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# Soft sensor enabled Carbon source dosing and ozonation control at full-scale WWTPs

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**Abstract:** Two cases of applying soft sensor for real-time process control at full-scale WWTPs were stated in this work. A soft sensor prediction of COD to support mechanistic model based external carbon source doing for denitrification was successfully applied at a full-scale WWTP with significant reduction of carbon dosage. Another application is an online application of a UV-VIS scanning spectroscope for ozonation control for wastewater tertiary treatment. As a result, soft sensor enabled MPC achieved 20.4% of external carbon saving compared with an parallel application of traditional PID control. The UV-VIS monitoring model was further developed into an extended ON/OFF control to control ozonation for wastewater tertiary treatment, which achieves substantial removal of recalcitrant organics and considerable energy saving. This work provided two cases of good practise in full-scale application.

**Keywords**: Wastewater treatment; process control; carbon source; UV-VIS spectroscopy

## 1. Methodology

**Case 1: SCOD Prediction for Carbon Dosing Control.**

The methodology involved developing a multivariate linear regression (MLR) model to predict influent soluble chemical oxygen demand (SCOD) in real-time. Inputs were drawn from commonly available sensors measuring parameters such as conductivity, pH, flow rate, temperature, and suspended solids. The model, calibrated with 332 datasets collected over a year, achieved an R2R^2R2 value of 0.74 and a root mean square error (RMSE) of 18.2, ensuring reliable predictions for operational needs. These predictions were integrated into a Model Predictive Control (MPC) system based on a mechanistic model (Ding et al., 2024). This integration allowed dynamic adjustments to external carbon source dosing, optimizing nitrogen removal while minimizing chemical usage. The full-scale implementation involved equipping two parallel bioreactors in a WWTP with the MPC system. A Proportional-Integral-Derivative (PID) control system was installed for comparison, with real-time nitrate monitoring used to enable dynamic feedback adjustments in both systems.

**Case 2: UV-VIS Monitoring for Ozonation Control**

In the second case, a full-wavelength UV-VIS spectroscope was deployed to monitor residual organics in effluent water, with specific absorbance peaks correlated to COD levels to guide ozonation processes. The system employed linear discriminant analysis (LDA) and support vector machine (SVM) models to classify influent water quality and determine ozonation requirements. A two-step control strategy was implemented: an ON/OFF control to activate or deactivate ozonation based on COD thresholds, and a quantitative dosing model to adjust ozone application dynamically during active phases (Rong et al., 2024). Continuous monitoring of effluent COD and UV-VIS absorbance ensured precise real-time adjustments, reducing energy waste and optimizing the efficiency of advanced oxidation processes. Mathematical modeling validated the correlations between spectral data and COD, with the LDA model achieving high accuracy in determining ozonation needs.

## 2. Results and conclusions

**Case 1: SCOD Prediction and Carbon Dosing Control**

The MPC system based on real-time SCOD predictions achieved significant improvements in operational efficiency. External carbon usage was reduced by 20.4% compared to PID control and by 29.1% compared to manual control, leading to monthly cost savings of 96,700 CNY during the stable operation phase. This reduction in chemical usage also minimized CO2_22 emissions and sludge production, enhancing the sustainability of the treatment process. Effluent nitrate

concentrations were maintained at around 7.25 mg/L, ensuring compliance with discharge standards. The MPC system demonstrated better stability and responsiveness to influent quality fluctuations than the PID control, making it more suitable for dynamic and varying operational conditions. The soft sensor-MPC integration showcased robust adaptability and scalability, offering a practical solution for real-time optimization of carbon dosing in WWTPs.

**Case 2: UV-VIS Monitoring and Ozonation Control**

Ozonation control enabled by UV-VIS monitoring achieved COD removal rates ranging from 16% to 71%, significantly improving effluent water quality. The precise real-time adjustments to ozone dosages ensured effective oxidation of recalcitrant organics while preventing energy waste. The ON/OFF control strategy, driven by UV-VIS data, minimized unnecessary ozone generation during periods of low COD, resulting in substantial energy savings. Quantitative dosing models further enhanced efficiency by dynamically adjusting ozone application to match treatment needs. The LDA model achieved an accuracy of 94.29% for determining the necessity of ozonation, while multivariate regression models provided precise dosing predictions. These results demonstrated the system's ability to comply with stringent environmental standards while reducing operational costs and energy consumption, offering a sustainable approach to advanced wastewater treatment.

## 3. Conclusion

This study demonstrates the successful full-scale application of soft sensors and advanced monitoring systems for optimizing wastewater treatment processes. By integrating SCOD prediction with MPC and using UV-VIS spectroscopy for ozonation control, significant reductions in chemical use, energy consumption, and costs were achieved while maintaining effluent quality. These innovations provide a practical example of effective ICA implementation, offering scalable solutions to enhance efficiency and sustainability in the water treatment sector.

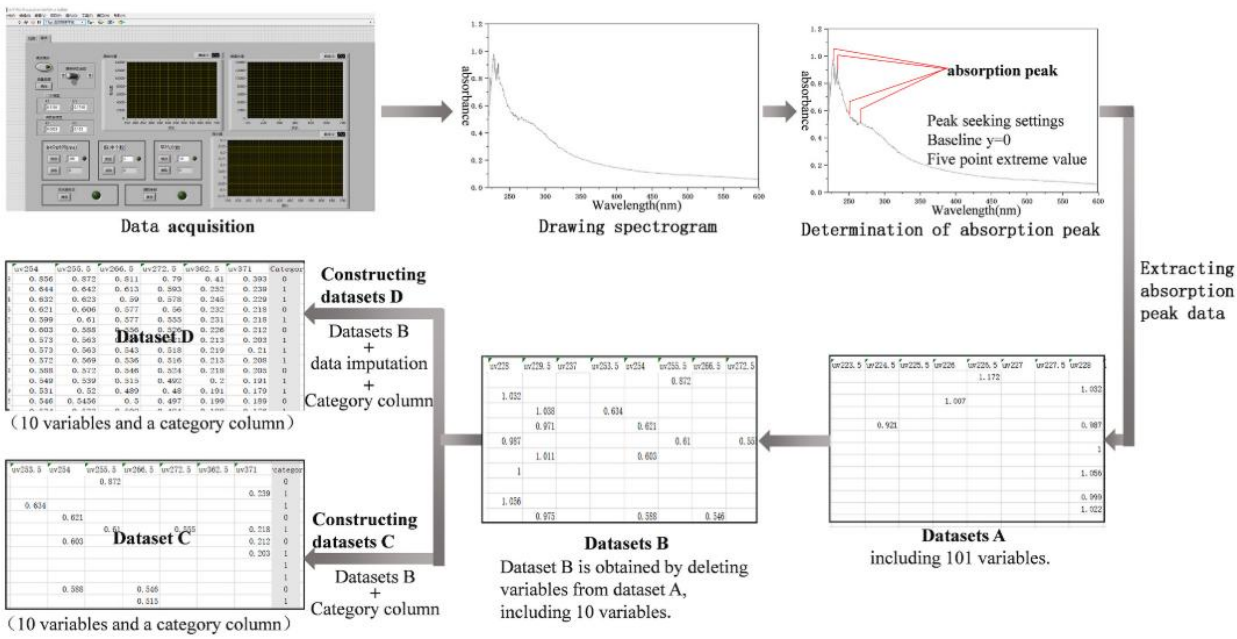


**Figure 1** Diagram of dataset construction of extended ON/OFF switch control for ozonation process.

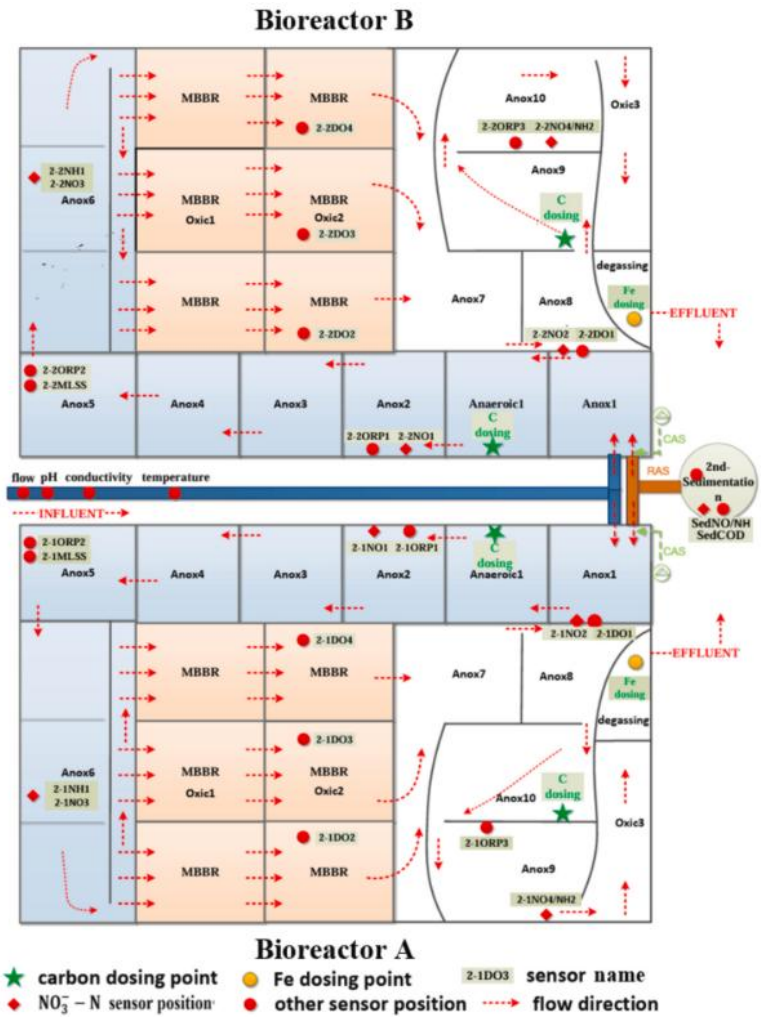


**Figure 2** Schematic diagram of online monitoring sensors and carbon source dosing points in bioreactors of WWTP.

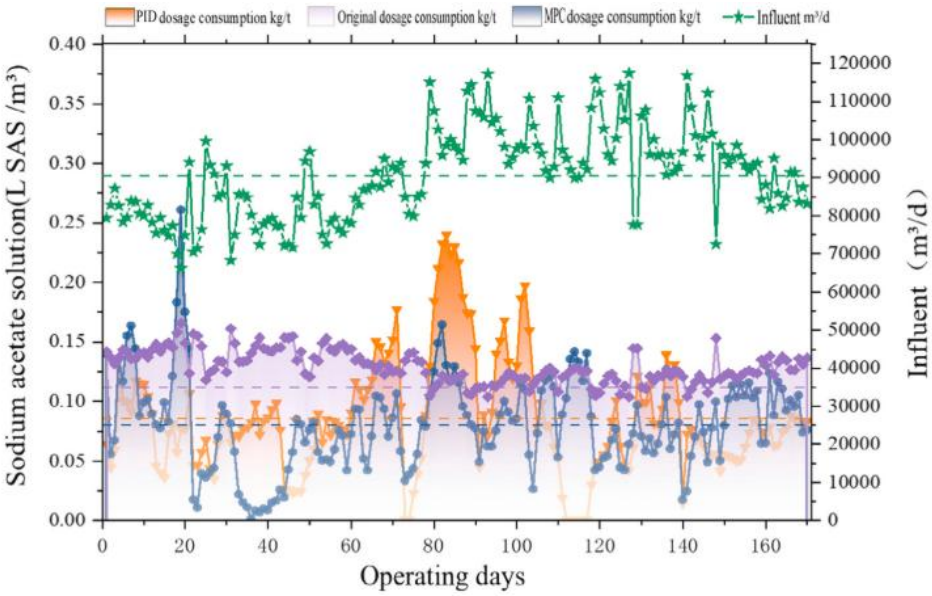


**Figure 2** Schematic diagram of online monitoring sensors and carbon source dosing points in bioreactors of WWTP.

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