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IoT Continuous Monitoring Biochemical Oxygen Demand Wastewater Effluent Quality: Machine Learning Algorithms

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Abstract : Effluent quality is of the highest priority for compliance with the permit limits of environmental protection agencies and ensures the protection of their local water system. Of the pollutants monitored, the biochemical oxygen demand (BOD) posed one of the greatest challenges. This work presents a solution for wastewater treatment plants - WWTP's ability to react to different situations and meet treatment goals. Delayed BOD5 results from the lab take 7 to 8 analysis days, hindered the WWTP's ability to react to different situations and meet treatment goals. Reducing BOD turnaround time from days to hours is our quest. Such a solution is based on a system of two BOD bioreactors associated with Digital Twin (DT) and Machine Learning (ML) methodologies via an Internet of Things (IoT) platform to monitor and control a WWTP to support decision making. DT is a virtual and dynamic replica of a production process. DT requires the ability to collect and store real-time sensor data related to the operating environment. Furthermore, it integrates and organizes the data on a digital platform and applies analytical models allowing a deeper understanding of the real process to catch sooner anomalies. In our system of continuous time monitoring of the BOD suppressed by the effluent treatment process, the DT algorithm for analyzing the data uses ML on a chemical kinetic parameterized model. The continuous BOD monitoring system, capable of providing results in a fraction of the time required by BOD5 analysis, is composed of two thermally isolated batch bioreactors. Each bioreactor contains input/output access to wastewater sample (influent and effluent), hydraulic conduction tubes, pumps, and valves for batch sample and dilution water, air supply for dissolved oxygen (DO) saturation, cooler/heater for sample thermal stability, optical ODO sensor based on fluorescence quenching, pH, ORP, temperature, and atmospheric pressure sensors, local PLC/CPU for TCP/IP data transmission interface. The dynamic BOD system monitoring range covers 2 mg/L < BOD < 2,000 mg/L. In addition to the BOD monitoring system, there are many other operational WWTP sensors. The CPU data is transmitted/received to/from the digital platform, which in turn performs analyses at periodic intervals, aiming to feed the learning process. BOD bulletins and their credibility intervals are made available in 12-hour intervals to web users. The chemical kinetics ML algorithm is composed of a coupled system of four first-order ordinary differential equations for the molar masses of DO, organic material present in the sample, biomass, and products (CO_2 and H_2O) of the reaction. This system is solved numerically linked to its initial conditions: DO (saturated) and initial products of the kinetic oxidation process; $CO_2 = H_20 = 0$. The initial values for organic matter and biomass are estimated by the method of minimization of the mean square deviations. A real case of continuous monitoring of BOD wastewater effluent quality is being conducted by deploying an IoT application on a large wastewater purification system located in S. Paulo, Brazil.

Keywords : effluent treatment, biochemical oxygen demand, continuous monitoring, IoT, machine learning
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