DOI 10.5162/EUROSENSORSXXXVI/PT6.304

Real-time water monitoring with advanced biosensor systems

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Summary:

BIOSENSEI (Biosensor-based diagnostic platform enabling real-time monitoring of existing and emerging pollutants) aims to develop a biosensor-based real-time monitoring system for typical nutrients (nitrates and phosphates), and Estrogentic endocrine-disrupters, PFAS (Perfluoroalkyl, and polyfluoroalkyl substances) and Mircocystines. This will allow for the first, continuous reliable, real-time, robust monitoring and detection of these pollutants in soil moisture and watercourses by cellular-based biosensors. This system will utilize a biosensor to detect the target analytes and express signals for combinatory detection by both electrochemical and fluorescence transducers with machine learning enhanced interpretation and decision-making. The system will be tested in Ireland, the Netherlands and Industrial use-cases

Keywords: water monitoring, real-time, modelling, Biosensor, machine learning

BioSensei Objective

In January 2023, the EU Drinking Water Directive [1] was revised to provide higher human health protection by implementing more stringent water quality standards, tackling pollutants of concern, such as PFAS, endocrine disruptors (EDs) and microcystins. These are of special concern due to the combination of their difficulty in real-time detection using current methods and their significant negative effects, e.g. EDs interfere with the action of the female hormone estrogen [2] and are bioactive at very low concentrations (below ng/L). Further, the application of animal manure or sludge bio-solids to agriculture lands has been identified as a main source of livestock-secreted estrogens [3], indicating that reducing over-fertilisation could also reduce associated pollution affects.

BIOSENSEI aims to facilitate novel real-time monitoring for these critical pollutants including Nutrients (nitrates [4], phosphates [5]), EDs, PFAS and microcystins in soil and water. This will be demonstrated through the combination of state-of-the-art electrochemical and fluorescent sensors [6] as transducers for highly specific biosensors. BIOSENSEI aims to:

1. Follow a sustainable-and-safe-by-design approach for sensor development
2. Develop and test whole-cell biosensors to detect a diverse range of analytes to produce detectable signals with high specificity
3. Utilize a bimodal sensing approach (electrochemical and fluorescence-based sensors) as transducers for biosensor-generated signals

4. Develop advanced neural edge tools for multi-sensor data fusion, maximizing sensitivity, selectivity, LOD, and lifetime enhancement of target analytes

BioSensei System

BioSensei aims to push the bounds on what is detectable in-situ, in real-time. The innovative approach will broaden the possibilities of monitorable pollutants and allow for future broad-scale monitoring.

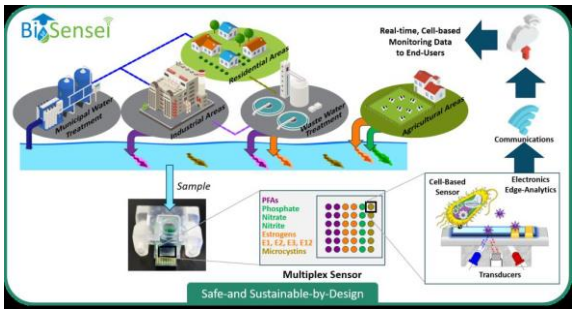

Figure 2. BIOSENSEI system Concept

Established electrochemical and fluorescence sensors will be integrated with encapsulated wildtype microbes, or or genetically modified organisms capable of responding to pollutant analyte presence. These microbes will be immobilised within the sensor enclosure to prevent accidental release and allow for their controlled maintenance and disposal.
Based on previous work [7], novel analog front ends will be developed to the combinatorial sensing approach and sampling conditions. These systems will transfer sensor data to the cloud to facilitate long-term autonomous sensing.

Multi-sensor data fusion methods will be used to determine underlying relationships between the measured (bio)chemical properties, cross-sensitivity in sensor measurements can be exploited to calibrate for environmental effects such as temperature, pH aging or contamination by other chemical species.

Finally, the biosensor will be demonstrated in an industrial setting, a protected ecological site, in agricultural regulatory use case.

Results

BIOSENSEI's vision is to enhance water quality and achieve the highest standards for groundwater in Europe by advancing real-time, cell-based water quality monitoring technologies and minimizing the harmful impacts of water pollution on ecosystems and human health. In both instances, the inclusion of user-case studies will provide region- and application-specific data fostering both climate mitigation in different climatic zones and raising awareness of pollution prevalence.

BIOSENSEI instead focuses on the initial development and assessment of a new technology. The potential for its future implementation, in a similar manner to FAMOSOS, is however evident, despite the early state of the technology. In addition, the facile sensing enabled in real-time has the potential for significant humanitarian benefits, given the extensive health risks of pollution, and the present difficulty in their detection.

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Acknowledgements

The project is funded by the European Union's Horizon Europe Framework Programme (Horizon) under grant agreement 101135241 – BioSensei.