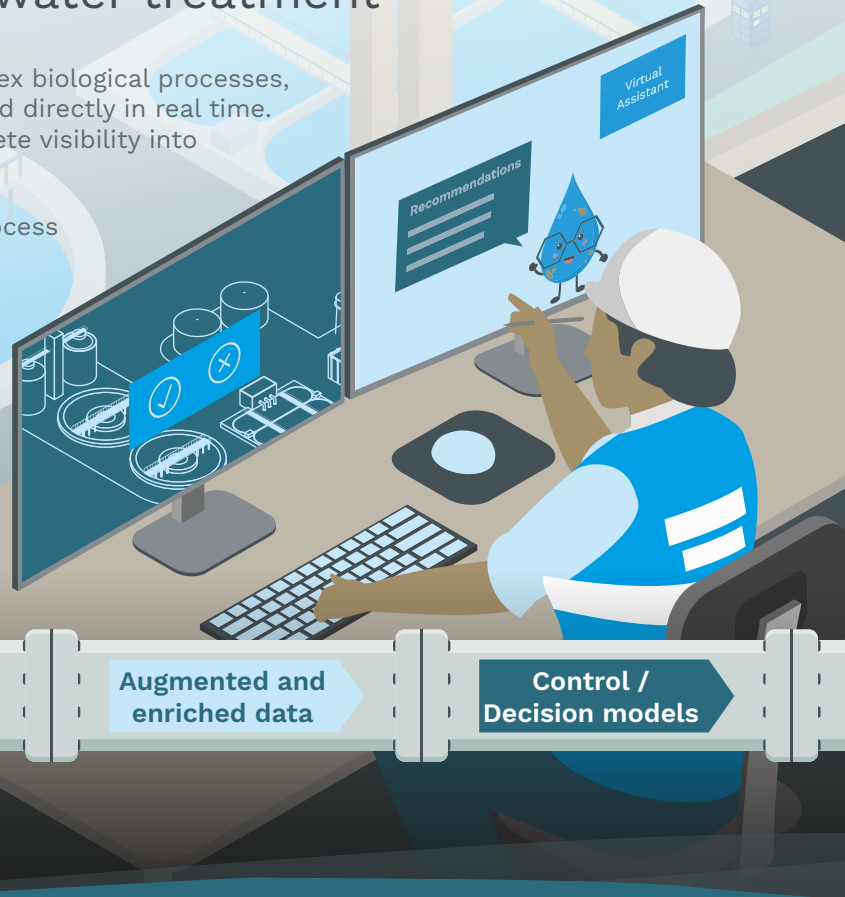


From prediction to optimised plant operation: Decision support for wastewater treatment

Modern wastewater treatment plants rely on complex biological processes, yet many critical process states cannot be measured directly in real time. Operators must often make decisions with incomplete visibility into what is happening inside the plant.

DARROW addresses this challenge by combining process knowledge with data-driven models to make key biological and operational states visible and predictable. The three models presented here estimate current biological performance, assess process capacity, and forecast future effluent quality. This supports informed, proactive operation that balances treatment performance, compliance, and energy efficiency.



DARROW's data pipeline

Raw sensor
and lab data

AI models

Augmented and
enriched data

Control /
Decision models

Biomass estimator

What it does

Predicts the amount of three key microbial biomass groups in the plant in real time: heterotrophic, autotrophic, and polyphosphate-accumulating bacteria.

Why it matters

Microbial populations drive nutrient removal, but they cannot be measured directly in real time. By estimating the concentration of these key biomass groups, the model provides continuous insight into the biological state and performance of the plant. This helps operators better fine-tune nitrogen and phosphorus removal, improving process stability and efficiency while minimising energy consumption.

How it works

Using data from multiple plant sensors, the model learns historical patterns and estimates current microbial biomass levels.

AI models used:

LSTM (Long Short-Term Memory): A neural network that recognises patterns over time, particularly effective for biological time-series data. It was extensively optimized to find the best set of hyper-parameters.

Output:

Real-time estimates of heterotrophic, autotrophic, and polyphosphate-accumulating bacteria in the plant.



Nitrification capacity estimator

What it does

Estimates the plant's nitrification capacity in real time by combining sensor data with mathematical models.



Why it matters

Nitrification is one of the key processes in a wastewater treatment plant and a major driver of energy consumption. Yet, the nitrification status is difficult to assess in real time, as it depends on multiple interacting factors that are not straightforward to interpret.

By providing a real-time estimate of nitrification capacity, the model supports informed decisions on oxygen setpoints and purge flow, helping operators balance treatment performance, stability, and energy use.

How it works

The model functions as a soft sensor: it combines sensor measurements with mechanistic models to estimate nitrification capacity in real time. Because it relies on both data and models, it continuously adapts to changing conditions and provides corrected, real-time information to the operator.

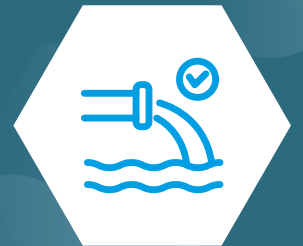
Algorithm used: Extended Kalman Filter (EKF): An advanced data-processing method widely used for state estimation in dynamic systems.

Output: Real-time estimate of the plant's nitrification capacity.

Effluent forecasting and optimisation model

What it does

Predicts effluent water quality for the next 24 hours based on current and planned operating conditions.



Why it matters

The model gives operators a 24-hour preview of how today's control decisions will affect tomorrow's effluent quality. It allows them to test "what if" operating strategies (e.g. changing oxygen setpoints or recirculation rates) and immediately see the expected impact on key effluent indicators.

This supports more efficient operation, reduced risk of non-compliance, and smarter use of energy and resources.

How it works

The model is trained on simulated data from calibrated digital twin of the wastewater treatment plant. For each forecast, the model uses recent sensor data and, where available, short-term influent forecasts to simulate plant behaviour and generate 24-hour effluent trajectories under different operating scenarios.

AI models used: Reduced Order Model (ROM) based on LSTM (Long Short-Term Memory) neural networks.

Output:

- 24-hour forecasts of effluent key performance indicators (KPIs): TP, TN, TSS, COD, NH₄.
- Recommended DO setpoints and internal recirculation profiles for the next 24 hours, respecting regulatory constraints and ensuring smooth control actions.



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