



Challenges in the reuse of municipal and industrial wastewater

Water treatment for the reuse of municipal and industrial wastewater is a crucial step towards sustainable water use. With increasing water scarcity and demand for clean water, it is imperative to develop efficient and effective methods of treating and reusing wastewater. This report highlights the key challenges that arise in water treatment for reuse.

Historical development

More than 4000 years ago, the early civilizations in Mesopotamia and Egypt used wastewater to irrigate agricultural land. The ancient Greeks and Romans built complex sewage systems that were also used to irrigate and fertilize fields. In the Middle Ages, water reuse in Europe largely stagnated because the infrastructure of the sewage systems was neglected. But in some regions, such as the Middle East and Asia, wastewater continued to be treated for agricultural use.

However, the development towards the targeted use of wastewater did not begin until the 19th and early 20th centuries with the Industrial Revolution. The first modern sewage treatment plants were built to control the increasing pollution of water resources. Systematic approaches to water reuse first developed in the U.S. and Europe, especially in areas with water scarcity.

From the middle of the 20th century, the development of advanced treatment technologies made it possible to reuse water on a larger scale. Methods such as activated carbon

filtration and reverse osmosis became popular. Israel and California, in particular, have become pioneers in water reuse due to their chronic water scarcity. Programs such as "Water Reclamation" and "Groundwater Recharge" were implemented. Since the turn of the millennium, interest in water reuse has been growing worldwide, especially in water-scarce regions such as southern Europe, the Middle East, Australia, and parts of Asia and North America. In addition to water applications in agriculture and industry, its use for human consumption is coming to the fore. Both indirect (via the detour of water bodies and aquifers) and direct reuse in drinking water treatment are increasingly found in areas with water scarcity. New technologies such as advanced membrane processes, UV disinfection and phytoremediation (plants to purify water) are gaining in importance. Water reuse is seen as an important part of sustainable development strategies and the circular economy to meet the water needs of a growing world population and mitigate the effects of climate change.

Challenges

1. Degree of contamination and variability

Municipal and industrial wastewater contains a variety of pollutants, the concentrations of which can vary greatly. This poses major challenges to the flexibility and adaptability of treatment technologies to effectively treat different levels of pollutants. In particular, the removal of trace substances such as pharmaceuticals, PFAS and microplastics requires different technologies depending on the quality needs.

2. Technological requirements

The selection of suitable treatment technologies is crucial. Technologies such as membrane filtration, biological treatment, chemical oxidation, and adsorption must be combined to achieve sufficient purification performance. Each technology has its own advantages and disadvantages, which must be carefully weighed up considering regional and climatic characteristics.

3. Costs and cost-effectiveness

The cost of installing and operating water treatment plants can be significant. Water reuse competes with conventional water resources. It is important to find economically viable solutions that minimize both capital and operating costs without compromising treatment efficiency. Those treatment stages are selected which only generate the water quality required for the respective application.

4. Regulatory requirements

Compliance with legal regulations and standards for water quality is essential. These regulations can vary by region and require continuous monitoring and adjustment of treatment processes to ensure that the treated water meets the required quality standards. For example, the European Union has defined the minimum requirements for water reuse for agricultural applications with Regulation (EU) 2020/741 of 25 May 2020. Most states in the USA also have guidelines for water reuse in industry and agriculture, and in some also for direct and indirect use as drinking water.

5. Ecological and health aspects

The reuse of treated wastewater must ensure that there is no negative impact on the environment and human health. This requires a thorough assessment of potential risks and the implementation of risk mitigation measures.

6. Acceptance and public relations

The acceptance of water reuse among the population and industrial companies is another important factor. Awareness campaigns and transparent communication about the benefits and safety measures of water treatment can help to reduce reservations and increase acceptance. Organizations such as the IDRA (International Desalination and Reuse Association) or the IWA (International Water Association) support this through their work.



Fig. 1: Industrial wastewater treatment will become more important in the future, as shown here in a neutralization plant for wastewater in surface coating

Drivers and obstacles

First and foremost, water reuse is driven by the lack of fresh water and the regulations that come with it. According to a forecast by the United Nations [UN World Water Development Report 2019], the world's water demand is increasing by 1% annually. On the other hand, in 2030, water demand will exceed supply by 40% [UN World Water Conference 2023].

The reuse of water increases the availability of water resources, which is particularly important in water-scarce regions. This can increase agricultural production and thus strengthen the local economy. In addition, the costs for the extraction, treatment and distribution of fresh water can be significantly reduced. This leads to savings for municipalities, industrial companies, and end consumers, because the production of drinking water by seawater desalination is about twice as expensive as that from treated wastewater.

It is particularly interesting for industry that the reuse of wastewater reduces discharge into the environment and reduces environmental pollution. Companies that use and reuse water efficiently can thus gain competitive advantages. The direct benefits are cost savings, improved sustainability profiles, and compliance with stricter environmental regulations in the future.

On the other hand, the reuse of treated wastewater is often associated with major hurdles. In most regions of the world, the cost of water from natural sources is lower than that from treated wastewater. The lack of regulations and guidelines for the requirements for the treated water and its application further complicates its use. This is associated with the technological uncertainty for the removal of undesirable trace substances. Depending on the quality requirements, complex procedures must be used to stay below the required limit values, e.g. for PFAS.

Challenges and technological trends in water reuse

There are some exciting technological developments for the reuse of municipal and industrial wastewater. Based on the standard processes in wastewater treatment, additional purification steps must follow to make the wastewater treatment plant effluent usable. The multi-barrier approach is often pursued here, in which different technologies are combined depending on the type of wastewater and quality requirements. The challenges lie in the selection of the right processes and components. Material selection can be particularly decisive in industrial wastewater treatment, especially in the case of high-saline or corrosive wastewater.

New developments in general water treatment support the special application in water reuse:

- Digitization and Water 4.0 can optimize processes and make them more efficient. The integration of sensors, artificial intelligence (AI) and digital twins will enable precise monitoring and control of water quality and quantity in real time in the future.
- Advances in membrane technology, such as the development of nanomembranes and hybrid membranes, improve filtration efficiency and enable the removal of micropollutants and pathogenic germs. These technologies are particularly useful for the reuse of wastewater.
- New processes such as plasma treatment and the use of ultrasound offer promising possibilities for removing pollutants and disinfecting wastewater. These technologies are still in the optimization phase but show great potential.
- Technologies for the recovery of nutrients, metals and other valuable substances from wastewater are becoming increasingly important. These processes not only contribute to the conservation of resources but can also contribute to the economic efficiency of water reuse.
- Advances in thermal separation processes, such as evaporation and distillation, enable effective concentration and removal of pollutants. These technologies are particularly useful for the treatment of industrial wastewater with the goal of ZLD (Zero Liquid Discharge).



Fig.2: Schematic structure of the multi-barrier concept

Valves in water treatment

In water treatment, different types of valves are used to control the flow, direction, and pressure of the water. Especially in water reuse, there may be higher requirements for material durability and connectivity, depending on the treated wastewater.

Typical valve types found in the plants are selected and used according to the specific requirements and conditions of the water treatment plant.

Quarter turn valves

Ball valves or butterfly valves are widely used due to their simple design and reliability. They offer fast on/off control and are ideal for applications where full flow or shut-off is required. They are robust and can be found in all areas of water treatment.



Fig. 3: Ball valves and butterfly valves are used in different variants

Linear Valves

Diaphragm valves are particularly useful in applications where reliable flow control is required. They are also well suited for handling corrosive or abrasive liquids. This is important in the treatment of highly aggressive wastewater.



Fig. 4: Diaphragm valves in plastic or as full-bore variant are suitable especially for aggressive or particle-containing media

Globe valves are found in areas that require precise flow control and high switching changes. They are used in particle-free water or for mixing functions with chemicals because they are susceptible to contamination.

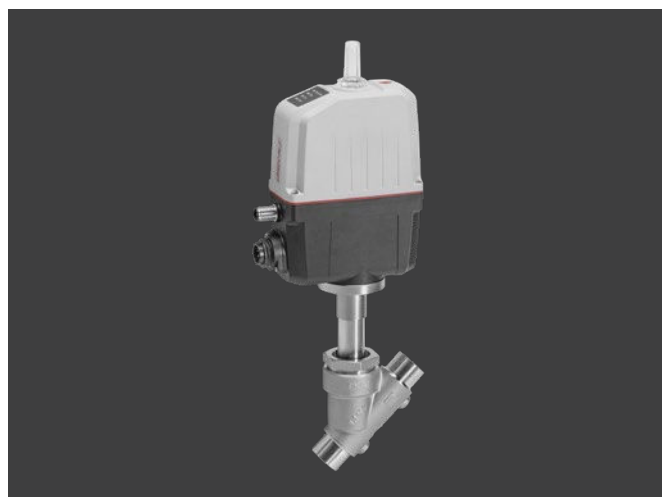


Fig. 5: Globe valves can be used for flow regulation

Solenoid valves are often used for small flows in on/off control, such as when adding chemicals.



Fig. 6: Solenoid valves are suitable for adding chemicals

This must be considered when choosing the valve

All valves have a number of technical challenges in common with the reuse of municipal and industrial wastewater:

- Valves must be made of materials that are corrosion-resistant and durable to withstand the harsh chemicals and varying pH levels in wastewater. Plastics such as PP, PVC or fluorinated materials (PTFE, PVDF) as valve bodies or gaskets or high-quality stainless steel or coated metal components are often used.
- Wastewater often contains solids and particles that can clog valves. This requires the use of valves with special designs that minimize blockages, as well as regular maintenance and cleaning. Diaphragm or full-bore diaphragm valves are well suited for this application.
- Modern water treatment systems often require automated control of valves to optimize operations and maximize efficiency. This is creating demands on the integration of sensors, actuators and control systems, which must work reliably and accurately. A flexible interface concept with different options, such as analog signals, TCP/IP or IO-Link, helps with integration.
- Valves must comply with legal and regulatory requirements, which can vary by region and application. This includes standards for materials, construction, and application. Especially in the treatment for drinking water, the necessary approvals must be observed.

These challenges require careful planning and selection of the right valves, as well as regular maintenance and monitoring to ensure reliable and efficient operation of water treatment plants.

Result

Water treatment for the reuse of municipal and industrial wastewater is a complex task that requires careful planning and implementation. Overcoming these challenges is crucial to ensure sustainable and safe solutions for water supply. GEMÜ valves meet all the requirements for water treatment for reuse. Depending on the application, metal or plastic variants of the different valve types are used in conjunction with various control options.