Factsheet

WATER PROOF

Wastewater Treatment

How to create a Circular Water Economy?

waterproof-project.eu

What is wastewater and why does it have to be treated?

Wastewater (or sewage) is water that has been used and contaminated by human activities. These activities include everything from household waste like bathwater, dishwater and toilet flushes to industrial and agricultural effluents. In the European Union, 544.4 million population equivalents (p.e.) of wastewater are generated every day. This is an amount that equals around 1087 million bathtubs.[1] In order to avoid pollution to the environment, urban wastewater needs to be treated before discharge.

Wastewater treatment takes place at specialised facilities known as wastewater treatment plants or sewage treatment plants. They are usually located near urban areas, in order to treat wastewater generated by the surrounding population. Local or regional governments, like municipal water departments, are usually responsible for treating wastewater. In some cases, private companies are hired to run these plants.

They have to follow standards and guidelines that are set by regulatory bodies at the state or national level. In the European Union, the Urban Waste Water Treatment Directive (UWWTD)[2] regulates how wastewater is collected and how it has to be treated. Although there are still differences in the efficiency of wastewater treatment between the individual European countries, in the EU already 82% of wastewater is treated according to this legislation[1].

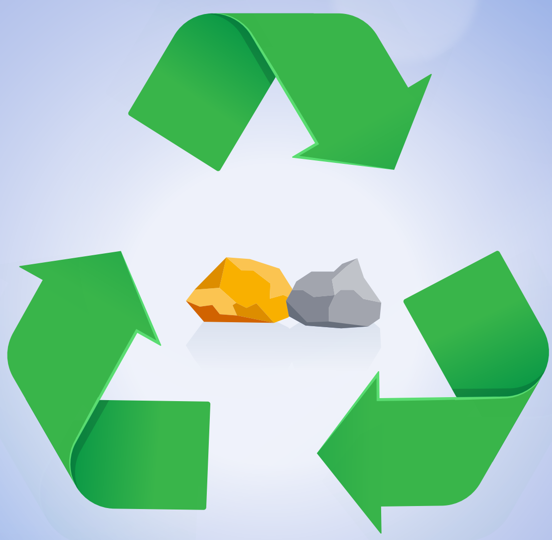
Wastewater treatment is a complex process that involves different treatment stages (see Information Box 1) to purify wastewater before it is reused or released back into natural water bodies. During the treatment process, a solid by-product is obtained, consisting of the solid particles present in the wastewater and of biomass produced within the biological treatment process itself.

This solid by-product, or **sludge**, can be further treated by digestion, to partly convert the organic content into biogas. The biogas can then be used as a (local) source of energy or, after further treatment, supplied to the gas grid. The remaining sludge still contains a mixture of carbon and nutrient rich materials, with small amounts of (precious) metals such as zinc, cobalt, copper, gold, silver, platinum, palladium and rhodium.

These precious metals enter urban wastewater streams when the products which contain the metals, e.g. catalytic converters in cars, metal-coated roof materials, food and food-additives, cosmetics (make-up) and medical products, are used and washed into drains, e.g. by rainwater or routine washing.

Wastewater treatment is a crucial process for:

- removing contaminants from sewage and industrial effluent, ensuring the protection of human and animal health and the environment, e.g. by preventing harmful, i.e. toxic, algal blooms,
- gaining clean drinking water,
- recovering resources for reuse.



Which challenges need to be tackled to make wastewater treatment sustainable?

In the EU, wastewater treatment plants, like other industrial plants, are under pressure to become more sustainable and cost-efficient. When done properly, wastewater treatment currently is expensive and energy intense. Also, there is an increasing need to advance treatment methods as more and more challenges are upcoming that complicate the proper management of wastewater sludge and pollutants. Therefore, the identification of gaps and bottlenecks is necessary to initiate adaptive measures.

The challenges that need to be tackled for a sustainable and cost-efficient wastewater treatment are:

Increasing consumption of freshwater and generation of wastewater

The higher concentration of business and people due to urbanisation leads to more household, industrial, and commercial wastewater. Also, as industries grow and new ones emerge, they contribute significantly to wastewater volumes. Climate change causes extreme weather events leading to overflowing and diluted wastewater treatment pools which increases the volume of wastewater. Last but not least, modern lifestyles and technologies often involve higher water usage for activities such as washing, irrigation, and cooling.

High emissions

Wastewater treatment plants are huge emitters of carbon dioxide (CO_2) and other greenhouse gases. The highest volume of greenhouse gases (mostly nitrous oxide, N2O, followed by CO_2) is formed by converting the carbon present in wastewater into biomass (sludge). Also, wastewater treatment requires a lot of energy. This energy often comes from burning fossil fuels which releases CO_2.

Loss of valuable resources

like precious metals because of insufficient recovery technologies that in addition are often harmful for the environment.

Increasing volumes of persistent and emerging contaminants in the environment:

Personal care products, pharmaceuticals, old and new types of pesticides, harmful algae, per- and polyfluoroalkyl substances (PFAS)[3], and microplastics are increasingly found in wastewater and can be difficult to remove with conventional treatment methodologies. Therefore, the development and application of advanced treatment technologies is indispensable.

Scepticism of the general public towards

- → new technologies that might be seen as experimental, too expensive for construction and maintenance, and potentially increasing the water bills, or affecting communities by noise and odours.
- → products derived from wastewater sludge (see Information Box 2), or from CO_2 from industrial plant emissions might cause worries about potential health risks.

Solutions offered by the WaterProof project

The EU-funded research project WaterProof (urban Waste and water Treatment Emission Reduction by utilizing CO_2 for the PROduction Of Formate derived chemicals) aims to develop an electrochemical process that converts CO_2 emissions captured from wastewater treatment plants into formic acid to be used in valuable green consumer products such as cleaning detergents and for the tanning of (fish) leather.

In addition, the WaterProof approach offers several solutions for closing the gaps in current wastewater treatment processes:

→ Making use of **renewable energy sources** to run the wastewater treatment. For example, by **replacing fossil fuels** with biogas or B-wood derived from regional recycling stations and from residues from the building industry, additional consumption of fossil carbon is prevented. Instead, by capturing CO_2 directly from the wastewater treatment plant and utilising it for valuable consumer goods the renewable carbon is kept in the loop supporting the **EU's circular economy.**

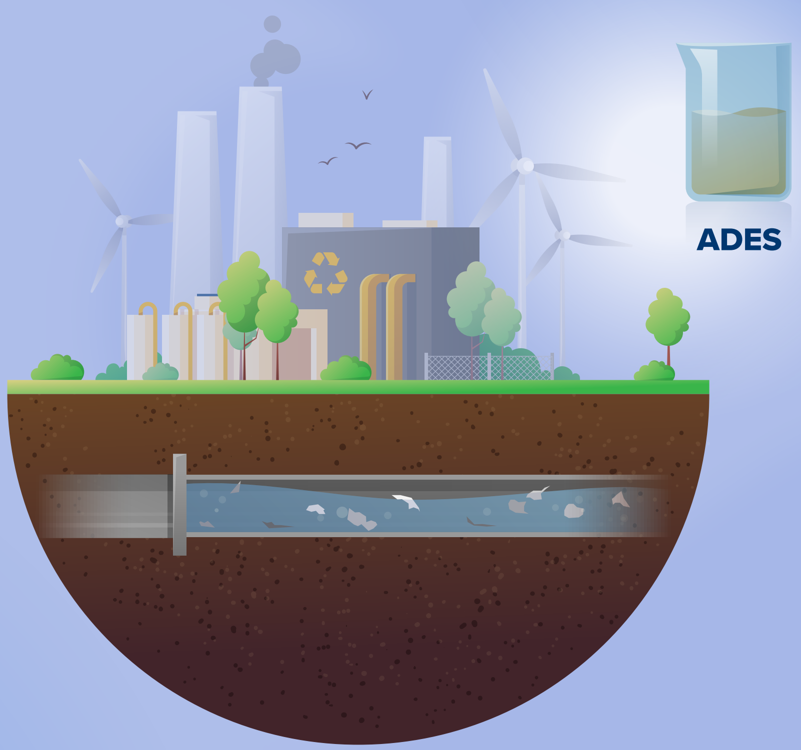
→ The captured and converted CO_2-emissions serve as a source for **renewable feedstock replacing fossil carbon** that is used for the production of chemicals and consumer goods contributing to a **clean water cycle with zero-emission.** Since CO_2 is used as a purified gas, consumers do not need to worry about contaminants contained in untreated wastewater or sewage sludge.

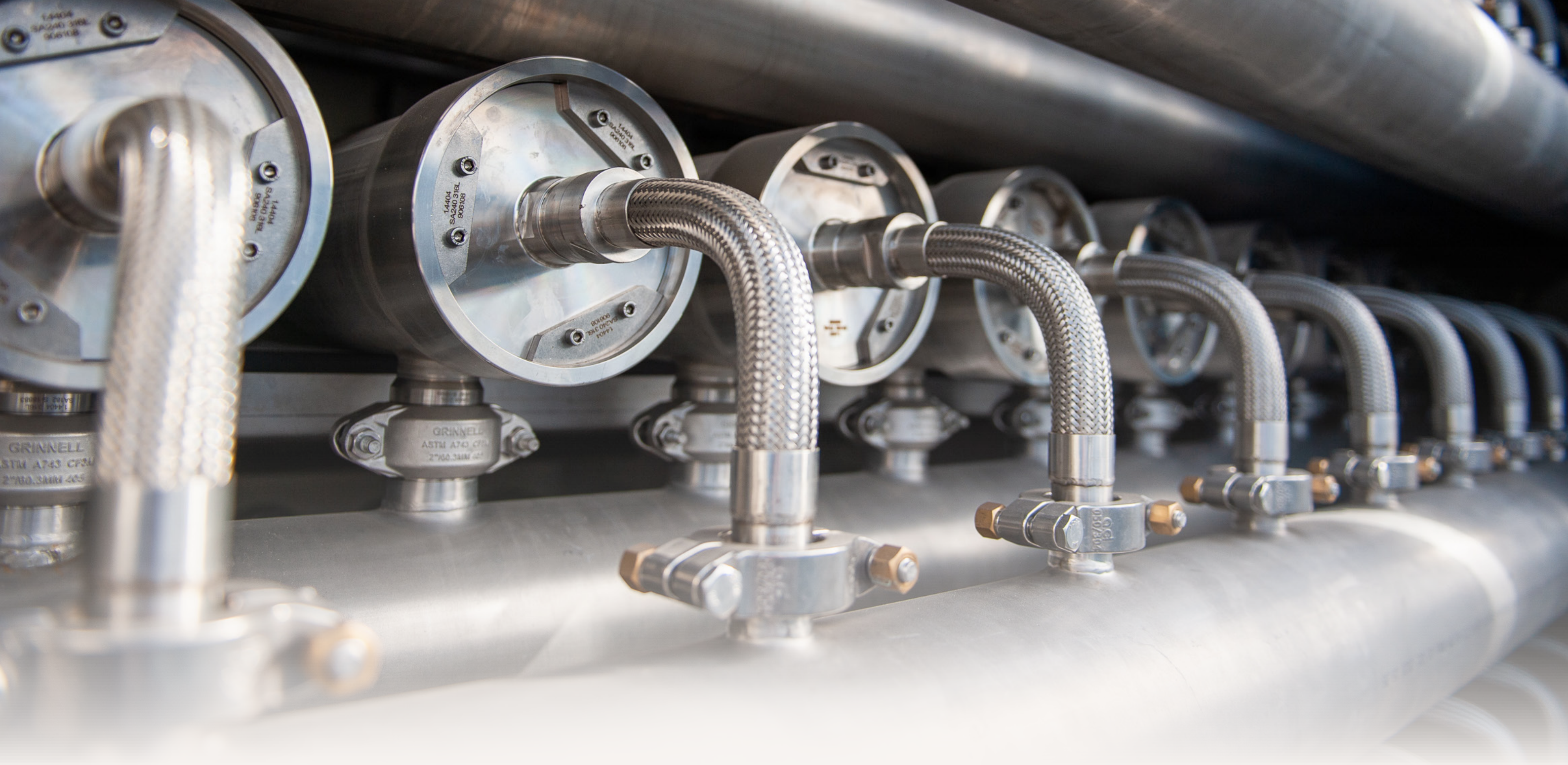
→ The formic acid derived from captured CO_2-emissions is used for the generation of **acidic deep eutectic solvents (ADES).** These chemicals can be applied **to recover precious metals** from wastewater sludge and incineration ashes. Furthermore, their use can **improve the environmental impact** of metal recovery by replacing currently applied mineral acids, and by needing less energy due to lower reaction temperatures[4].

→ Additional products of the electrochemical conversion of CO_2 into formic acid are **peroxides** that can be applied to **degrade persistent organic pollutants**[5] such as pharmaceuticals, antibiotics, pesticides or harmful algae in wastewater or sewage sludge.

WaterProof aims to concisely **inform the general public** about the environmental impact of the WaterProof technologies. In addition, consumers are involved to measure the **social perception and acceptance** of WaterProof processes and products. To increase the environmental consciousness towards more green and conscious consumption, WaterProof will formulate **recommendations for communication and public engagement.**

Furthermore, the WaterProof technology will be evaluated for transfer to different developing economies such as Columbia that currently do not have efficient and sustainable wastewater treatment.





Conclusion

The integration of WaterProof's innovative technological solutions can significantly improve the efficiency and sustainability of wastewater treatment systems by closing the wastewater carbon loop, reducing CO_2-emissions and shifting from fossil to renewable carbon sources. Wastewater treatment thus transforms from a disposal system into a solution for the recovery and tapping of new renewable resources. Making use of advanced technologies in wastewater treatment supports the circular economy and the independence of the European Union from fossil resources and third countries. Furthermore, elaborate wastewater treatment supports to reach the United Nations' 17 sustainable development goals (SDGs)[6], especially "Good health and well-being" (SDG3), "Clean water and sanitation" (SDG6), "Sustainable cities and communities" (SDG11) and "Life below water" (SDG14). This way, circular wastewater treatment not only enhances sustainability and economic stability but also contributes to a more resilient and independent society.

Selection of relevant legislations in the EU

- The Water Framework Directive (2000/60/EC) establishes a framework for the protection of inland surface waters, transitional waters, coastal waters, and groundwater and aims to achieve „good status“ for all EU waters by a set deadline.
- The Directive (EU) 2020/2184 on the quality of water intended for human consumption (Drinking Water Directive) sets quality standards for drinking water to protect human health. It includes provisions for the monitoring and reporting of drinking water quality.
- The Directive 2006/118/EC on the Protection of Groundwater Against Pollution and Deterioration complements the Water Framework Directive by setting specific measures to prevent and control groundwater pollution.
- The Urban Waste Water Treatment Directive (91/271/EEC) aims to protect the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors and requires member states to ensure that urban areas have systems for the collection and treatment of wastewater.
- The Sewage Sludge Directive (86/278/EEC) regulates the use of sewage sludge in agriculture to prevent harmful effects on soil, vegetation, animals, and humans and sets requirements for sludge quality and application rates.
- The Directive 2008/105/EC on Environmental Quality Standards in the Field of Water Policy establishes limits for certain pollutants in surface waters and aims to reduce the levels of hazardous substances in water bodies.
- The Industrial Emissions Directive (2010/75/EU) regulates pollutant emissions from industrial installations, including wastewater discharges.

Box 1: Different process stages for wastewater treatment[7]

Primary Treatment: Mechanical Stage
Physical removal of debris, oil/grease, waste solids and heavy particles (e.g. sand, gravel) with combs and filters followed by a sedimentation step in which heavier particles sink to the ground. The wastewater above this sedimented particles/primary sludge is transferred to the biological treatment.

Secondary Treatment: Biological Stage
Utilisation of microorganisms such as bacteria to degrade and remove dissolved and suspended organic matter and pollutants in the water by making use of aerated tanks or oxidation ponds and sunlight.

Tertiary Treatment: Physical-Chemical Stage
Use of chemicals to remove contaminants and disinfect the treated water. Common processes include coagulation and flocculation, where chemicals like aluminium or iron salts are added to aggregate fine particles into larger flocs that can be easily separated. Advanced chemical treatments also include metal recovery and nutrient removal to eliminate excess nitrogen and phosphorus, preventing eutrophication of downstream water bodies. Finally, disinfection processes are used to kill pathogenic or toxic microorganisms, ensuring that the treated water is safe for discharge or reuse.

Fourth Treatment Stage
Since ingredients of household chemicals, pharmaceuticals, pesticides and industrial substances cannot be completely eliminated during the conventional three treatment stages, a fourth stage will increasingly become necessary. Already applied techniques include ozonation, ultraviolet light irradiation, absorption, e.g. with activated charcoal and nano-filtration. Many of these processes are costly or still being tested.

From each of these different wastewater treatment steps, sludge that contains organic and inorganic materials is collected, combined and concentrated. Different wastewater treatment plants can differ in the applied methods and in the number of treatment stages.

Box 2: What happens to wastewater sludge?

In Europe, more than 8,800 kilo tonnes of wastewater sludge are produced yearly. The quantities differ greatly between the individual European countries[8]. This is because of differences in the produced wastewater volumes as well as differences in the efficiency of wastewater treatment plants. Wastewater sludge is often incinerated to produce energy or to reduce its volume as incineration ash is easier to handle and dispose of.

What is more, there are several other applications for wastewater sludge:

→ Sludge can be used as nutrient-rich fertiliser or soil conditioner in agriculture and gardening.

→ Sludge can be processed in anaerobic digesters to produce biogas, which can be used for generating renewable electricity and heat.

→ Sludge can be used in the production of construction materials, such as bricks, cement, and tiles.

→ Sludge can be used for the production of bioplastics: Wastewater sludge contains organic material that can serve as a food source for specific bacteria. Under controlled conditions, these bacteria convert the organic matter into biopolymers that can be used for the production of bioplastics. This process not only provides a sustainable way to manage wastewater sludge but also creates a valuable, fossil-free and sustainable material contributing to the circular economy.

References

1 https://water.europa.eu/freshwater/countries/uwwt/european-union

2 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0271

3 PFAS are a large class of thousands of chemicals that are used throughout society. However, they are increasingly detected as persistent and accumulating environmental pollutants and some are linked to negative effects on human health. https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

4 https://www.mdpi.com/2673-4079/1/3/16

5 Devi, P., Das, U., & Dalai, A. K. (2016). In-situ chemical oxidation: principle and applications of peroxide and persulfate treatments in wastewater systems. Science of the Total Environment, 571, 643-657.

6 https://sdgs.un.org/goals

7 https://www.geo.fu-berlin.de/en/v/iwrm/Implementation/technical_measures/Wastewater-treatment/Off-site-treatment/Sewage-Treatment-Plants/Primary-Treatment/index.html

8 https://www.statista.com/statistics/1393771/sewage-sludge-generation-europe/

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