Biofouling and *in situ* electrochemical cleaning of a boron-doped diamond free chlorine sensor

Robert Euan Wilson, Ivan Stoianov, Danny O'Hare
Imperial College London

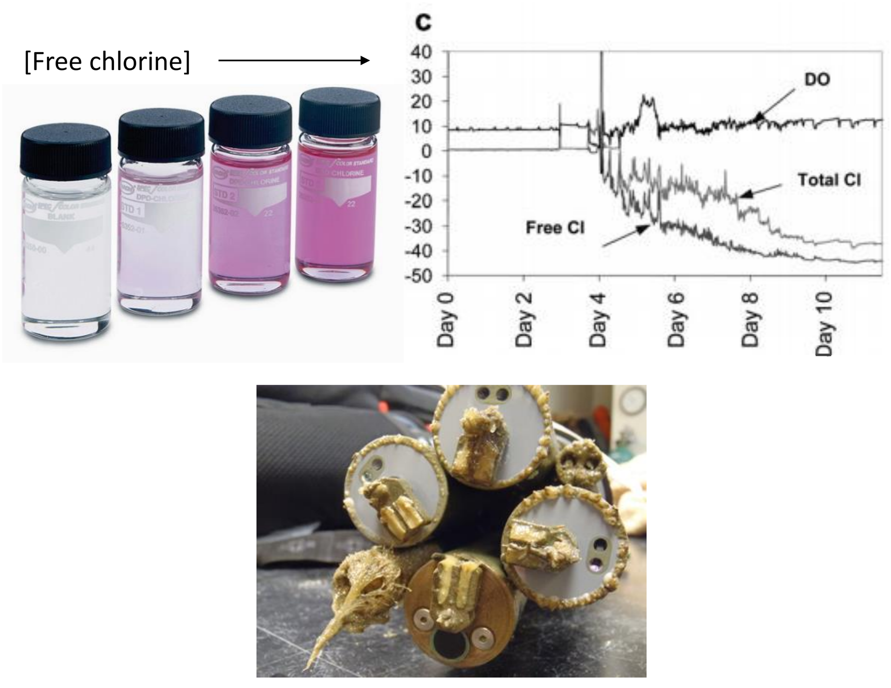
Stream

The Industrial Doctorate Centre for the Water Sector

Continuous, on-line, real-time, accurate, and remote detection of residual free chlorine in drinking water is essential to prevent waterborne disease and to reduce disinfection byproduct formation. Fouling remains a major obstacle to the long-term use of water quality electrochemical sensors.

1. The problem

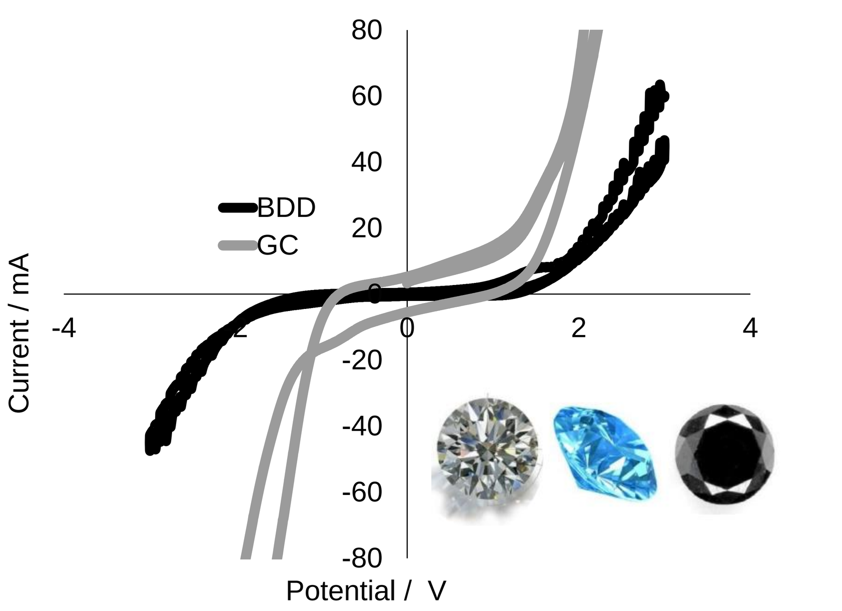
- Residual free chlorine must be closely monitored to prevent waterborne disease and disinfection byproducts
- Chemical tests are not suited for continuous monitoring
- Existing electrochemical sensors require disposable filters or regular cleaning
- Sensor fouling prohibits long-term, continuous monitoring in drinking water distribution systems



(Top left) DPD chemical test for chlorine, (Top right)) Chlorine analyser data showing a rapid reduction in accuracy of residual chlorine measurements over time (Bottom) A biofouled water quality probe.

2. Sensor design

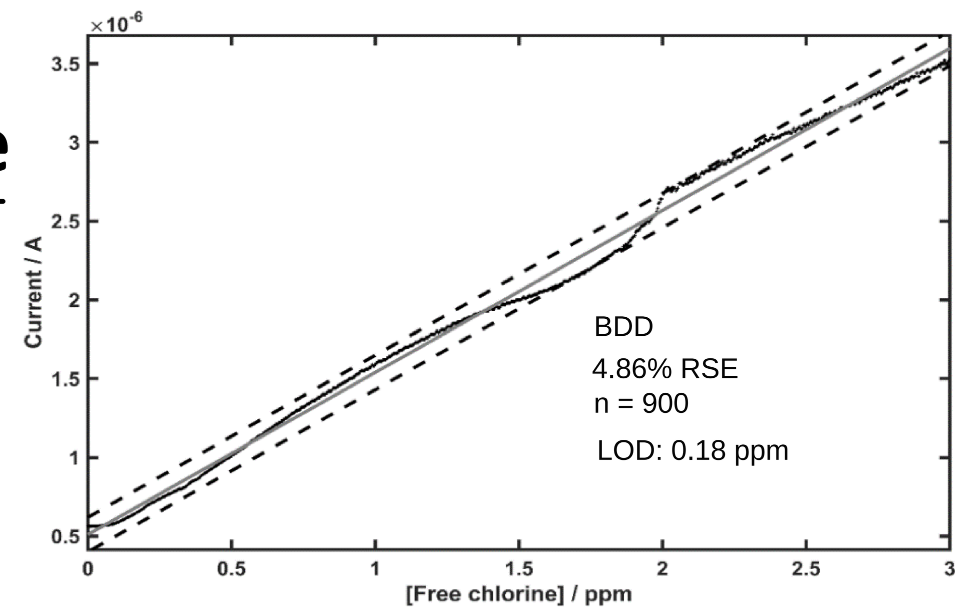
- Boron-doped diamond (BDD) is a fouling-resistant electrode material
- Tolerance of high overpotentials allows for *in situ* cleaning
- Widest window of detection of any electrode
- BDD will be integrated into a wall-jet flow cell



(Above) Comparison of solvent window size of boron-doped diamond and conventional glassy carbon sensors in deionised water (Inset) Three samples of diamond progressively doped with boron

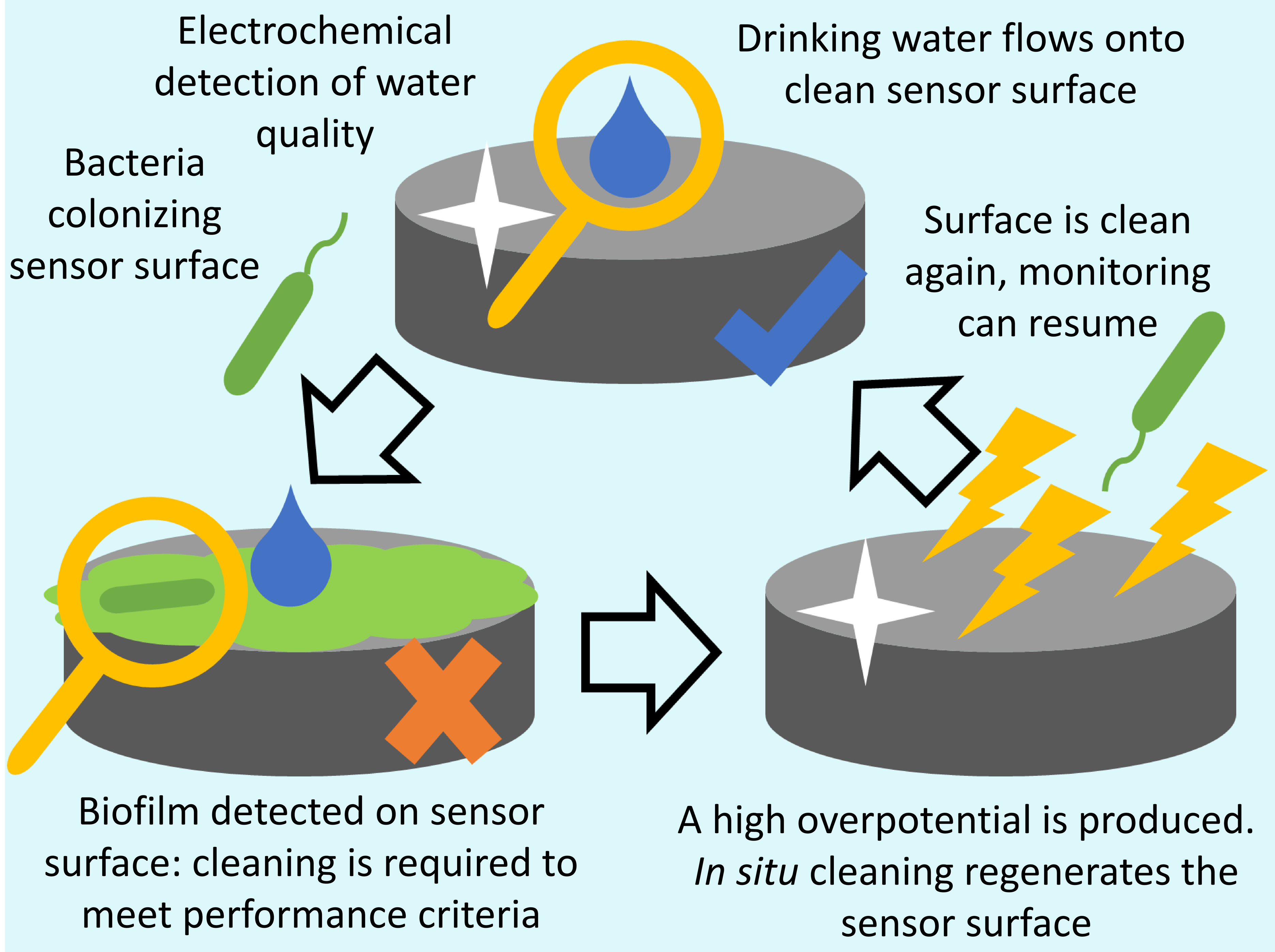
3. Reliable and accurate detection of free chlorine

- Prototype calibrated with solutions of sodium hypochlorite
- Limit of detection below 0.2 ppm lower limit, <5% error



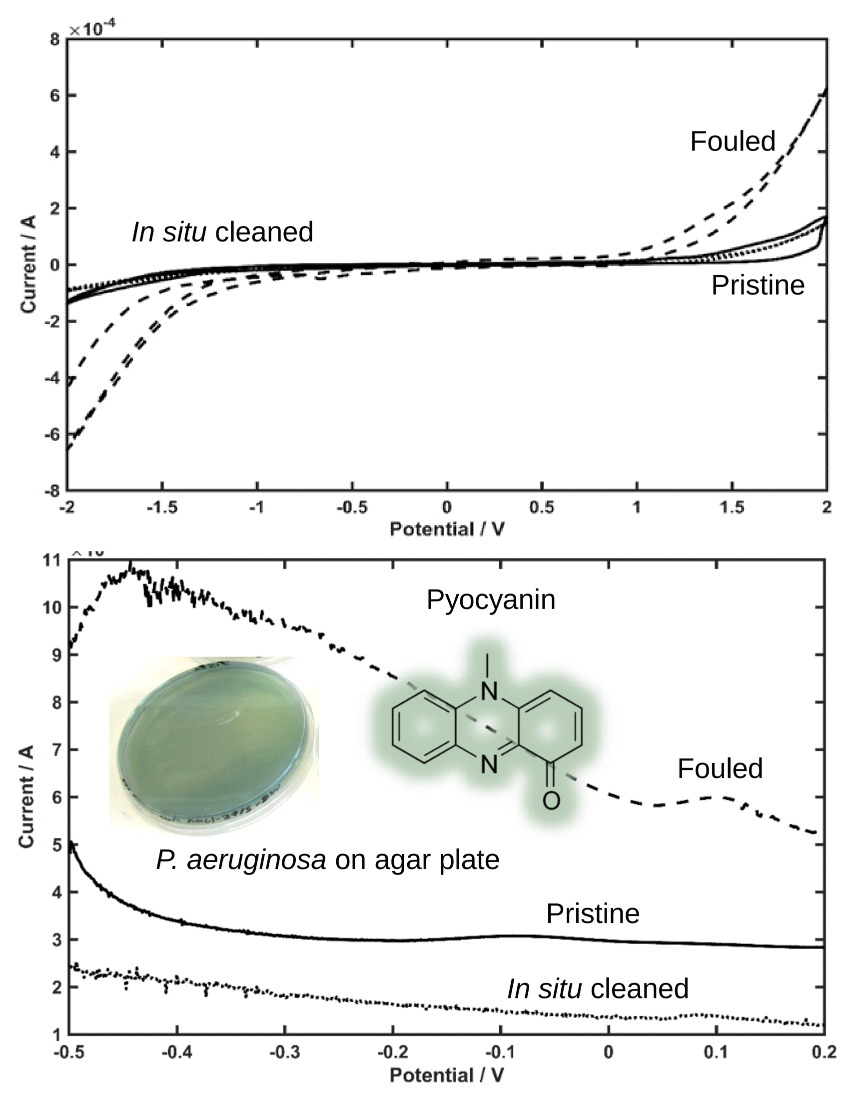
(Above) Relative standard error in chlorine concentration of 1.24%. 900 data points were recorded for each curve and 7 curves were used to generate an average. Amperometric i-T parameters were: potential 1.052 V; sample rate, 1 point per second. 90% prediction bounds are shown as dotted lines, individual data points are shown in black and lines of best fit are shown in grey. The concentrations of stock solutions were standardised by the approved sodium thiosulfate method used by UK drinking water utilities.

4. Biofilm detection and *in situ* cleaning allows water quality sensors to be used continuously without replacement, disassembly, manual cleaning or disconnection



5. *In situ* cleaning and biofilm detection

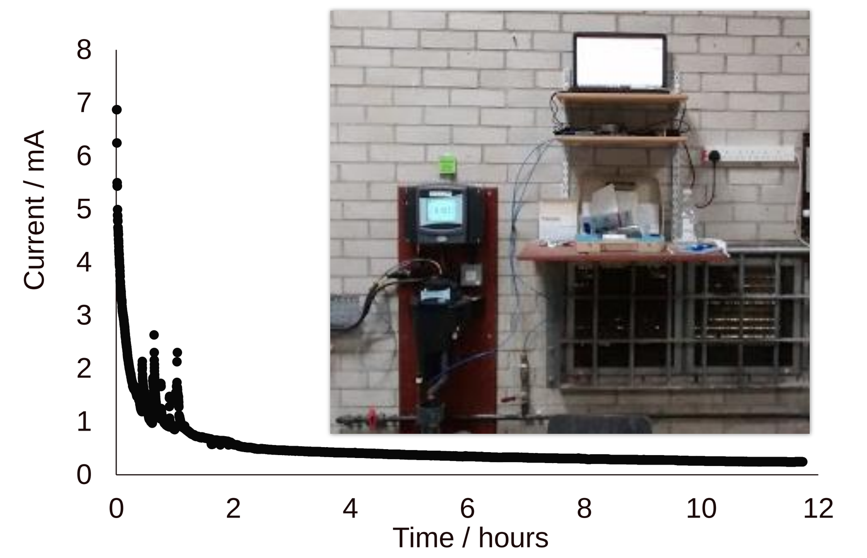
- Sensor fouled in tap water
- *In situ* cleaning as effective as standard cleaning method
- Detection of fouling by changes in background current
- Detection of biofouling by presence of electroactive biofilm compound



(Top) Cyclic voltammetry of pristine, fouled (30 days, flowing tap water) and *in situ* cleaned BDD sensor in drinking water (Bottom) Detection of biofilm indicator compound pyocyanin with pristine, fouled and *in situ* cleaned DD sensors using square wave voltammetry (Inset) A petri dish of indicator organism *P.aeruginosa* and the chemical structure of pyocyanin with characteristic oxidised copper colour

6. Field trials

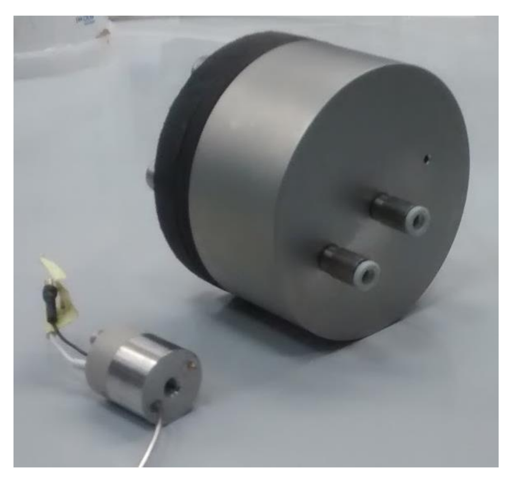
- Prototype installation at drinking water treatment works
- Continuous, remote monitoring in "real life"
- Settling time of 2 hours
- Further trials to commence in the near future



(Above) Chlorine detection data of BDD sensor in a drinking water system showing settling after 2 hours. (Inset) The location of the sensor in the treatment works and the apparatus used.

7. New prototype

- 3 iterations of the sensor
- Optimisation of design for reliability, compatibility, cost and ease of use
- Testing of Prototypes 1 and 2 are completed, Prototype 3 to follow
- Prototype 3 will be production-ready



BDD sensor prototypes (Left) Prototype 1 (Right) Prototype 2. Prototype 3 is in development

8. Summary

- BDD used as drinking water residual chlorine sensor
- LOD below minimum safe residual concentration
- Demonstrated fouling detection and self-cleaning
- Tested in the field
- Production-ready prototype in development

www.stream-idc.net

CLA-VAL | Imperial College London | Bristol Water | EPSRC Engineering and Physical Sciences Research Council

For further information: r.wilson14@imperial.ac.uk
Postal Address: Robert Euan Wilson, Imperial College London, Royal School of Mines, Prince Consort Road, London, SW7 2AZ

Wilson, R. E., Stoianov, I. and O'Hare, D. (2016) 'Biofouling and in situ electrochemical cleaning of a boron-doped diamond free chlorine sensor', Electrochemistry Communications. Elsevier B.V., 71, pp. 79–83. doi: 10.1016/j.elecom.2016.08.015.