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# Fluorescence sensor enabled real-time control of UV and ozone doses during Advanced Oxidation Processes (AOPs)

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**Abstract:** AOPs are widely applied to degrade persistent pollutants. However, in view of new stringent regulations on micropollutants, the real-time monitoring of AOPs become crucial to ensure high quality standards over time. Thus, controlling in real-time parameters like ozone and UV doses is highly desirable for ensuring efficient degradation of target compounds and minimizing by-product formation. However, challenges such as variations in effluent organic matter (EfOM) reactivity and fluctuating water quality complicate the accurate determination of effective doses. This study introduces a novel real-time AOP control approach utilizing an online tryptophan-like fluorescence sensor. Based on fluorescence data obtained in real-time with the sensor, accurate predictive models of UV and ozone doses were developed for two different tertiary wastewater effluents. This approach shows how fluorescence sensors can be used to optimize AOPs in real-time in terms of efficiency, chemicals and energy consume.

**Keywords**: fluorescence; sensors; real-time monitoring; AOPs

Effective process management is vital in wastewater treatment and reuse to ensure compliance with water quality regulations and enhance operational efficiency. AOPs are extensively applied to break down persistent pollutants, including contaminants of emerging concern (CEC). The recently introduced European Directive (2024/3019) on wastewater management mandates member states to implement quaternary treatments, such as AOPs, to facilitate CEC removal in wastewater treatment plants (WWTPs). As a result, the importance of real-time control of AOP effectiveness has grown significantly, particularly in water reuse applications, where rapid responses to operational changes are essential. Controlling key parameters, such as ozone and UV doses in real-time plays a pivotal role in optimizing AOP efficiency, minimizing the risk of insufficient CEC degradation, and mitigating by-product generation (Deniere et al., 2021). Effective ozone dosing strategies must account for temporal variations in EfOM load and reactivity. Similarly, determining the actual UV dose delivered to target compounds can be challenging, as it often deviates from predictions due to fluctuating water quality. Fluorescence spectroscopy has emerged as a rapid, sensitive, and cost-efficient method for characterizing organic matter and monitoring CEC removal in WWTPs (Korshin et al., 2018). However, its potential for real-time AOP optimization remains largely unexplored. This study try to address this gap by introducing an innovative real-time AOP control method utilizing an online tryptophan-like fluorescence sensor. Experimental investigations were conducted under relevant environmental conditions using a pilot-scale system installed downstream of two different wastewater reuse facilities. Processes tested included $O_3$, $O_3/H_2O_2$, UV, and $UV/H_2O_2$. Ozone doses ranged between 2 and 9 mg/L, UV doses between 150 and 1600 mJ/cm², and $H_2O_2$ doses between 4 and 9 mg/L. The sensor provided real-time feedback on treatment performance, detecting rapid water quality changes due to adjustments in operational parameters (e.g., flowrate, UV dose) on the two wastewaters (WW-1, WW-2) tested (Figure 1). Correlation models were developed between real-time fluorescence data and applied theoretical doses. Strong correlations were observed for ozone dose predictions ($R^2 = 0.94$) in both WW-1 and WW-2 and for UV dose predictions ($R^2 > 0.96$) in WW-1 (Figure 2). These results validate the novel application of

fluorescence sensors as real-time control tools for UV and $O_3$ doses in AOPs. This optimization approach has the potential to reduce chemical and energy consumption, lower by-product formation, and enhance overall process efficiency. The findings of this study pave the way for the development of advanced real-time monitoring systems that can adapt to dynamic water quality conditions, leading to cost savings and a reduced environmental footprint for quaternary treatments.

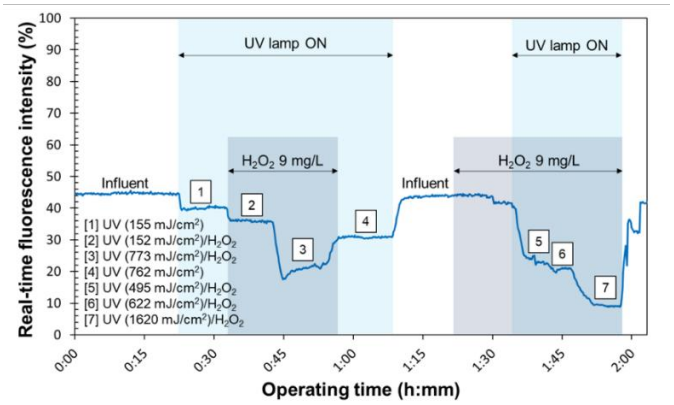


**Figure 1** Real-time fluorescence trends recorded by the sensor during UV/$H_2O_2$ process in WW-1

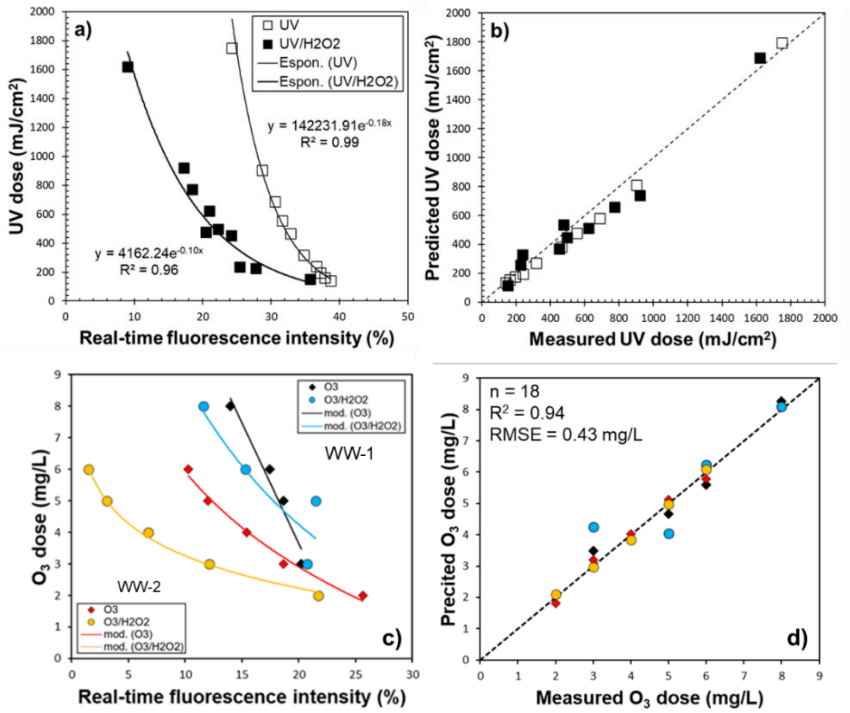


**Figure 2** Correlation models for UV dose (a, b) and ozone dose (c, d) prediction

## References

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