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Implementing an IoT sensor network in a horizontal subsurface flow constructed wetland pilot for real-time monitoring of hydraulic patterns

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Introduction:

Constructed Wetlands (CWs) are a type of Nature-based Solution (NBS) that aims to be environmentally friendly for wastewater treatment in buildings, urban areas, or small communities. While proven effective in small areas, key challenges for CWs in larger scales include preferential flow pathways (flow short-circuits) or stagnated zones (dead zones). With the help of digitalization and the Internet of Things (IoT), integrating sensor networks and data acquisition tools can help optimize the efficiency of the CWs and overcome the challenges. So, the main purpose of this paper is to implement and evaluate an IoT sensor system that enables real-time monitoring of hydraulic patterns in horizontal subsurface flow constructed wetlands.

Methods and data:

The experimental apparatus was installed in the Technical University of Denmark - Ballerup Campus. The pilot test setup consisted of a Horizontal Subsurface Flow Constructed Wetland (HSFCW) with a capacity of 500 Liters. The system was operated using a dosing pump to provide a constant inlet flow. The inlet flow used in the tracer tests was 5 L/hour. Sixty (60) conductivity sensors were placed all over the pilot to enable a detailed resolution of local monitoring. The data acquisition aims to obtain local conductivity information and generate a heat map to support real-time flow pattern monitoring upon tracer tests. The data that comes from the conductivity sensors was sampled by an analog-to-digital converter (ADC). An ESP32 microcontroller was used to control the system, and due to the high number of sensors, 4 multiplexers have been used to sample data from the sensors. The monitoring system was validated based on tracer tests. NaCl was used as a tracer element to test the system's capability to monitor flow patterns during operation.

Results:

Figure 1 shows an example of a heat map generated during the tracer tests based on the information gathered from the network of sensors distributed throughout the HSFCW. The IoT sensor monitoring system provided insightful information on flow patterns in a real-time basis during the tracer test results, indicating the conductivity variation measured over time in different points of the HSFCW. The system has proven to be a low cost effective way to local spatial real-time characterization of flow behaviour in the HSFCW regarding preferential flows and dead zones.

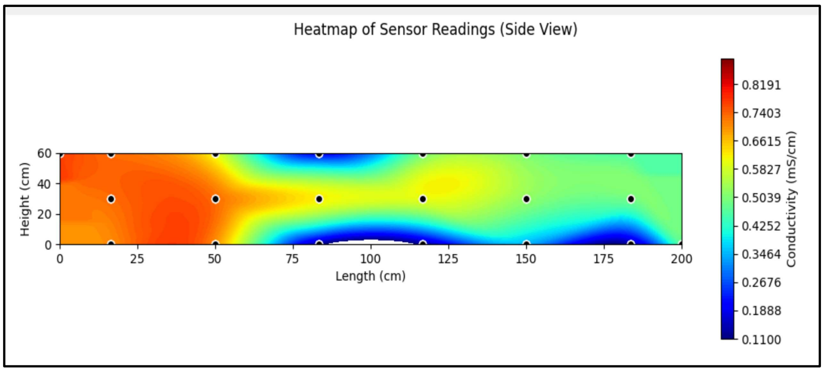

Figure 1: Heat map of conductivity values for a longitudinal section of the HSFCW pilot.

Discussion and take-home message:

This monitoring system can support improvements in HSFCW design and operation by enabling the verification of geometric conditions and operation settings that can enhance flow distribution, avoiding dead zones and consequently providing better use of the whole system volume. Future steps include testing the same approach in a full-scale CW system and a long-term monitoring operation to assess system durability.

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