



**DrinkIA<sup>®</sup>**  
Digital Twin Technology

Smart resilience for your water supply

**lequia** ECO-INNOVATIVE  
ENVIRONMENTAL  
SOLUTIONS  
UdG





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# FROM SOURCE TO TAP: THE COMPLEXITY OF DRINKING WATER SUPPLY

Drinking water treatment plants (DWTPs) provide safe water to citizens, yet this simple day-to-day service is the result of complex processes and advanced technologies

The **water scarcity**, the changes in **demography** and the **operational efficiency** of the facilities are the top issues for the water sector globally. Despite the long-term impact of climate change is uncertain, many expect it to exacerbate the water scarcity and reduce its quality, while the aging of the infrastructures makes the system more vulnerable.

DWTPs **provide safe water** to citizens, a day-to-day service resulting from **complex processes** and **advanced technologies**. It is of paramount importance to counteract microbial contamination from surface water using several treatment units, which act as **chemical and physical barriers** against **pathogens** and **pollutants**, reducing any health risks.

Managing the **trade-off** between **microbial and chemical risks** is still a challenge, due to the unintended outcome of Disinfection by-products (**DBPs**), formed via the chemical reaction between water disinfectants and **natural organic matter**. DBPs are the **major contributors** to the **chemical risk** of drinking water, with trihalomethanes and haloacetic acids being the most frequently groups and at the highest concentrations in water supplies worldwide.

In this context, with the increasing extreme weather episodes and some disruptive events, such as the COVID-19, drinking water utilities are compelling to accelerate their **digital journey** to assure a greater **resiliency** towards **operational improvements**.

*Drinking water supply systems are being affected by the global warming with an uncertain long-term impact*







ETAP Abrera (ATL)



ETAP Ter (ATL)



# DIGITALISATION OF WATER SUPPLY

Digitalisation is shifting DWTP towards a more informed, predictive, and risk-based operation by using real-time quality analysis and the operational data provided by sensors.

The monitoring and analysis of the treatment performance is a task regularly performed by skilled operators and process technologists, leading to an operator-dependent, subjective and variable plant operation.

In a context of raising complexity for water treatment due to stricter legislations and advancing technologies, the optimization of DWTP requires an integrated approach in terms of **quality, environmental** and **economic costs**. Until now, the operation of most DWTP relies on the experience of the skilled operators and the process technologists, who monitor and analyse the treatment's performance. However, human criteria are subjective, and their actions depend on variables that prevent to anticipate operational requirements and oversee the gradual changes in water quality and overall performance.

**Digitalisation** is shifting drinking water treatment plants towards a more informed, predictive, and risk-based operation by using real-time quality analysis and the operational data provided by analytic sensors. Using these technologies, detrimental vents and information in source water quality will ensure safety of water in an integrated manner.

The water sector is undergoing a digital transformation to face challenges related to sustainability of resources, infrastructure management, climate change and demographics, and Augmented Intelligence predictive models will have an important effect giving a real-time support on the operation of DWTPs. In these systems **Artificial Intelligence** (AI) methods enhance human decisions, which are at the centre of the control loop, by the data analysis and evolutionary learning mechanisms that have the potential to carry out water quality diagnosis, autonomous decision making and operation process optimization.

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*AI-based data analysis and evolutionary learning mechanisms are performing water quality diagnosis, autonomous decision making and operation process optimization*

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*The water sector is undergoing a digital transformation to face challenges related to the sustainability of resources, infrastructure management, climate change and demographics*







# DrinkIA - Team

DrinkIA-Digital Twin technology has been developed by a multidisciplinary team of the Laboratory of Chemical and Environmental Engineering (LEQUIA), a research group of the University of Girona (UdG). Led by Dr Maria Martín and Dr Hèctor Monclús, the team brings together knowledge and expertise from different scientific-technological disciplines, such as computer science (artificial intelligence, modelling), chemical engineering (coagulation, adsorption), social sciences (socio-economic assessment) and technology transfer. Research on drinking water treatment digitalisation has been carried out within the framework of national research projects funded (WATSON, SHERLOCK, RITA) and R&D contracts with leading industrial players such as ATL or FISERSA. Main achievements on drinking water treatment digitalisation include 2 doctoral theses completed (one of them awarded), 3 doctoral theses under development, 6 articles in high impact scientific journals and several presentations in international conferences. In 2018, prestigious Botín Foundation awarded DrinkIA – Digital Twin<sup>®</sup> technology with the “Prize to Young Talent for Sustainable Water Management”.

| RESEARCHER                  | POSITION                                        | EXPERTISE                                                    |
|-----------------------------|-------------------------------------------------|--------------------------------------------------------------|
| • <b>Maria Martin</b>       | Associated Professor                            | Adsorption, oxidation and coagulation processes of DWTPs     |
| • <b>Hèctor Monclús</b>     | “Ramón y Cajal” fellow                          | Environmental Decision Support Systems in DWTPs              |
| • <b>Manel Poch</b>         | Full professor                                  | Environmental Decision Support System in urban water Systems |
| • <b>Marta Verdaguer</b>    | Associated professor                            | Optimization algorithms in urban water cycle                 |
| • <b>Alba Cabrera</b>       | “Juan de la Cierva-Inc” fellow                  | Adsorption and oxidation processes of DWTPs                  |
| • <b>Alexandra Popartan</b> | “Juan de la Cierva-For” fellow                  | Socio-economic and ethical issues of water technologies      |
| • <b>Meritxell Valentí</b>  | PhD student                                     | Advanced techniques for water characterisation               |
| • <b>Laura Ferràndez</b>    | PhD student (industrial doctorate with FISERSA) | Process Engineering in DWTPs                                 |
| • <b>David Albert</b>       | PhD student                                     | Data science in water supply                                 |
| • <b>Teresa Bosch</b>       | Project manager                                 | Technology transfer, project management                      |







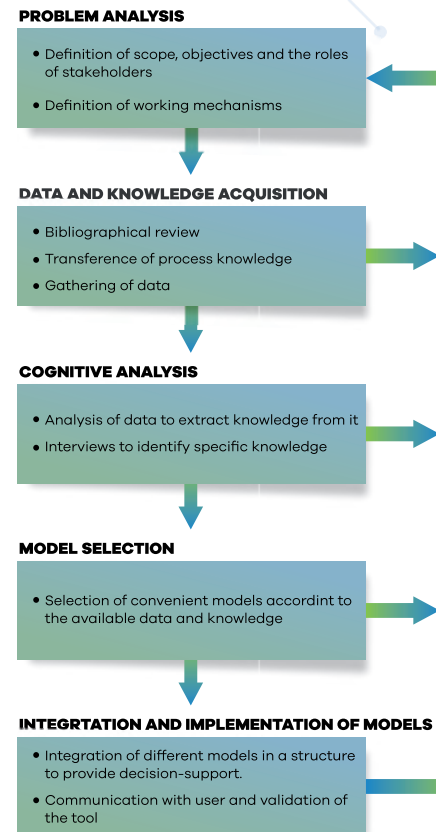
# EDSS: THE DIGITAL SOLUTION TO IMPROVE WATER SUPPLY RESILIENCE

DrinkIA-Digital Twin Technology is an intelligent knowledge-based EDSS for the integrated control and optimization of drinking water supply processes.

To ensure robustness, autonomy and objectiveness, DrinkIA integrates models derived from the full-scale operation of DWPs: Data driven (Sensors, probes, and operating conditions), Expert knowledge (the cumulative expertise of plant managers) and the Experimental knowledge acquired in laboratory.

DrinkIA-Digital Twin, the first Integrated Control and **Environmental Decision Support System** (EDSS) for drinking water treatment plants, provides the framework to systemize and standardize the strategic and management decisions. The implemented strategies are expected to improve the water quality while reducing the operational and environmental costs of the treatment process.

EDSSs integrate mathematical and AI models with expert knowledge to deliver contested problems in a structured way, to provide the user with a better understanding of the problem and augment their decision capacity. Thus, EDSSs cope with the complex decision-making of water supply, increasing the resilience of these utilities in front of changes in source water quality in the global change context.



*DrinkIA ensures the minimum DBPs formation by profuse characterization of raw water features followed by the optimization of the treatment*



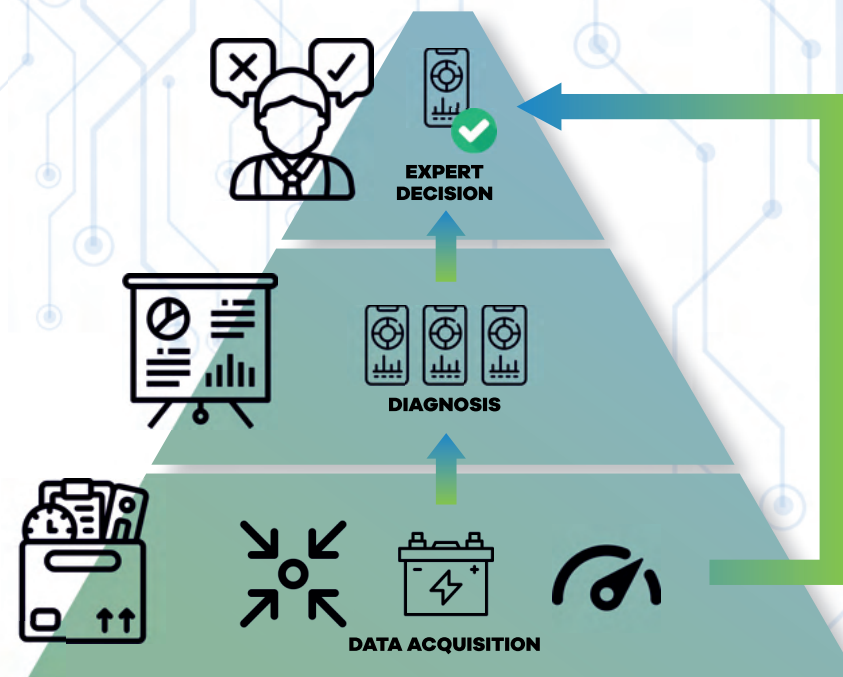
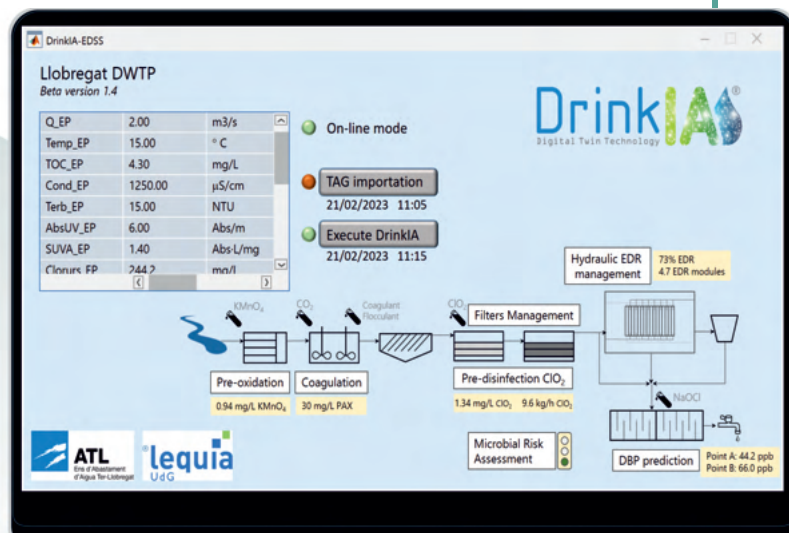




## EDSS: THE DIGITAL SOLUTION TO IMPROVE WATER SUPPLY RESILIENCE

DrinkIA-EDSS was developed following five steps: 1) Analysis of the problem; 2) Data and knowledge acquisition; 3) Cognitive analysis; 4) Model selection and 5) Implementation and validation.

DrinkIA operates following a 3-level hierarchical architecture, where the lowest level is responsible for data gathering and signal processing, the diagnosis level proposes the most suitable control action based on data driven, expert and experimental knowledge, and finally the supervision level ensures that the decision taken is robust by a set of knowledge-based rules.



*DrinkIA predicts operational set-points, recommendations and chemicals dosages delivering support to decision-making in the more transparent and user-understandable manner*







# DrinkIA: A DIGITAL TWIN TECHNOLOGY®

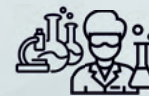
DrinkIA is the result of 6 years collaborative work between LEQUIA (University of Girona) and ATL (Drinking water supply company) to develop and implement an EDSS to manage the DWTPs of Abrera and Cardedeu and the water distribution centre. The **prototypes of DrinkIA-EDSSs** are being tested since September 2018 at the Llobregat DWTPs and Ter DWTP operated by ATL, which supply drinking water to 4,5 million inhabitants.

Some of the benefits that were accomplished using DrinkIA-EDSS for aiding in the management of Abrera and Cardedeu DWTPs were:

- Augmented capacities for DWTP users by means of process modelling and predictive tools
- Deeper understanding on the process characteristics by performing treatment scenarios.
- Increased awareness and quantification about consequences of certain actions on the DBPs formation and/or microbiological risk.
- Real-time decision-support to face changes in raw water quality, increasing robustness of DWTPs' management.
- Increased autonomy of operators who are on shift works, especially when working out of office hours.

DrinkIA-EDSS retrieves data from the online data acquisition system but allowing the users to edit input values for performing analysis of treatment scenarios. DrinkIA-EDSS includes:

## EXPERIMENTAL



Experimental knowledge module based on a profuse NOM characterisation using UV-VIS multiwavelength spectroscopy for the mitigation of DBP formation.

## DATA-DRIVEN



Data-driven modules for predicting the chemical dosages, THM formation and the filters management.

## EXPERT



Expert knowledge based modules for predicting the pre-desinfectant dosages, the coagulant dosage, the microbial risk assessment and the water distribution management.









## EXPERIMENTAL

### Experimental knowledge based module

Using advanced analytical techniques for the characterization of NOM can be a powerful tool for advanced control strategies related to the minimization of DBPs.

Natural organic matter (NOM) plays a key role in water treatment that impacts on the efficiency of operations and it is a critic precursor for DBPs generation.

Our laboratory team has developed a specific methodology based on size exclusion chromatography coupled to a UV-VIS diode array detector, and an organic carbon detector (HPSEC-DAD-OCD) to identify the main DOM fractions according to their molecular weight distribution and determine their role in the formation of DBPs. Also, we have combined this information with other techniques such as fluorescence spectroscopy and the full scale monitoring data.

Thanks to the Experimental Knowledge acquired at our laboratories, we could correlate the best parameters that link off-line fractionation analysis and on-line measurements. Changes in NOM profiles after different operational treatments in DWTP helped us optimizing DBPs reduction by seeking maximum NOM removals.

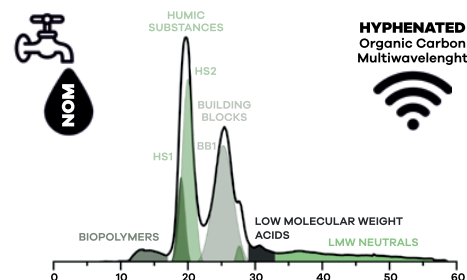
DrinkIA aims at the continuous integration of this Experimental knowledge as one of the main objectives to maintain the most robust tool.

*We use NOM fractionation analysis for predicting disinfection by-product formation*

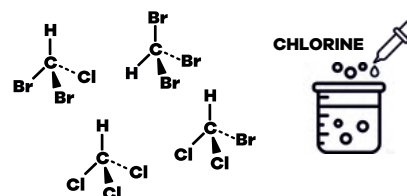


#### SIZE EXCLUSION CHROMATOGRAPHY

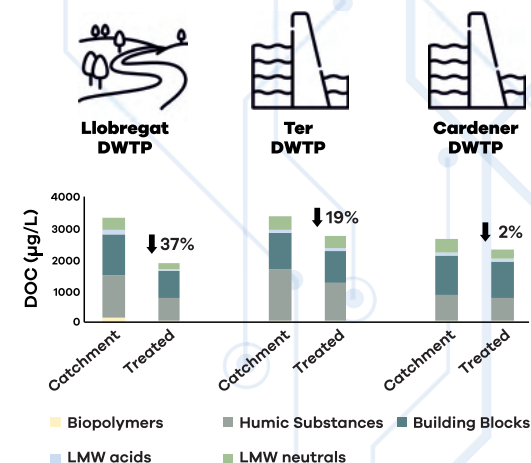
#### 2 COLUMNS IN TANDEM BETTER RESOLVE NOM FRACTIONS



#### 4 REGULATED DBPs



#### DETERMINING NOM REMOVAL EFFICIENCY



Fractionation techniques can provide an in-depth analysis of the efficiency of NOM reduction through the treatment works

#### LINEAR MODELS FOR PREDICTING DESINFECTION BY-PRODUCTS FORMATION



Spectroscopic monitoring of NOM fractions might help track trihalomethane formation and optimize NOM removal strategies

*Closing the gap between advanced characterization techniques and real-time monitoring*









# DATA-DRIVEN

## Data-driven based modules

### Dosing rate of potassium permanganate at the pre-oxidation step

Some DWTPs use variable dosages of potassium permanganate as pre-oxidant agent as pre-treatment depending on the influent features.

This module uses the online analysis of temperature, turbidity, absorbance at 254nm and inflow rate as input variables in a feed-forward strategy to apply the most suitable reactive dosage, including a case-based reasoning that shows previous similar conditions. This way, the daily decision-making can be speeded-up and improved by offering consistent and robust results to the users, who can consult the model outputs at any time and according to real-time raw water characteristics and operation conditions of the plant.

### The prediction of THM formation

Treated drinking water goes from DTWPs to tap, which takes from a few hours to a few days. During this time, many parameters affect the formation of DBPs along the distribution systems.

This module predicts the THM formation in water distribution based on a multiple linear regression model, including organic matter concentration (UV254 and TOC), the chlorine dosage, the pH, the temperature and the hydraulic retention time expected in water distribution sector. The results propose some actions in order to provide real-time support for a hydraulic management.

### Filters management

The classification of the activated carbon and sand filters permits an optimization management in order to structure the cleaning frequency and planning of maintenance tasks in large filtration systems.

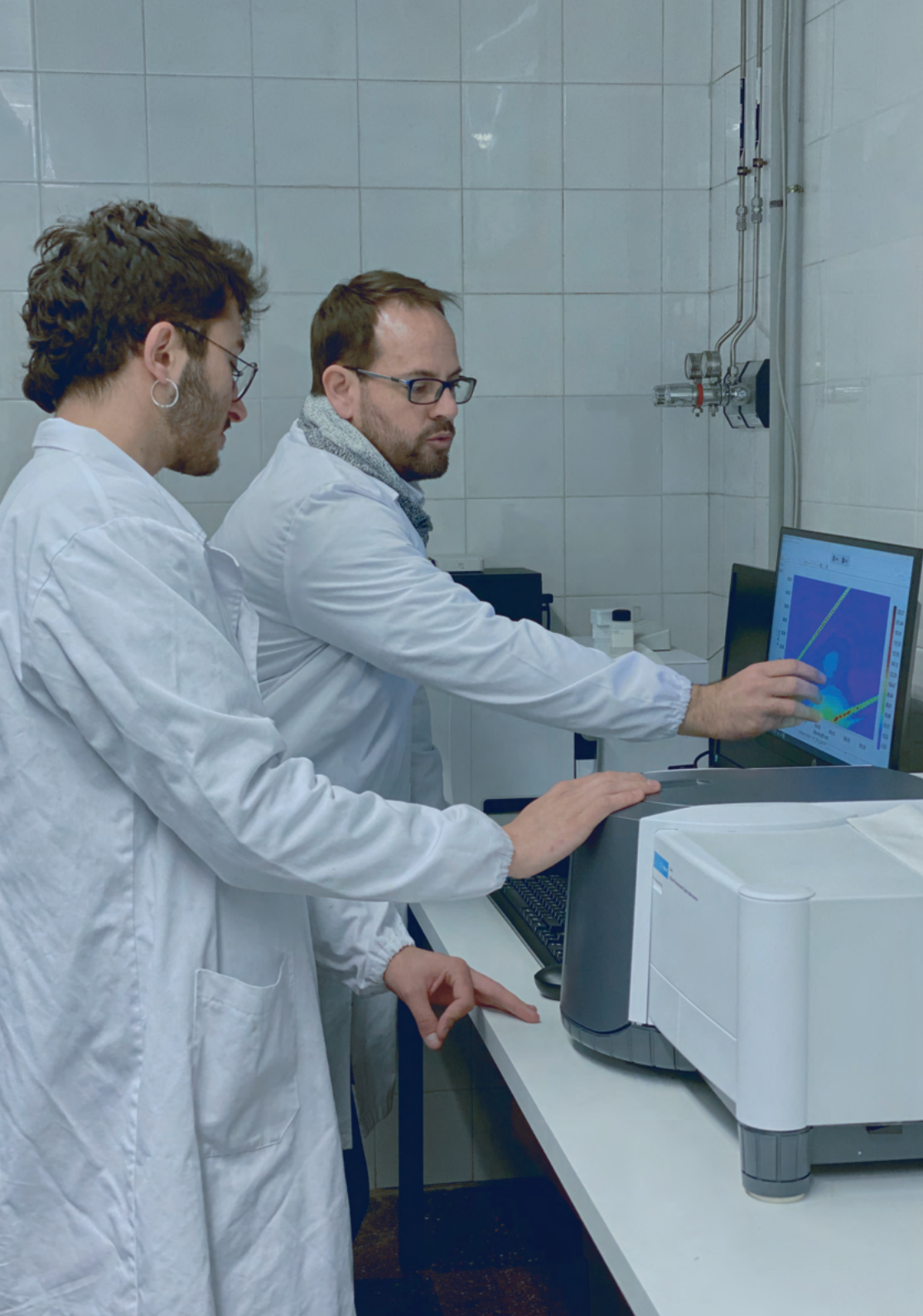
This module identifies and classifies the operation of the filters, by modelling their pressure tendency it identifies those that deviate from a correct behaviour.

### Dosing reagents in the primary disinfection step

Primary disinfectants used in DWTPs include ClO<sub>2</sub> or OCI- depending on the facilities. This module operates in both feed-forward and feed-back strategies to estimate the most suitable combination of oxidants in the primary disinfection of the DWTP.

Influent quality and operating conditions, combining real-time data, scientific bibliography and expert knowledge, are the basis to predict the minimum disinfectant dosage needed, finally recalculated according to the formation potential of DBPs.









## EXPERT

### Expert knowledge based modules

#### Dosing rate of coagulant

Turbidity fluctuation at the DWTPs influent makes it necessary to use a feed-forward strategy to estimate the most suitable dosage of coagulant.

This control module uses the turbidity online measurement with some expert control rules as the basis to predict the optimal coagulant doses. Moreover, this module is complemented with a case-based reasoning to compare the proposed coagulant dosage with previous scenarios with similar conditions.

#### Microbiological risk-based supervisor system

Catchment events such as intense storms and long drought episodes cause variations in the microbiological load at the DWTP influent.

This module operates as an early warning system based on data-driven models to quantify the microbiological risk of tap water. The system monitors DWTP water microbiological quality in real-time and provides alerts to the DWTP managers in cases of any deviation from the safe levels of microbiological contaminants. To do so, the system employs the integration of on-line influent and meteorological data sources to facilitate a real-time monitoring and analysis.

#### Distribution management and optimization

Daily and weekly fluctuations in water demand together with ecological directions and network capabilities set the amount, quality and continuity of treated water through the supply network.

This tool, consisting in two modules, is designed to support drinking water distribution managers in decision-making processes when more than one water source is required to satisfy the demand.

The first module includes the prediction algorithm that optimizes the water production at each DWTP, ensuring produced water quality, quantity and ecological requirements accomplishment. The second module includes an optimization algorithm for supplying water through the distribution network with the minimum electricity consumption on water pumping.

#### Predicting dosing demand of ozone at the pre-oxidation step

Ozone is used as pre-oxidant in some DWTPs, an efficient technology associated with an increase in the electricity expenses.

This module predicts the required ozone demand using a fuzzy logic system in a feed-forward control loop. Based on the experience of the managers and technicians of the plant, the parameters used to control the peroxidation step were the temperature and the 254nm absorbance of the influent, and with this online input data the tool provides an optimized solution to reduce the expenses associated to the electricity consumption of the ozonisation unit while guaranteeing the proper quality of the produced water.





Smart resilience for your water supply

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