Water Supply Networks

Meeting the Challenges of Water Management
with Sensor Technology

Water Supply Networks: Meeting the Challenges of Water Management with Sensor Technology.

As the world's population continues to increase, so does the need for and consumption of the vital resource of water. According to UN estimates, global water demand is expected to increase by 1% until 2050. Already, 2.2 billion people do not have access to safe drinking water. And this figure is more likely to go up than down.

All the more reason why water treatment, especially recycling, is a globally important issue to ensure people's quality of life now and in the future. In total, roughly 1,000 cubic kilometres of wastewater are generated each year. In Germany alone, there are about 10,000 municipal wastewater treatment plants, which treat about 9.8 billion cubic metres of private and commercial wastewater annually and return it to the water cycle. Further, around 3,000 businesses in Germany have their own wastewater treatment plant to transfer water back to the water cycle after treatment as direct dischargers.

Around 1,000 cubic kilometres of wastewater are produced worldwide every year.

Wastewater treatment has changed a lot since Europe's first wastewater treatment plant opened in what is now Frankfurt am Main back in 1882: In addition to established biochemical processes, technical solutions that enable more environmentally friendly and hygienic water purification are also used. This has also led to an increase in the number of people connected to the wastewater disposal system. According to the German Federal Ministry for the Environment, this figure was 95.6% or 78.1 million people in 2013. The unit used to express the performance of wastewater treatment plants is the population equivalent (PE). The population equivalent of one person corresponds to the amount of bio-degradable load that the person puts into the wastewater system on average each day and for whose bio-degradation 60 g of oxygen are required over a five-day period. A lot of wastewater is also produced by industry and agriculture; in Germany, it is an additional 30 million PE that wastewater treatment plants have to cope with.

However, wastewater treatment is only one part of the water cycle. The actual water supply is partly in the municipal administration's hand and partly in the hand of the private sector. Water supply is also a key part of the municipal administration's business, although its practical implementation is often subcontracted out to private companies. The level of individual water consumption per person in Germany was 125 litres per day in 2019. According to estimates by the German Association of Energy and Water Industries (BDEW), consumption is set to have risen to 129 litres in 2020, taking into account the changes in everyday life and hygiene caused by the Covid-19 pandemic. In general, water demand in Germany has been steadily decreasing since 1990 (147 litres) and remained constant at 121 to 123 litres per day between 2007 and 2017. In addition to public water extraction, which has remained constant at around 5 billion cubic metres annually in recent years, industry, agriculture and the energy sector also extract water through their own extraction facilities; in 2016, this amounted to just under 19 billion cubic metres – compared to the 27 billion cubic metres in 1991, this is a decrease of around one third. The reason for the continuous decline is also the more efficient use of water, for example through multiple and circular use in production processes.

Industrial water demand alone will increase to 1,170 cubic kilometres by 2025.

However, if we take a look at industrial water demand worldwide, it was 776 cubic kilometres in 2000, but is expected to rise to 1,170 cubic kilometres by 2025 as developing countries become more industrialised.

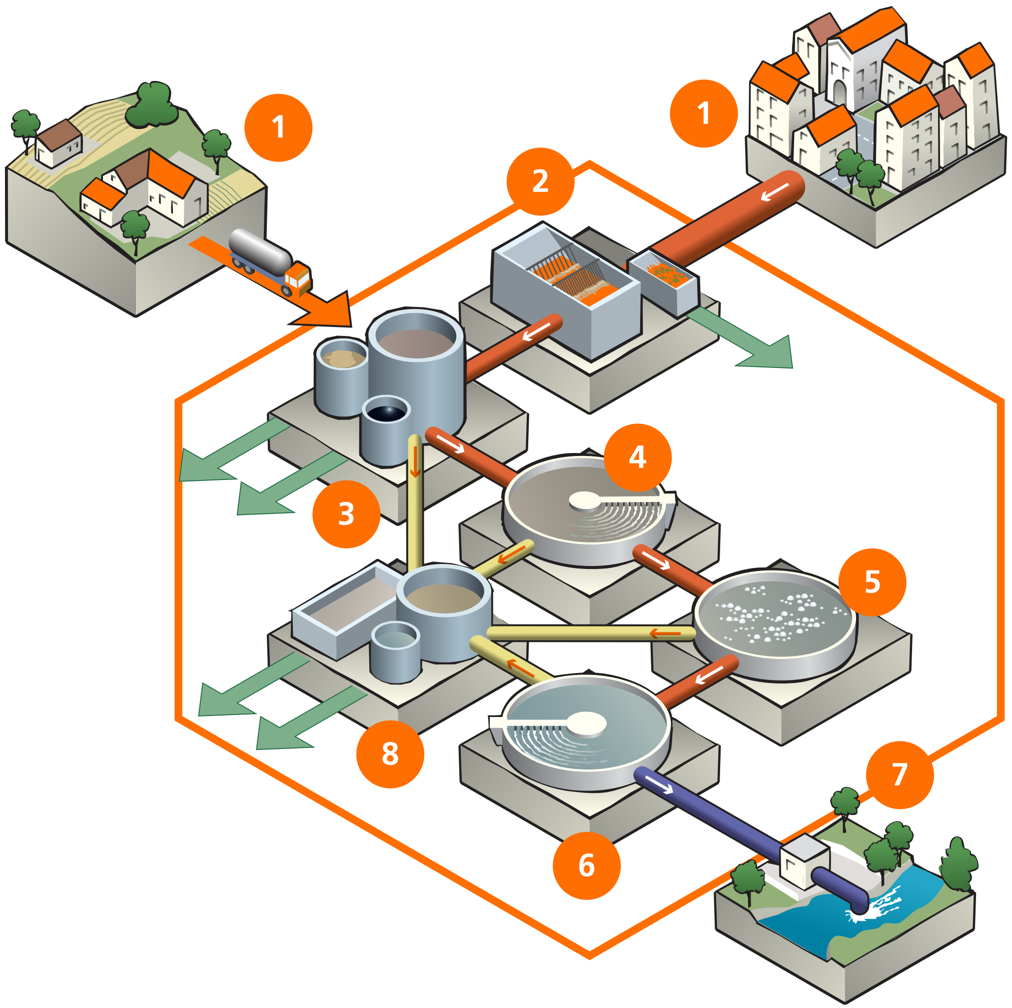
Overall, the issue of water must be viewed as a cycle, consisting of supply and disposal, which needs to be governed and managed in a holistic manner. As such, the challenges facing municipalities are similar in terms of extraction and disposal: Both contain installations characterised by pumps and pipes. A reliable controller is indispensable when it comes to guaranteeing the fail-safe availability of the plants. Climate change and the accompanying water scarcities have posed a significant threat to water supplies in recent years. In the future, municipalities will have to overcome ever greater hurdles to ensure a reliable water supply. Added to this are problems caused by increased pollution from microplastics, saline wastewater or nitrate in the groundwater. Due to demographic changes, water suppliers are facing further challenges: There are not enough skilled workers to keep up with growing demands. This situation is addressed with increasingly decentralised control and monitoring of plants using cutting-edge sensor technology and customised software solutions.

Climate change is making water supply more difficult, which will become a challenge for many municipalities.

Example of a wastewater treatment plant: Complex systems in use

When viewing the process steps of a wastewater treatment plant, it becomes clear just how complex a wastewater disposal system actually is: Water enters the plant via the sewage system (1). During the initial step, mechanical cleaning (2), a bar screen removes larger impurities from the water. Coarse impurities settle in the downstream grit chamber (3). This step is essential to filter sand, stones or pieces of glass out of the water, as they would otherwise cause damage to the plant components in which further treatment steps take place. In the primary sedimentation tank (4), the flow velocity is reduced to such a degree that organic matter settles. The resulting sludge is removed directly before being stabilised through mesophilic anaerobic treatment (8).

This mechanical purification step is followed by a biological purification step (5). The water is first transferred to the activated sludge process. Through the addition of atmospheric oxygen, aerobic bacteria in the oxygen break down wastewater constituents; the nitrogen in the organic compounds is first broken down into ammonia and then oxidised into nitrates by nitrification. Denitrification then breaks down the nitrates into molecular nitrogen. Once this process has been completed, the wastewater and activated sludge run into the clarifier (6). This is where the activated sludge is separated from the water by changing the water hydraulics; part of it runs back into the aeration tank as return sludge, the rest is discharged as excess sludge and finally fed to sludge treatment (8). The purified water then flows out of the wastewater treatment plant and back into the water cycle (7).



Although this basically completes the water purification process, treatment of the digested products in the wastewater treatment plant still continues technically. The sludge is thickened and pre-treated in the pre-thickener. This is followed by digestion through mesophilic anaerobic sludge stabilisation before the digester gas is processed and utilised, for example, as an energy source in combined heat and power plants. Once the digested sludge has been dewatered, it can be disposed of. Today, sewage sludge is generally used as fuel in energy production. Its use in agriculture for fertilisation is declining sharply, not least due to stricter legal requirements to reduce soil pollution caused by phosphate and nitrate.

Complex water treatment processes can be efficiently controlled and centrally monitored.

The wastewater treatment technology described here is not only used in Germany. Plants around the world use comparable processes and procedures. Depending on the country, individual process steps are subject to different regulations, but the basic process and the associated challenges and problems remain the same. In order to be able to control the complex process, wastewater treatment plants (sewage treatment plants) have a control room as a central unit, in which all information or operating states can be queried and process steps controlled. Older plants are operated via programmable logic controllers (PLCs), more modern wastewater treatment plants are equipped with process control systems. In both systems, data from the various sensors is transferred to the control room via a bus system.

State-of-the-art plant controllers ensure smooth operation

A state-of-the-art plant controller is important to ensure a continuously smooth process in the wastewater treatment plant, which, like all plants in the water cycle, is categorised as a critical infrastructure. Plants in this category must be protected against external influences and failure. If a wastewater treatment plant fails, this can lead to restrictions in everyday life for thousands of people and a risk to the environment. The same applies to the provision of water. Water treatment plants are also of particular importance, as groundwater is not automatically suitable for human consumption. As in wastewater treatment, complex technologies are used in water treatment plants. Every error in the process means a loss of precious water. This becomes particularly important when there are fewer and fewer staff available in the facilities. The shortage of skilled workers is also affecting the water industry, with less young people entering the profession.

Solutions to solve the conflicting issues of process safety and the shortage of skilled workers.

The solution is decentralised control rooms in which conditions can be queried very quickly on large screens. The control room allows staff to check sensor data remotely and, in a first step, to evaluate the functionality or the condition of individual plant components – so-called condition monitoring. If this IT-based condition monitoring is continuously operated and evaluated, it enables predictive, demand-oriented maintenance in the next step. Since age-related deviations from the ideal plant condition up to a condition that requires maintenance can thus be detected at an early stage, maintenance measures can be planned in good time. This means that wastewater treatment plants can at best also be operated beyond the 20 years for which they are designed. In order to obtain the best possible insight into the plant at all times, it is important to regularly update both hardware and software to the latest state of development. Older plants can also be updated and operated more efficiently through retrofitting. These plants often still feature sensors that are individually wired to the PLC. Conversion to innovative systems such as sensor technology with IO-Link (key technology for Industry 4.0) provides the ideal remedy here.

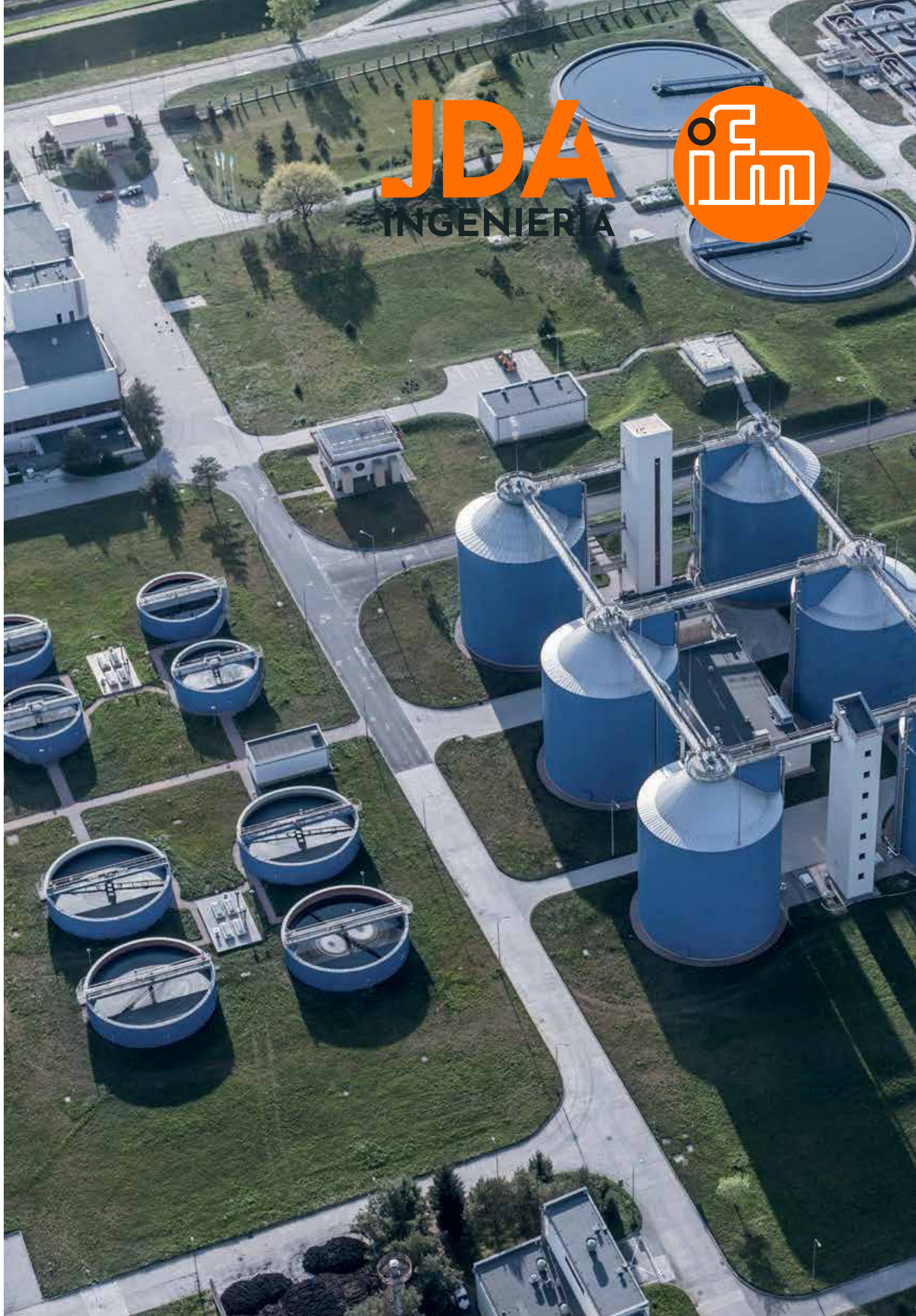
Predictive maintenance can extend the service life of plants beyond the estimated time period.

A look inside the plant: How information from the sensor reaches the IT level

Sensors play a key role in the control of cutting-edge wastewater treatment plants. They measure various parameters in the pumps, pipes and machines. This also includes distance and conductivity measurements as well as condition diagnostics. Sensors can be found at various points in the water treatment process: Position sensors can measure the chain tension in the bar screen, detect the position of pneumatically operated valve actuators and monitor the longitudinal and circular scrapers. Position sensors also ensure the proper closure of maintenance hatches to guarantee the occupational safety of machine operators and maintenance staff.

Flow sensors are used in the mechanical stage to detect the screening washers and the rinsing water in the bar screen. Pressure sensors measure the rinsing water and level sensors can be used in the digestion process. In the biological purification stage, too, sensors can support the ideal course of the process, thus helping to ensure that nitrates and phosphates are degraded in an energy-efficient manner and to the required extent. Sensors that observe chemical or physical measurands are used here. In the outlet of the wastewater treatment plant, they can help identify harmful substances, thus allowing staff to take appropriate countermeasures. By monitoring this late step in the process, conclusions can be drawn about the purification quality of the entire plant as well as about any remaining impurities in the outlet of the wastewater treatment plant. This promptly available information enables the plant operator to optimise quality assurance.

The flow, pressure and condition of the water can be monitored with sensors, as can the proper functioning of mechanical plant components.



Overall, the sensors ensure permanent plant availability. Ideally, sensor application is implemented using IO-Link. Multi-vendor digital communication technology simplifies the installation and replacement of sensors, enabling smooth sensor operation. Another advantage: The data can be easily transmitted both to the PLC and to the IT level – and thus also to a central control room – any malfunctions are reported at an early stage and failure of important plant components is prevented. The sensors, which monitor the flow, levels, temperature or pressure, for example, are installed directly in the plant. Instead of hard-wired communication with the PLC, however, they are connected to an IO-Link master using a standardised sensor cable with M12 connector technology, which then forwards the data both to a higher-level fieldbus and to the IT system. The IO-Link system has the further advantage that sensor parameters can be set remotely. Thanks to the simple connection technology as well as the low wiring effort, the installation time is reduced by up to 60%.

By using sensor technology, maintenance staff is also informed more efficiently about the respective malfunction, as the manual inspection and monitoring of pumping systems and pipes can be significantly reduced and carried out in a more targeted manner through condition monitoring. Vibration diagnostics via a sensor can be used to monitor drives, lifting equipment, bar screens and pumps. Vibration behaviour that deviates from the normal condition indicates, for example, foreign bodies that can be removed promptly before they cause damage in downstream processes. Sensors in pumps provide basic monitoring and detect cavitation or dry running. Unbalance and wear are also recognised at an early stage. To put it in a nutshell: The former black box thus becomes a transparent, easy-to-control system.

IO-Link enables remote data readout and sensor parameter setting.

Overcoming plant-related challenges

Another source of damage that can lead to pump failure is cavitation. The term describes the formation of bubble-shaped cavities in hydraulic applications, which can lead to mechanical damage or destruction during operation. Sensors can be used to permanently check pressure levels and flow rates for limit value violations. Imbalance vibrations, shaft misalignments or wear also pose challenges for users. Vibration sensors, speed sensors and temperature sensors are used in pumps to solve these problems. These systems have the advantage of working completely autonomously. When used accordingly, the sensor data can thus be transmitted directly to the IT level without any losses. This enables continuous remote maintenance in the control rooms. Staff members thus no longer have to check the pipe or pump themselves and go to great lengths to detect foreign objects by listening to the changed sound of the pump – as was the case in the past. Maximum plant availability and process reliability is provided by a coherent overall solution from the sensor and the infrastructure to the IT level. Vibration sensors are then

Vibration sensor technology ensures effective monitoring of pumps and motors.

evaluated via diagnostic electronics, which optionally act as a stand-alone solution or transmit the information directly to the control room. This results in a pump monitoring system that is correspondingly scalable and can be adapted to the respective requirements in the wastewater treatment plant. Overall, this means that fewer staff are needed. This optimises staff deployment and helps to counteract the shortage of skilled workers. Last but not least, plant availability is also increased.

Automation solutions: More efficiency in the water cycle

The use of sensors in the supply and disposal of water pays off on several levels. On the one hand, it counteracts the ever-increasing pressure on staff, as fewer people are needed to monitor the condition of the installed plant components. The work process also becomes more efficient since the sensor data is collected effectively and efficiently in the control room.

Predictive maintenance increases plant availability and the quality of the treated water.

On the other hand, sensors can prevent failures that could have serious consequences, especially in critical infrastructures. Using predictive maintenance or condition monitoring, errors are detected and rectified early on. In addition, more information about the machine is made available to users. This concerns not only the machine components, but also the measurement of the water quality in the wastewater and the regulation of the bacteria balance. As a result, plants operate in a more environmentally friendly manner and the water is of a higher quality. Holistic solutions for the automation and monitoring of plants are therefore a key element for the efficient and sustainable water supply of the future, on which more and more people depend due to increasing changes to the climate.

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