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# Title: Unlocking insights from smart automated aeration tests

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**Abstract:** Wastewater treatment plants (WWTPs) play a crucial role in protecting environmental water quality. Aquafin, which manages 325 WWTPs across Flanders, makes a significant contribution to regional energy consumption, accounting for 0.7% of Flanders' total energy demand. Fine-bubble aeration, widely used for its efficient oxygen transfer, faces challenges such as fouling, air leakage, and material aging. These issues reduce efficiency, increase operational costs, and elevate risks. To tackle these challenges, Aquafin has developed and implemented a fully automated aeration testing methodology and data processing system, aligned with Industry 4.0 principles. The testing and data analysis are performed entirely without manual intervention. This automated approach marks a paradigm shift in wastewater treatment asset management. By moving from age-based or reactive maintenance to predictive, data-driven strategies, operators can improve efficiency, lower costs, and ensure regulatory compliance. Aquafin conducts weekly tests, generating actionable insights for individual WWTPs while also contributing to a broader understanding of aeration system dynamics. In a context of rising energy costs and growing environmental concerns, such innovations are vital for fostering a sustainable future in wastewater management.

**Keywords:** aeration test; treatment efficiency, condition based asset-health, activated sludge activity, Industry 4.0

Wastewater treatment plants (WWTPs) play a vital role in protecting environmental water quality. However, these operations are resource-intensive, with significant energy demands, particularly from aeration systems. For Aquafin, a company managing 325 municipal WWTPs in Flanders, aeration accounts for a substantial share of its energy footprint. This represents 0.7% of the region's total energy consumption, or approximately 200 GWh annually. Given the importance of aeration in meeting discharge standards, optimizing this process is a priority for reducing costs and enhancing sustainability.

Fine-bubble aeration, the predominant technique used across these plants, is highly energy-efficient but prone to performance degradation. This degradation can increase the risk of effluent quality issues and operational costs. Challenges such as fouling from scaling and biofilm growth, equipment tearing, and material aging reduce aeration efficiency and drive up operational expenses [ref 1].

These issues necessitate effective monitoring and maintenance strategies. However, the submerged nature of these systems complicates direct observation, making manual or reactive approaches insufficient.

To address these challenges, Aquafin has developed and implemented a fully automated aeration testing methodology and data processing approach aligned with Industry 4.0 principles. The tests are performed without any manual intervention, and the data is processed automatically.

Weekly, the SCADA control system overrides the normal aeration control when conditions allow for testing, such as during low-load periods at the WWTP. The aeration equipment is operated in a standardized manner, as described in [ref 2], while several critical parameters are measured: backpressure, water temperature, power usage, mixed liquid suspended solids, and dissolved oxygen. No additional sensors or equipment were installed to avoid extra costs and complexity, ensuring the method's scalability across other WWTPs. Data processing is handled in the cloud, including fitting the aeration curve as described in [ref 2]. Since air temperature and humidity are

relevant but not directly measured at the WWTP, this information is automatically sourced from an external cloud service.

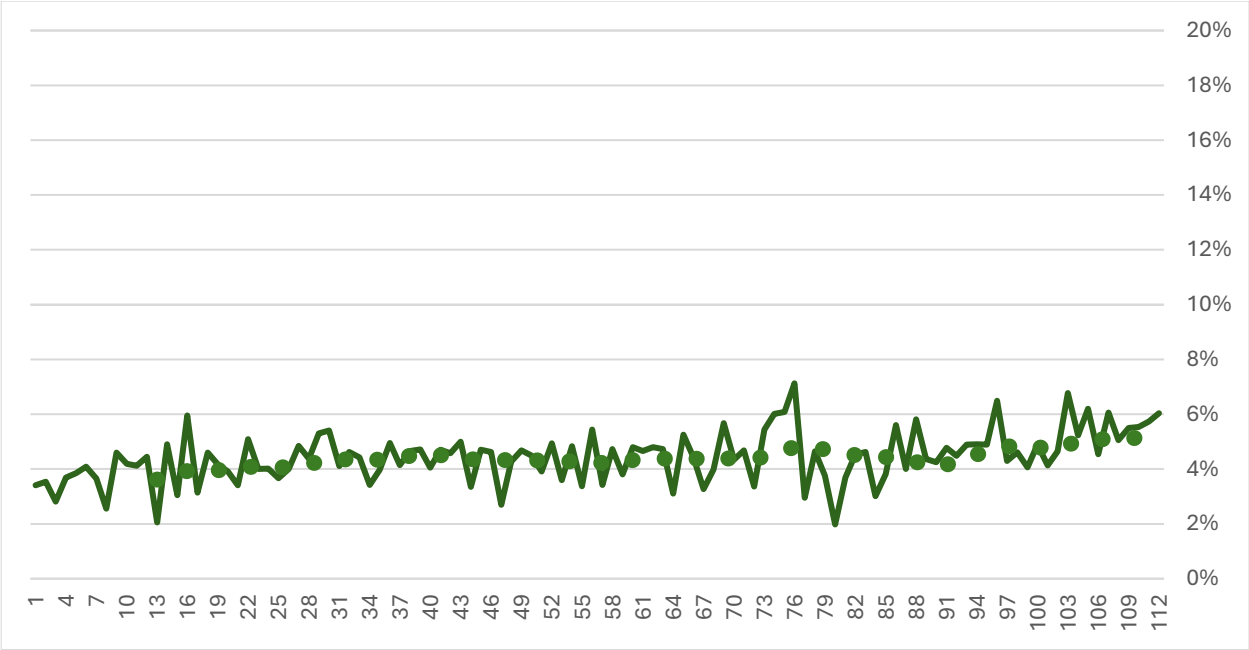


**Figure 1.** Measured Standard Oxygen Transfer Efficiency under process conditions at the WWTP of Temse (αSOTE) (%/m) (8 months of data)

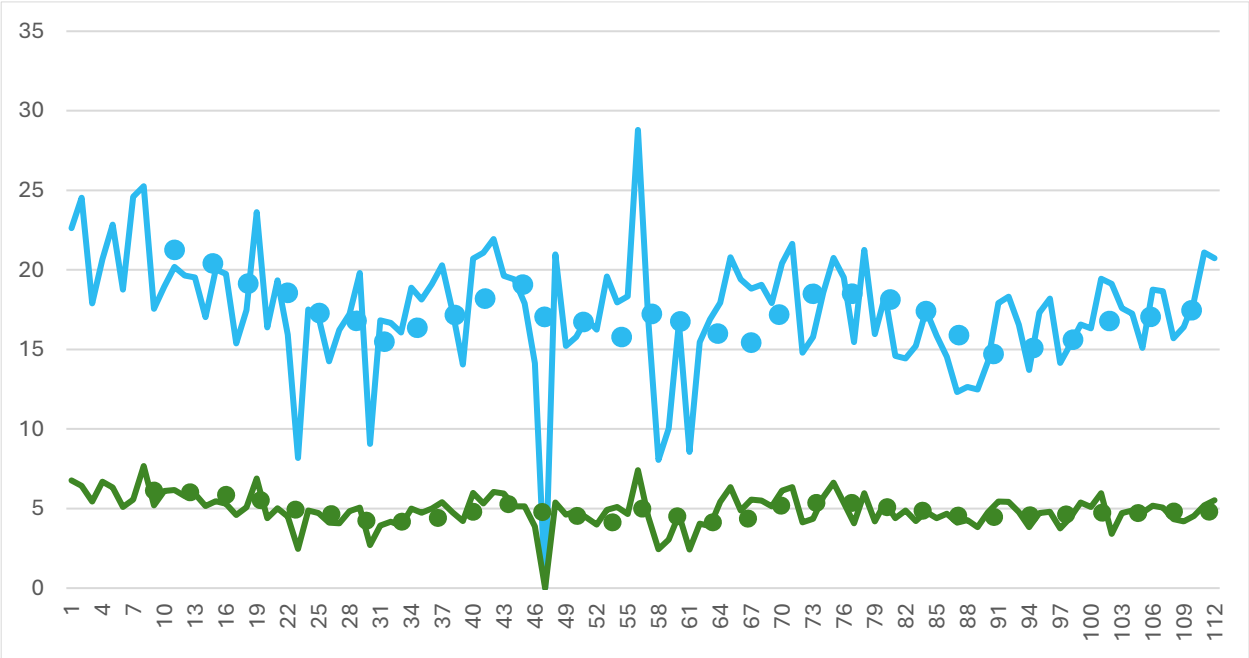


**Figure 2.** Measured Oxygen Uptake Rate (OUR) at the WWTP of Temse: blue: as measured (mg/(L.h)) / green: corrected for MLSS (mg/(h.g)) (8 months of data)

The collected metrics and corrections (temperature, humidity) provide a comprehensive view of the aeration system's asset-health and energy efficiency, offering valuable insights into performance trends (αSOTE, αSOTR, αSAE, backpressure and power consumption) and process conditions. Additionally, information on leak rate and activated sludge quality is obtained by measuring the oxygen uptake rate (OUR) and the backpressure when the aeration is switched off. The combined data from these weekly tests enables Aquafin to detect issues such as:

- **Fouling and Scaling:** Over time, scaling and biofilm growth on diffusers increase backpressure, leading to larger bubbles and reduced oxygen transfer efficiency [ref 1]. This deterioration is quantified through the backpressure and the measured oxygen transfer coefficient (αkLA) [ref 2].
- **Tearing and Leaks:** Equipment failures, such as air leaks, are often difficult to detect but can result in hidden costs and risks. Monitoring anomalies in power consumption, oxygen transfer performance, and pressure drop speed allows for early detection.
- **Aging and Material Degradation:** Diffusers made from EPDM rubber - for example - degrade as plasticizers leach out, reducing flexibility and performance, Blower efficiency can degrade, …. Automated testing provides data to model aging trends, enabling operators to plan timely replacements.
- **Changes in Activated Sludge Activity:** Changes in OUR can lead to reduced treatment of the wastewater.
- **Changing Process Conditions:** Actual oxygen transfer to the activated sludge in actual process conditions.

By analyzing trends across multiple WWTPs, patterns emerge that inform:

- **Optimal Cleaning Intervals:** Balancing energy efficiency improvements with cleaning costs is critical. Data-driven insights help determine the optimal timing for acid dosing to address fouling and scaling.
- **Replacement Planning:** Widely used age-based replacement strategies are often inefficient. Automated testing supports predictive maintenance by identifying the precise point at which diffuser performance significantly declines.
- **Anomaly Detection:** Subtle deviations in performance metrics can indicate underlying issues. Advanced analytics identify these anomalies, enabling proactive interventions.

The implementation of automated aeration tests has far-reaching implications for operational efficiency and environmental sustainability. Key benefits include:

- **Energy Savings:** Maintaining optimal aeration efficiency minimizes energy waste, resulting in significant cost savings across WWTPs.
- **Reduced Maintenance Costs:** Timely cleaning and targeted replacements prevent over-maintenance and reduce the risk of costly emergency repairs.
- **Improved Compliance:** Continuous monitoring ensures treated water meets regulatory standards, minimizing environmental risks.
- **Scalability:** Insights from one WWTP can guide practices across others, leveraging data from the entire network to optimize regional operations.

Automated aeration testing represents a paradigm shift in wastewater treatment asset management. By transitioning from age-based or reactive maintenance approaches to predictive, data-driven strategies, operators can enhance efficiency, reduce costs, and ensure compliance. The weekly tests conducted by Aquafin not only provide actionable insights for individual WWTPs but also

contribute to a broader understanding of aeration system an process dynamics. As energy costs rise and environmental concerns grow, such innovations are essential for a sustainable future in wastewater management. Through continuous refinement and integration of these methodologies, Aquafin aims to position itself as a leader in energy-efficient wastewater treatment, setting a benchmark for the industry.

## REFERENCES

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**[2]** DWA-M 209. 2007 *Messung der Sauerstoffzufuhr von Belüftungseinrichtungen in Belebungsanlagen in Reinwasser und in Belebtschlamm*. Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall, Hennef.