xylem

Whitepaper

Digital transformation of WWTPs

Key to a more sustainable future

xylem vue

Table of contents

Introduction

Recent population growth from 6 billion people in 1999 to 7.7 billion today has brought with it an increase in the demand for water resources and greater amounts of waste that need to be treated. Organizations such as the World Bank, the UN and UNHCR estimate that by 2025, 45% of the world's population will be living in countries with water scarcity.

As a result, society sees wastewater treatment as a challenge that can bring multiple benefits in environmental, economic, social and health terms. As the World Bank pointed out in its "From Waste to Resource" report, published in 2020, "wastewater can be treated up to different qualities to satisfy demand from different sectors, including industry and agriculture. It can be processed in ways that support the environment and can even be reused as drinking water. Wastewater treatment for reuse is one solution to the world's water scarcity problem, freeing scarce freshwater resources for other uses, or for preservation" (Rodríguez, Serrano, Delgado, & Nolasco, 2020).

In fact, some of these benefits are included in the 2030 Agenda's Sustainable Development Goals. More specifically, in point 6, Clean Water and Sanitation, and in its subsections 6.3 and 6.A. The former proposes improving water quality by halving the percentage of untreated wastewater, increasing recycling and reuse, while the latter addresses the need to expand international cooperation to set up wastewater treatment facilities.

Thus, the importance today of wastewater treatment plants (WWTPs) is clear, as complex systems made up of different processes whose objective is to eliminate all or part of the pollution present in water, becoming a valuable asset for sustainability and the circular economy. When we talk about water pollution, we are referring to wastewater or sewage, which is water whose quality is affected by human activity. This is divided into urban or industrial wastewater, depending on its source.

Therefore, the objective of collecting water from a populated area or industrial sector and removing its pollutants is to return this resource to the water cycle, either by discharging it into watercourses or reusing it in activities such as agriculture.

Wastewater treatment stages

After identifying what wastewater is and where it comes from, it is necessary to define the stages it undergoes in a WWTP.

The water entering a WWTP undergoes a series of physical (gravitational, centrifugal, retention and cohesion forces), chemical (flocculation, coagulation, neutralization, oxidation, etc.) and biological processes to remove the pollutants it contains.

These processes are usually **divided into four stages**, known as preliminary (pretreatment), primary, secondary and tertiary treatments.

In addition, WWTPs also carry out **other processes associated with the by-products obtained in the different treatments**. Some of these processes, such as the treatment and management of sludge, are significant because they are complex to manage and are of great interest.

Pretreatment

Preliminary, or pretreatment, is the first stage of wastewater treatment and is used to prepare water for purification during the following phases. Thus, it consists of **removing objects that could damage the plant or the equipment that will be used during the purification process.**

First, roughing filtration is usually carried out. This process separates out the large and medium-sized solid waste using different thickness screens and sieves. Subsequently, grease and sand particles are removed using desanders and degreasers.

Primary treatment

The objective of **primary treatment** is to remove part of the suspended solids. To this end, **water is retained for one to two hours in decanter centrifuges where gravity helps to separate these particles.** The water that remains in the upper part of the decanter is transferred to the next process and the decanted particles, called sludge, which remains in the lower part, is conveyed through pipes to a sludge treatment area. Other benefits of this process include flow homogenization and the removal of organic matter linked to the suspended solids. During this process, **chemicals such as coagulants and flocculants can also be added** to improve the sedimentation of solids and remove phosphorus (phosphorus pre-precipitation). In some cases, bases and acidic agents are used to neutralize the water's pH.

Secondary treatment

Secondary treatment is designed to remove organic matter from the water, as well as nutrients such as nitrogen and phosphorus. This is a **mainly biological process, utilizing bacteria and microorganisms**. The most widespread treatment is activated sludge, where the water to be treated is left in a tank for several days under varying oxygen conditions (aerobic, anoxic and anaerobic) depending on the required removal requirements. Here, the different types of bacteria that live in the tank or reactor feed on the organic matter and the nutrients contained in the water, removing them from the water and taking them into their organisms.

A second or secondary settling process is usual after the biological treatment. Here, **the bacteria that have grown in the previous process precipitate to the lower part of the settling tank,** generating a mixture of water and solids, which is called biological sludge. This mixture is extracted or flushed out through the lower part of the decanter and the purified water flows out through the upper part without most of the bacteria and solids, giving rise to clarified water. **It is common in wastewater treatment plants for water treatment to end at this point,** when the treated water meets the defined discharge requirements and there are no additional water quality requirements for reuse or further use.

Tertiary treatment

During **tertiary treatment**, the aim is to increase the final quality of the water so that it can be returned to the environment (sea, rivers, lakes and other hydrographic basins) and, in some cases, used for human activity. To achieve this, a series of processes are carried out **to eliminate pathogenic agents and increase the removal rate of organic matter, suspended solids and nutrients**. The techniques used include filtration with sand beds or other materials, and disinfection, either using chlorine (usually sodium hypochlorite) or UV light, to reduce the amount of microscopic living organisms that have been generated in the previous stages.

In parallel to the water treatment process mentioned in the previous paragraphs, **WWTPs also treat sludge, which is a by-product of the same process, and is generated and extracted in the primary and secondary decanting processes.**

First, the sludge is thickened to reduce the volume of water to be treated. Subsequently, this mixed sludge (primary and secondary sludge from decanting) is digested by aerobic processes (with air) or in anaerobic digesters (with oxygen deficit) to stabilize the growth of bacteria and remove them. This is followed by a process to reduce the amount of water by dewatering, usually with decanter centrifuges.

When this sludge complies with dryness, stability, heavy metal, nutrient and pathogen content requirements, **it must be managed with the least impact possible on the environment, for example, by reusing it in agriculture as fertilizer,** since it contains a concentration of nutrients similar to artificial fertilizers.

Digital transformation to improve operational performance

The main objective of WWTP management is to achieve the required standards of treated water quality at the lowest possible operating cost and with the minimum environmental impact. This challenge is particularly important in a context in which WWTP operators must be able to process and transform the immense amount of data from multiple and heterogeneous sources into real actions.

In this context, the digital transformation of wastewater treatment plants through **the implementation of Information Management Systems is the best solution to standardize and simplify process management**, while addressing challenges.

To achieve this, **WWTPs are implementing technological solutions** such as SCADA, IoT sensors, laboratory information management tools (LIMS software), and computerized maintenance management systems (CMMS), etc., which enable them to standardize and streamline project management, thanks to the integration of information from different systems in a common platform and the application of Big Data, as well as to offer innovative solutions for their use.

Numerous WWTPs have started to take steps towards digital transformation through SCADA systems, IoT sensors, laboratory information management tools (LIMS software), and computerized maintenance management systems (CMMS).

However, very few have taken the next step on the road to digital transformation, namely the integration of all data sources into a single environment. This is a fundamental step and provides WWTPs with comprehensive control of all their processes through dashboarding, alert systems, data quality controls and real-time calculation of new variables based on the original ones. In addition, a single point where all the data from the wastewater treatment plant coexists, regardless of their type and source, is essential to move on to the next steps quickly, ensuring robust results.

At a more advanced level of digital transformation, this data is used to create, train and feed predictive models, simulations, anomaly detection algorithms and decision support systems. These all aim to improve plant operation in terms of quality, costs, environmental impact and transparency.

Stages prior to digital transformation

To ensure optimal digital transformation of WWTPs, two steps should be taken first:

Preliminary consultancy work at the WWTP

In the first step, preliminary consultancy work is carried out to assess the needs of the processes used in the WWTP. **Meetings and visits are carried out so that the facility managers can provide us with relevant information** on quality requirements, historical performance, records of problems and anomalies, electricity consumption reports, characteristics of the WWTP's processes and assets, devices and sensors deployed, whether data management systems are in place, etc., **to create a list of the WWTP's needs**. This first phase is influenced by the size and complexity of the processes.

Measures will be taken in the key areas of the infrastructure if there is a need to implement new instrumentation, based on the data gathered during the consultancy phase.

Implementation of data management systems

The implementation of data management systems **enables the integration of all WWTP data, standardizing it with advanced intelligence** and presenting the most relevant system information to the user through a single holistic dashboard. Thanks to this system, WWTP managers can monitor the plant's entire operations from a single interface. In addition, **this type of system can be used to create rules of all types to automate the treatment plant's processes, creating alarms for each one**.

For example, alarms can be created when the hydraulic conditions of the primary settling tank change in the primary treatment phase. In the secondary treatment process, the organic load and the C:N:P nutrient balance can be monitored in real time, establishing dynamic set-points for the aeration systems and recommending adjustments to achieve optimum cell and hydraulic retention times.

Characteristics of applicable technology

However, not all technology is suitable for the digital transformation of wastewater treatment plants; it must comply with a series of characteristics in order to enable operators to develop the main use cases listed below. The technology must be:

Adaptable	Flexible	Scalable	Multi-env
Competitive	Easy to deploy	Easy to maintain	Implementation
Fast, performant....			

Adaptable, enabling integration with multiple user authentication systems (auth/login) and taking different data repositories into account.

Flexible, in line with the above, enabling standard customizations and specific behaviors according to the client's business processes.

Scalable, that is, capable of responding as the number of users increases. In this case, we are talking about horizontal scaling (increasing power by increasing the number of nodes) and vertical scaling (increasing the power of existing nodes).

Multi-environment, enabling on-premise deployments, private cloud deployments and cloud-based (service-based) deployments.

Competitive, capable of operating with third-party technologies and affordable licenses, with a low initial hardware footprint, and high availability if required.

Easy to deploy, with automated pipelines, and available both on-premise and in the cloud, with reliable roll-back processes.

Easy to maintain, with efficient logging, enabling remote and centralized monitoring.

Easy to implement, that is, having rich and well-documented APIs, without direct access to the database and business logic to prevent damage to the system

Use cases

Digital solution integration is becoming more and more common in the water sector, as it brings benefits compared to conventional management. In the latter, each process has its individual control point and there is no holistic overview that brings together all the process data. Thanks to digital transformation, utilities can visualize the main indicators or KPIs and take proactive decisions in any situation that affects the system, obtaining an overview of the level of optimization taking place in each area and in the overall facility.

Control and prediction of influent quality and flow rate

Thanks to LIMS integration and the use of measuring equipment such as flow meters and quality sensors for parameters such as pH, conductivity, turbidity and temperature, influent flows and inlet loads can be **monitored in real time, and future forecasts of internal factors can be made**.

In addition, the provision of alarms and warnings about anomalies in the influent flow, alterations in the biodegradability of organic matter and nutritional imbalances in the influent is key.

Control of hydraulic conditions and quality of the primary treatment effluent

Digital transformation enables control points to be established for primary treatment about the hydraulic conditions of the primary decanters, as well as on the quality of the primary sedimentation effluents. The latter provides an **overview of the main parameters of the primary decanters**, such as the hydraulic retention time (HRT), the hydraulic load and weir load with maximum and average flow rates, as well as the number of units in service. The recommended HRT and the number of decanters required to comply with this recommendation are also displayed.

Control of solids removal performance and sludge generation calculations

Digital transformation provides an **overview of real-time and historical flow values and the concentration of biological sludge generated, based on sensor and LIMS software data**, and compares them with accepted sludge concentration values.

In addition, **the daily generation of sludge produced in the primary decanters** can also be calculated to provide greater control. This calculation is based on the suspended solids removal performance and the recommendation of the optimal sludge pumping flow rate, taking into account the nutritional needs of the secondary treatment and the production of biogas.

Monitoring of operational parameters on a single dashboard

Digital transformation helps to **monitor and visualize the different parameters within the WWTP processes in real time on a single dashboard** enabling better decision-making.

For example, current and historical data on concentrations and loads entering the biological reactor from the primary treatment and leaving the secondary treatment enable plant operators to calculate and monitor pollutant removal performance. **Some of the key parameters monitored are**:

- MLVSS: amount of mixed liquor volatile suspended solids, which is an indicator of organic matter in the aeration tank.
- SRT: solids retention time or sludge age.
- HRT: hydraulic retention time .
- Mass Load: ratio of organic load (food for bacteria) compared to the quantity of microorganisms in the aeration tank.

Thus, **a control point can be set, generating alarms in the event of deviations that exceed the optimum operating threshold**, as well as recommendations to guide the process to the established optimum operating values. This requires minimum instrumentation, namely inlet flowmeters, temperature and recirculation flowmeters.

Nutrient removal optimization and biological process early warnings

In the secondary treatment biological process, **identification and early warnings are obtained through real-time or historical data visualization of anomalous variations in the MLVSS** (mixed liquor volatile suspended solids, consisting mainly of microorganisms and organic matter), variation of oxygen consumption, sedimentation variation, and with trend analysis and parameter alerts.

Thanks to this analysis, decisions can be made to adjust or modify the recirculation set-points and oxygen measurement and control points.

Control of the anaerobic digestion process and solid loading in the digester

A digitally transformed WWTP can **monitor anaerobic digestion using the main control parameters** such as temperature, volatile acids, alkalinity, volatile acids-alkalinity ratio, pH, total solids, volatile solids, flow rate, gas composition (CH4%, CO2%, H2% and H2S%), gas production, gas consumption and storage, power and heat generation, and process efficiency. This optimizes energy consumption and biogas production and prevents acidification.

Control of agri-food waste co-digestion

When additional agri-food waste is used as a co-substrate to increase anaerobic digestion performance and biogas generation, **expert knowledge of the co-substrate and continuous monitoring of its dosage and state in the digester is essential to ensure maximum controlled biogas production**. In this sense, the technological solutions quantify the economic and environmental benefits achieved in real time:

- on the **economic side**, they quantify the reduction in operating costs thanks to information on energy and co-substrate prices and engine performance;

- and on the **environmental side**, they quantify the tons of CO2, SOX and NOX emissions avoided thanks to information on the composition of the sludge and co-substrates used.

Monitoring effluent pollutant parameters

When the water has been treated by all the WWTP processes, it is discharged into public watercourses and must comply with legal quality requirements. Therefore, it is essential to monitor the main water pollution parameters (suspended solids, turbidity, BOD5, COD, TN, PT, pH, conductivity, pathogens, etc.), with the real-time data obtained and the historical data of the same parameters, enabling the **configuration and generation of advanced alarms in the event of non-compliance with the minimum quality requirements**.

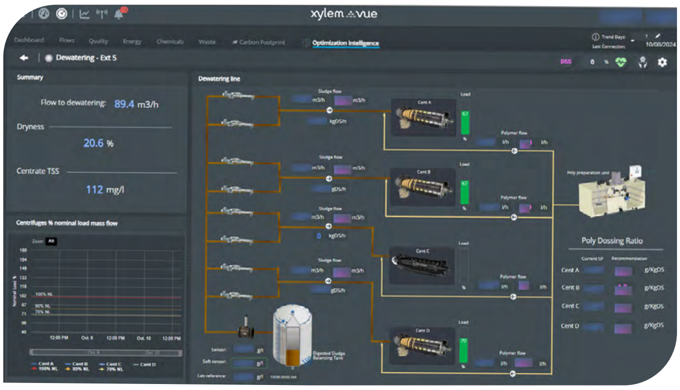
Reduction of energy consumption

In addition to consumption monitoring and alarm systems, there are modules or tools that can be used to achieve major savings in WWTPs' electricity consumption. These include systems that act or send recommendations to adjust the aeration equipment to the plant's needs in real time and systems that optimize biogas production.

Identification of optimum chemical dosage

Real-time data monitoring of chemical product usage (dosage rate, flow rate and economic cost) applied to each of the processes in the wastewater treatment plant **improves the results obtained with the application of these products by calculating the optimum dosage, based on advanced analytics and automatic learning**.

Equipment reliability and performance is enhanced thanks to automation and the resources used are optimized, resulting in savings in the use of chemicals and other consumables.



Greater scalability, safety and overall WWTP performance

The integration of new devices in the WWTP means that the WWTP data monitoring and control management system can be expanded, and everything can be centralized without the need to implement new independent systems to manage data. In addition, **early detection of errors and adverse events provides greater leeway to minimize losses**. Finally, improvements in process performance come through the optimization of the purification processes to achieve good water and sludge quality, the reduction of operating and maintenance costs, as well as the environmental impact produced by the activity.

WWTP Trends: Looking to the future

Social awareness of the circular economy, water treatment and reuse is rising. In addition, circumstances such as population growth, coupled with **an increase in industrial production and higher energy and reagent costs, have led to a need for improved wastewater management**, and with it, improvements in wastewater treatment plants.

Accordingly, **the modernization of wastewater treatment plants is taking place slowly but surely**, and little by little they are moving towards the idea of a WWTP for the future, in which certain advances that reinforce the social awareness of the circular economy and sustainability are already in place or in progress.

Use of more sustainable and environmentally friendly resources

The use of more sustainable resources and benefits for the environment, not only in terms of technology, but also in terms of more sustainable and environmentally beneficial resources such as renewable energy, biodegradable reagents, low energy consumption and high efficiency electromechanical equipment engines.

A tangible effort is being made to reduce greenhouse gas emissions, and to use renewable energy sources, in line with the United Nations' SDGs.

Likewise, **renewable energies are being implemented in WWTPs to mitigate their climate impact by reducing CO2 emissions and even becoming completely self-sufficient** in terms of energy consumption.

In this regard, it should be remembered that **WWTPs must protect the environment through water treatment**, ensuring water quality so that this finite resource is not increasingly depleted. Therefore, these plants need to optimize treatment and all the parts of the water purification process, ensuring quality and availability. The best way to achieve efficient and effective management is to automate wastewater treatment plants.

Digital Transformation of WWTPs

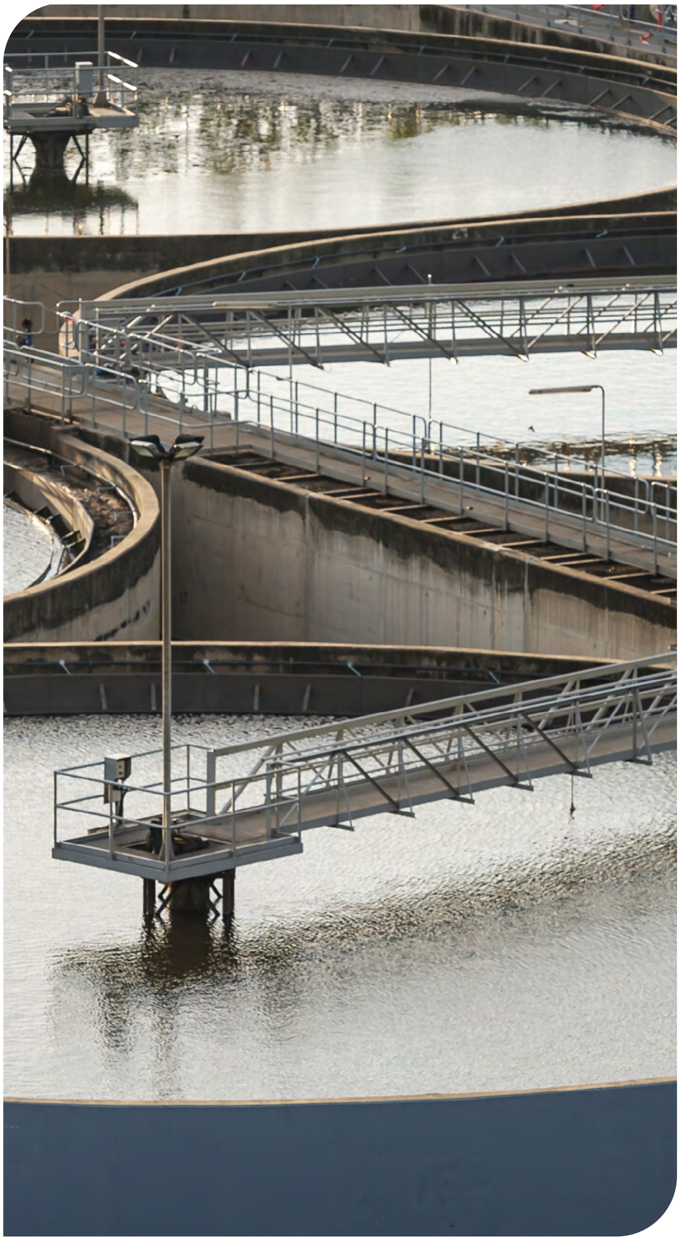
Another trend lies in **digital sustainability**, understood as the **process by which data from digital solutions and applications that water companies implement or decide to implement in the future is always accessible**. This concept is gaining traction within the water sector given that many companies have detected the importance of extracting, transforming and exploiting the data they receive.

However, **the problem lies in the fact that many of these companies have developed "bottom-up" digital transformation processes**, i.e., solutions in which software has been acquired from different suppliers as incidents have come up. The problem, at this stage, is that they are working with different software packages, and **they need to integrate all this data and be able to extract value from it**.

Accordingly, digital sustainability, understood as accessibility to and integration of the largest amount of data in the same tool, with no restrictions, is one of the most interesting operational trends on the table.

Digital Transformation of WWTPs

A third trend, arising from digital sustainability, is the **digital transformation of WWTPs. If these plants have a system that brings together information and extracts data from it, they can start to automate their facility**, working with systems from different suppliers and using this data to analyze them, enabling comprehensive and even automatic decision-making with the algorithms developed, based on previously defined indicators.



This task, in addition to overall optimization of the water sector, leads to optimized energy costs and increased savings in WWTP operations, thanks to aspects such as:

1. Integration of different software from different suppliers
2. Remote control and remote management systems
3. Generation of customized reports to optimize data exploitation
4. Generation of alarms and activation of work orders
5. Analysis and supervision thanks to SCADA systems

In short, **the automation and digital transformation of WWTPs paves the way to a new reality that can respond to the challenges and needs of today's society** mentioned at the beginning of this paper: population growth, increased waste and water scarcity.

Therefore, **digital transformation provides a holistic process scenario, facilitating the integrated management of the systems that affect WWTP operations**, and becoming key in the drive towards a circular economy.

Xylem |ˈzīləm|

1) the tissue in plants that brings water and nutrients upward from the roots.
2) a leading global water solutions company.

Xylem is the connective tissue and system in plants which cleanses and transports water from the root to where it is needed most to sustain life.

And this is the essence of Xylem as a company. We are committed to driving sustainable impact by ensuring our connected technologies and solutions support our customers and the communities they serve, to tackle the water challenges that matter most to them.

For more information on how Xylem can help you, visit xylem.com.

Xylem Vue is the result of the partnership between Xylem, a global leader in water technology and Idrica, an international pioneer in water data management, analytics and smart-water solutions. Through this partnership, Xylem and Idrica bring together their technology, innovation, and expertise to solve the world's most critical drinking water, wastewater and other water-related challenges.

Our single, integrated software and analytics platform – built by utilities, for utilities – enables utilities to take digital transformation to the next level, maximize investments, identify and solve problems more quickly, operate more efficiently and deliver water more effectively and affordably to their communities.

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