

Deliverable 3.3: Machine Learning Models

What is the deliverable about?

Deliverable D3.3 presents the advanced Machine Learning (ML) models developed to optimise process control across the R3VOLUTION project's four industrial pilot sites. These algorithms are paired with explainability tools (XAI - Explainable Artificial Intelligence) that goes beyond simple outputs into human-readable, transparent reasoning. The solutions created for each pilot site are as follows:

- For Bloom (Chemicals), a prediction of when water filtration membranes are starting to clog, allowing operators to clean them proactively and extend their lifetime.
- For Celsa (Steel), a Virtual Sensor (VS) to estimate ion concentrations in salt-separation systems (a stack of membranes).
- For Felix Schoeller (Pulp & Paper), Reinforcement Learning (smart control) and Deep Learning (DL) to automatically balance fluctuating wastewater pH levels and predict effluent temperature.
- For Repsol (Refinery), Computer Vision (smart cameras) to automatically detect surface anomalies like oil solids, sludge or foams in different steps of wastewater treatment, and a VS to infer Chemical Oxygen Demand (COD) from Total Organic Carbon (TOC).

What challenges are addressed?

Water quality measurements can rely on manual laboratory sampling or high-cost physical instruments, thus virtual sensors can provide further information about a process with minimal costs. Furthermore, traditional wastewater treatment operations are heavily reactive and variable, with operators responding to issues after they occur. ML algorithms enabling early alarm systems or helping with stream management can help react more efficiently to changes and keep key variables within strict ecological limits with less effort. Finally, ML is difficult to deploy because expert operators can be hesitant to trust automated recommendations that impact plant safety and environmental compliance without explanation. The layer of XAI on top of our solutions solves this issue.

What is the innovation?

The primary innovation is the integration of predictive ML with XAI to create transparent, trustworthy process-control tools that help make industrial water reuse smarter and more efficient. These types of technologies (CV, VS, DL) are relatively new and as such are more often applied to the main product's industrial process, rather than wastewater treatment as is the case here.

Contact for further information:

Clothilde Breger (CETAQUA): clothilde.eva@cetaqua.com

Prodromos Mouratidis (CERTH): prodromosm@iti.gr

CETAQUA
WATER TECHNOLOGY CENTRE



CERTH
CENTRE FOR
RESEARCH & TECHNOLOGY
HELLAS



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