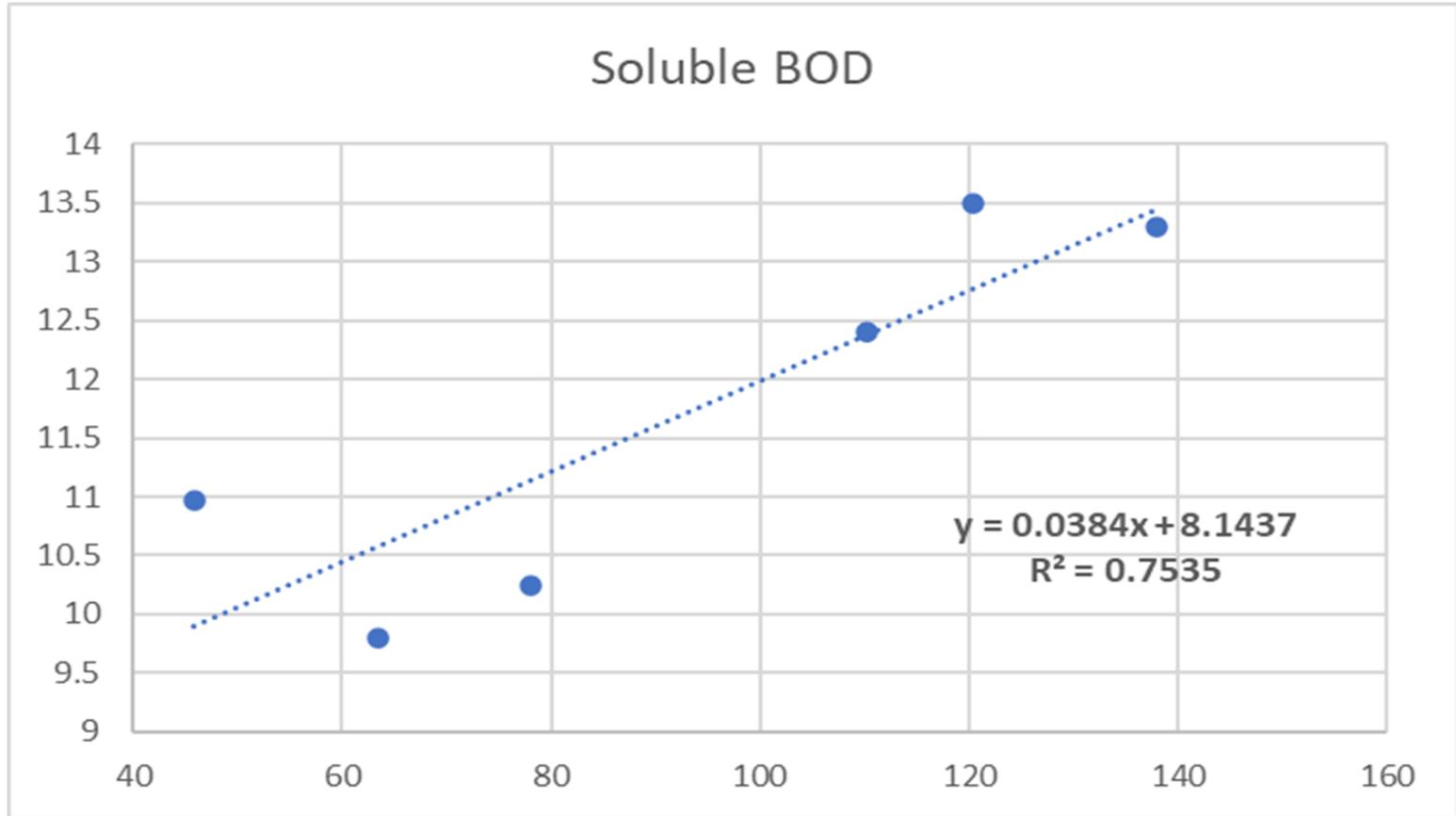
R2= 0.6457



R2= 0.7315

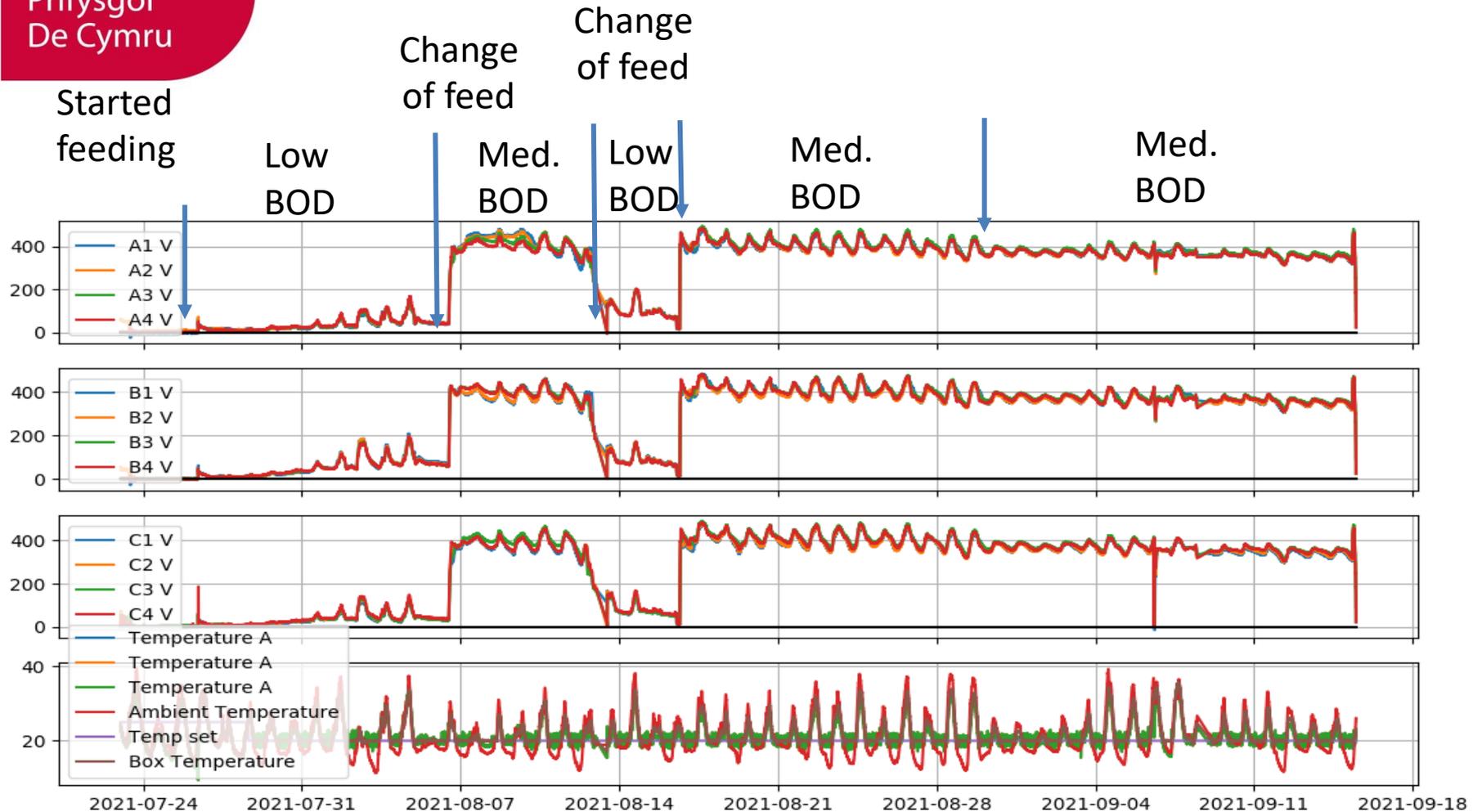
Closer Correlation with Soluble BOD

Sensor Response Current Density ($\mu\text{A}/\text{cm}^2$)



BOD (mg/L)

Response to Changes in Organic Load



Conclusions

- Bioelectrochemical sensor was used for over 12 months and maintained bioelectrochemical activity despite freezing, power outages etc.
- Good correlation between soluble BOD>Soluble COD> Total BOD> Total COD
- Influenced by temperature
- Need to identify role in improving WWTP

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