European Wastewater Sector Foresighting

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FACTORS INFLUENCING THE WASTEWATER SECTOR IN NORTH WEST EUROPE

Introduction

Water crosses many industries and is part of a huge range of economic activities including agriculture, energy, manufacturing, food, tourism and many more.

The worldwide market for Water and Wastewater Treatment is expected to grow at a compound annual growth rate of roughly 3.3% over the next five years, with a value of 6010 million US$ in 2023, from 4950 million US$ in 2017, according to a new GIR (Global Info Research) study.

This European Wastewater Sector Foresighting report sets out ideas, challenges and influences impacting on the wastewater sector in Europe. Our aim for this report is to set out ways in which transforming the wastewater sector can be approached, exploited and improved upon by SME's with cutting edge technologies and knowledge. By no means is this report a comprehensive overview of an extremely diverse industry, but it will hopefully help guide, inspire and feed disruptive technologies and methodology the wastewater industry requires to achieve the standards set by European and International law.

If you have a technology and would like to make use of the Innovation support Vouchers offered by the Water Test Network, please head over to the North-West Europe Water Test Network to find out more.

Political Factors

The EU sustainable development goals are about making lives better. Goal number six is to ensure availability and sustainable management of water and sanitation for all.

The EU Water Framework Directive (EUWFD) has been in operation since 2000, providing a framework for regulation of water legislation across the EU community.

Talking about the EUWFD in a recent paper from the Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Germany's largest freshwater research centre, Professor Mark Gessner, Acting Director of IGB, states that, "[the EUWFD] is a technically sound and expedient policy document. But the very limited ecological improvements that have been observed to date indicate that the directive falls short of striking an appropriate balance between the conflicting goals of protecting fresh waters and using them as a resource—and that significant shortcomings exist in the practical implementation."

From 2017, the EUWFD amended the quality consent for effluent which included lowered levels of ammonia, suspended solids and biochemical oxygen allowed in treated effluent.

The Urban Wastewater Directive (UWTTD) was developed in 1991, it aims "to protect the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors" by mandating wastewater collection and treatment in urban agglomerations with a population equivalent of over 2000, and more advanced treatment in places with a population equivalent above 10,000 in sensitive areas.

Now over 30 years old, it's widely suggested that technology, water treatments, threats to the environment, demographics, science and society have all progressed beyond the scope of the original UWWTD. Plus, the Water Framework Directive, along with the Marine Strategy Framework Directive, which came after, have altered the legal context of the UWTTD.

An evaluation of the UWTTD by chemical experts, Kemira, suggests that while the Directive has improved wastewater treatment practices in EU member states, it has not kept up with technological advances, and some severe shortcomings exist with regard to implementation and it concludes, a review of the Directive would not only bring benefits for both human health and the environment, but would also serve in meeting the EU's climate and circular economy goals.

In the meantime, EU member states (some more than others), strive to meet the standards outlined by the UWTTD's articles by employing a range of technologies to wastewater treatment and strong governance is required to ensure a level of industrial and domestic compliance to, and standardisation of, wastewater regulations.

While 30 years ago, the priority was to protect the environment, entering the third decade of the 21st century, effective wastewater treatment has become critical to the planet.

While the UWWTD initially was put in place to protect the environment, within the last 30 years technological advances have developed beyond the pace that anybody could have envisioned at the time of creating the UWWTD. The creation of new technologies and industries has brought around several new environmental issues which must be tackled using these new technologies and techniques and therefore the argument to modernise the UWWTD is most certainly justifiable. The corona virus pandemic has led to an increased public interest in the environment and has led to an increased awareness in reporting pollution incidents from underperforming sewerage systems. First, we must look at what the challenges are involving WWT.

Extreme weather conditions, the presence of new contaminants and obsolete existing water infrastructure have been identified as some of the main challenges to wastewater treatment capacities. At the same time, 80% of wastewater in the world is currently discarded without sufficient cleaning and proper treatment, further impacting and posing a threat to marine and water ecosystems. To alleviate these pressures and enable progress in adequately treated wastewater and overall freshwater quality, Orgalim, Europe's Technology Industries, advocates for the sustainable use and management of water in Europe. These involve the management of the sustainable use of water in support of climate ambitions, zero-water leakage, an appropriate water value, solutions for global water challenges and digitally enabled water technology (Orgalim, 2019).

A wide range of smart and sustainable European technologies apply to industrial and municipal wastewater treatment, resource recovery processes, closed-loop water treatment and nature-based solutions. These technologies have played a key role in reducing pollutants in wastewater, driving forward the main goal of the Urban Wastewater Treatment Directive. As such the EU government has been urged by Orgalim to revise the directive in light of new societal challenges and technological advances and enforce the directives implementation by setting targets, enabling sustainable water financing and directly incentivising the deployment of innovative wastewater technologies (Oraglim, 2020).

As part of the new common agricultural policy (CAP) proposals for 2021-27, a new tool is being developed to help farmers manage the use of nutrients on their farm. The Farm Sustainability Tool for Nutrients (FaST), proposed in the framework of the Good Agricultural and Environmental Conditions (GAECs), aims to facilitate a sustainable use of fertilisers for all farmers in the EU while boosting the digitisation of the agricultural sector

The CAP proposals include high ambitions for environmental and climate action and the digitisation of the agricultural sector. In line with those objectives, the FaST aims to contribute to the increase of competitiveness, climate change action, and environmental care.

Its use will bring environmental benefits, such as reducing nutrient leakage in ground water and rivers, as well as positively contributing to soil quality and reducing greenhouse gas emissions. The tool will also make sense from an agronomic perspective. It will help decrease the use of nutrients, when there is over-fertilisation or increase crop yield, when there is under-fertilisation. In both cases, this will lead to an increase in farmers´ revenues and efficiency. (European Commission (2020) *A new tool to increase the sustainable use of nutrients across the EU*)

As part of the European green deal there has been new regulations brought into effect surrounding agriculture. The new Directive on minimum requirements for water reuse for agricultural irrigation has entered into force. The new rules will apply from 26 June 2023 and are expected to stimulate and facilitate water reuse in the EU.

The Regulation sets out:

- Harmonised minimum water quality requirements for the safe reuse of treated urban wastewaters in agricultural irrigation.
- Harmonised minimum monitoring requirements, notably the frequency of monitoring for each quality parameter, and validation monitoring requirements.
- Risk management provisions to assess and address potential additional health risks and possible environmental risks.
- Permitting requirements.
- Provisions on transparency, whereby key information about any water reuse project is made available to the public.

The new rules are to be situated in the context of the new Circular Economy Action Plan adopted in 2020, which includes the implementation of the new Regulation amongst Europe's priorities for the circular economy. The Action Plan also announces that the Commission will facilitate water reuse and efficiency in other sectors, including in industrial processes. (European Commission (2020) *Water Reuse*)

As part of the sustainable development goals the issues highlighted were the need to investment in infrastructure which reflect the argument for additional investment in and modernisation of the treatment of wastewater. Some of the challenges on the implementation of WRM that have been raised in different fora include insufficient financing and a need for improved financing in water resources management. Many countries already suffer an infrastructure deficit. Without a major increase in investment for infrastructure many countries will struggle to meet targets. Little progress has been made on payment for water resource services and ecosystem services.

There are also challenges for implementing appropriate technologies. In fact, in the lowest three Human Development Index (HDI) categories water efficiency is not integrated into water resources management. Few countries have advanced implementation for irrigation and rainwater harvesting. "Technology divides" could be addressed to ensure technology becomes an effective means to attain socially and ecologically sustainable development.

Water resources management programmes (including allocation systems, groundwater management, environmental impact assessment and demand management among others) are being implemented in more than 84% of the highest HDI group countries but only 40% of other countries. Strategic planning, national policies, transboundary agreements and integrated water resource plans are often non-existent or inadequate. (United nations department of economic and social affairs (2020) *Action on water resources management*)

New water reuse regulation (part of EU circular economy action plan) - new integrated nutrient management plan (part of EU circular economy action plan) - new European Water Framework Directive - Nowadays, the concept of wastewater treatment plants as a process for removing water pollution is undergoing a deep transformation towards its novel conception as bio factories. This new approach supposes the re-definition and re-design of wastewater treatment technologies towards new value-added processes that enable not only water reuse but also resource recovery and energy production. Bio factories using wastewater have a dual emphasis on compliant effluent requirements, especially for water reuse, and reduce adverse impact through new alternatives for biowaste transformation into added value bioproducts. This novel concept creates new business opportunities that respond to the European Union and their initiatives of circular economy and resources recovery and therefore, represent the main niche for innovation in the sector. Innovation actors are currently focused on developing innovative solutions that convert wastewater and sludge in clean water and energy, recover metals, nutrients or minerals and produce sustainable bioplastics, proteins, alcohols, fertilisers, biogas and hydrogen. The overall goal of bio factories is to achieve zero waste, zero environmental impact and zero consumption of fossil energy by reusing 100% of the wastewater and transforming it into new resources, such as biogas or fertiliser for local farmers. - new missions of Horizon Europe (mission on healthy oceans, seas, coastal and inland waters) - new water reuse regulation (part of EU circular economy action plan) - Common Agricultural Policy - World water development report 2020

Environmental Factors

In some areas, climate change means heavy rainfall is more frequent, overloading networks, causing surface flooding and overflow in treatment plants. Wastewater technology needs to be higher capacity and higher spec to cope with this and there also needs to be consideration given to green infrastructures, such as rain gardens, green rooftops, porous pavements and artificial wetlands, to prevent stormwater from infiltrating sewers and causing them to overflow.

There are several impacts on the need for potable water to satisfy population growth and industrial requirements with a need to improve the quality of discharges from sewerage and WWT. The UWWTD set requirements for treatment of biodegradable wastewater from industries who discharge water directly to the environment. However, the directive does not set standards for these industrial discharges but only requires that discharges greater than 4000 comply with discharge authorisations. With a large increase in the amount of rainfall per annum the quantity of overflowing events of raw sewerage from storm overflows and from infrastructure through surcharges from manhole covers has greatly increased, these overflow events have an impact on all the areas of the water environment and drive the need for improvements on the collection of wastewater.

The sewerage treatment providers in the UK are responsible for maintaining and improving the public sewers which serve most of the UK population. About 96% of the UK population is connected to sewers leading to sewage treatment works. Most of the remainder are served by small private treatment works, cesspits or septic tanks. All sewerage systems that also collect rainwater (combined sewers) need overflow outlets (combined sewer overflows) to deal with the extra water collected during some rainstorms. Without these safety valves both domestic, other properties, and sewage treatment works would be at risk of flooding. The Directive recognises that although sewage in these overflow discharges is diluted with significant amounts of rainwater, it can affect the environment. The legislation therefore requires that pollution from these overflows is limited. In the UK we have the necessary regulatory controls and design criteria to limit pollution from combined sewer overflows. For example, in England and Wales for the five years to 2000, 1,200 unsatisfactory combined sewer overflows were improved. Furthermore, between 2000 and 2005 another 4,700 overflows will be brought up to standard in England and Wales. (Department for environment food and rural affairs (2002) *Sewage Treatment in the UK*, United Kingdom: Department for Environment, Food and Rural Affairs.)

Despite the standards of the UWWTD and the recognised need from domestic governments to improve processes for collecting and treating wastewater, in 2019 water companies in England discharged raw sewerage into rivers more than 200,000 times. The figures, obtained via environmental information requests, trace releases of sewage from storm drains in rivers across England by all nine water companies and provide a comprehensive picture of the scale of pollution from what critics say is the routine dumping of untreated sewage. Countries are legally obliged to treat sewage before it is released into waterways. Discharges of untreated human waste are permitted only in “exceptional circumstances” for example after extreme rainfall, the European court of justice has ruled. (Sandra Laville and Niamh McIntyre (2020) *Exclusive: water firms discharged raw sewage into England's rivers 200,000 times in 2019*)

In 2018 an action plan was created with regards to surface water management by the Department for Environment Food and Rural affairs. Section 7 of this plan titled ‘Making sure infrastructure is resilient’ recognises clearly in section 7.2 through 7.4 that water and sewerage companies have a particularly important role to play in the management of surface water risks, as they are responsible for much of the drainage network. The 2017 strategic policy statement makes clear that securing the long-term resilience of wastewater systems and providing for resilience against flooding and wider risk is a key priority. Under the strategic policy statement, Ofwat will challenge and incentivise water and sewerage companies to improve planning and investment to meet the drainage and wastewater needs of current and future customers, and to develop an innovative mix of solutions. This could include promoting, adopting or maintaining sustainable drainage systems or coinvesting in flood risk management, working creatively with partners "upstream" as a means of effectively draining their area and delivering multiple benefits where possible. (Department for environment food and rural affairs (2018) *Surface water management action* plan) Despite the recognition of the need for investment it is evident with many water companies still discharging raw sewerage into UK water ways that more must be done to truly tackle the situation.

Over 10 billion litres of sewage are produced every day in England and Wales (Ofwat, 2006). To treat this volume of sewage required approximately 2,800 GWh of energy in 2006/07, equating to 1.7 million tonnes of greenhouse gas emissions (Water UK, 2007a). Across the whole of the water industry (potable and wastewater), 515 GWh of renewable electricity was generated, and 13 per cent of the energy demand was met by renewable sources. The electricity demand required to treat sewage is expected to increase in the future as the population grows and consent standards tighten. The Water Framework Directive (WFD) is an overarching piece of legislation which came into force in 2000 and is likely to drive investment in the water industry. It aims to achieve "good ecological status" in inland and coastal waters through River Basin Management Planning. Within the WFD are regulations relating to Annex X substances (priority and priority hazardous substances) and Annex VIII substances (including nutrients and endocrine-disrupting substances). These substances have, or will have, environmental quality standards (EQS) that will need to be complied with to meet the requirements of the WFD. (Environment Agency (2009) *Transforming wastewater treatment to reduce carbon emissions*)

In other areas, water scarcity from reduced rainfall is increasing the need to reduce, recycle, reuse and high-level water treatment becomes more important – a greater level of contaminants must be removed from wastewater to make it reusable. The Water Risk Atlas 2019 issued by the World Resources Institute (WRI) shows the ratio of water extraction to water supply and groundwater reserves, and the height of the drought and water shortage risk for 189 countries in the world. Worldwide, there are 17 countries on the verge of 'Day Zero', through exploitation of 80 percent of their ground and surface water. The ranks 18 to 44 include many Mediterranean countries such as Italy, Portugal, Spain and Greece, as well as some Balkan states and, surprisingly, Belgium. On average, they use around 40 percent of their available water resources. It is predicted that by 2030, over half of EU river basins will be affected by water scarcity, and this growing pressure on water resources will force the consideration of new supply options, such as water reuse.

Microplastics (plastics with particle size smaller than 5 mm) are becoming an increasing environmental concern, not only posing a threat to aquatic life and humans. Scientists believe that human beings consume at least 50,000 micro-plastic particles every year, through food and water. While contributing to accumulation of plastics in the environment, microplastics are also contributing to the spread of other micropollutants; due to their large specific surface area and hydrophobic surface, persistent organic pollutants, metals and pathogens could be easily adsorbed on the surface of microplastics.

Microplastics are reported to inhibit both the effectiveness of both bacteria in biological wastewater treatments and the sludge digestion process. They are proving a real problem for successful wastewater treatment.

Micro rubber is being spoken about. The amount of micro rubber in the environment is said to be huge, entering air and water from the finest particles of tire abrasion. Microfibers are also ‘a thing’, making their way into wastewater predominantly via laundry cycles. Realistically, while they may decrease over time, these pollutants, are impossible to cut off at source and even reductions will require a major social shift.

Most wastewater treatment plants were never set up with the capacity to remove pharmaceuticals. Many pharmaceuticals are proving difficult to remove from water systems which is having an impact on all aspects of the environment, from soils to aquatic life.

Societies increasingly care about sustainable living and optimising wastewater management processes could unlock solutions to some of society’s biggest sustainability challenges, from food production to renewable energy.

Economic Factors

Recovery from wastewater is becoming increasingly important as we move towards a global circular economy; businesses need to be looking for the most efficient and economically viable point of water recovery. Energy costs and scarce resources should be reasons to promote water efficiency and provide opportunities for urban wastewater treatment to contribute more to the circular economy through energy generation, water reuse and material recycling.

Wastewater offers the potential to have wide-ranging impact in areas such as energy production (biogas), agriculture (fertiliser) and industrial development and of course in human survival. There is also a need to reduce energy consumption in wastewater treatment and there are opportunities to create energy, heat, biogas, fertilisers and other valuable resources from processes.

Wastewater is still full of potentially valuable materials including depleted/finite resources and there is high potential value from recovered materials including metals and chemicals for example, there are twin global issues of phosphorus pollution in water and shortage of phosphorus for other purposes (e.g. agricultural fertilisers). As phosphorus is no longer an inexhaustible resource, along with the higher cost of commercial fertilisers and more demanding legislative requirements, many biological and chemical processes have developed to recover nutrients from wastewater and sludge. There is also increased demand for usable water from the agriculture sector for farmland irrigation which may not need to be treated to the same standard as for human consumption but is still vital for human survival.

Though the treatment of wastewater is essential to the survival of our environment and there are several economic possibilities associated with efficient treatment of wastewater, in recent years wastewater treatment processes are moving away from less energy intensive, simple processes to more industrial treatment processes which in a time when energy consumption is an important focus, this is not necessarily a good thing. Processes such as Desalination, the process of removing salt from either sea water or ground water is often touted as one of the most effective ways of providing fresh supplies of clean drinking water or water for industry. However, it can also be very energy intensive and costly and can result in a brine. Efforts are underway to make this process more efficient in the future. Oasys Water has developed a forward osmosis system, known as Engineered Osmosis, which uses the natural process of osmosis to force sea water through a membrane instead of pressurising it with electricity to reach the same goal while achieving low cost points.

Several companies are in the process of or have already developed treatment processes which are created with the intention of being as energy efficient as possible. Processes such as purification meanwhile, removes unwanted chemicals, materials, and biological contaminants from water, often by trapping pollutants in filters. Puralytics' photochemical water purification system is designed to purify water in a cost effective and greener way, removing the need for a filter and avoiding a problem of how to dispose of contaminants. Its system uses light emitting diodes (LEDs) to illuminate a nanotechnology coating on a mesh, through which the water flows. This process creates a chemical reaction that causes molecules to break apart and then break down in the water. Puralytics is using renewable energy to help supply safe drinking water to people without access in the developing world. Its 'Solar Bag' can be filled with water and placed in the sun, allowing the nanotechnology to purify the liquid over the course of several hours. (Jessica Shankleman (2011) *What are the latest advances in water treatment and management?*)

Social Factors

The proportion of households connected to wastewater treatment facilities varies across Europe, from 97% in western and central Europe, to around 70% in southern, south-eastern and eastern Europe. While the majority of the water network is invisible to the average citizen, some will have concerns about the quality of water at the point of consumption, some about the environmental impacts of effluent waters and some about the environmental/aesthetic impacts of wastewater treatment plants in their community, forcing industry to seek and implement more sustainable and modern alternatives.

As before, there is a growing public demand for sustainability and reuse of all resources. In urban areas, it is a challenge to find space to install treatment plants (and to face opposition of noise/odour) or upgrade existing plants. Urban dwellers consume around three times more water compared to their rural counterparts. Hence, increase in urbanisation poses a serious threat to the water resources of the region. In rural areas, individual treatment systems are often used due to low volumes and economies of scale.

The world's growing and aging population has a massive impact on wastewater including elements such as:

- More pharmaceuticals in wastewater
- Increased sewage sludge

- Newly identified pollutants
- More chemicals in wastewater

Water consumption in European countries has been in constant decline since 1990 thanks to water-saving devices and home appliances but further education is vital. We all need to become responsible consumers and use resources wisely. It has been predicted that two-thirds of the world's inhabitants could live in water-stressed conditions by 2025, exacerbated by the demands of a growing population, increased urbanisation and climate change. According to the World Economic Forum, water supply crises are among the 3 greatest threats facing the planet.

In recent years climate change and the importance of protecting the environment have really come to the forefront of political and social debates. People seem to have woken up more and more to the fact that resources are finite, and we must do everything we can to protect the worlds resources. One further issue is that with the aging population this is the demographic which according to a study from Phillip S. Morrison and Ben Beer from the university of Wellington care the least about the effects of their consumption on the environment, that has been put down to the fact it would not have been a topic of education prior to the 2000's.

It is in fact the middle-aged buyers who are the most environmentally conscious. The relationship of environmental awareness and age takes an inverse U shape: awareness rises with age, reaches a peak in early to late middle age and then declines with the oldest age groups. Middle-aged consumers are more likely to declare knowledge of the environmental impact of the products they buy and are most likely to appreciate the importance of the environmental consequences of their purchases. They are also the most likely to support ecolabelling and to the mandatory labelling of carbon footprints. At the same time, the magnitude of the difference between ages varies depending on which measure of environmental awareness is being considered. (Phillip S. Morrison and Ben Beer (2017) *Consumption and Environmental Awareness: Demographics of the European Experience*)

Technological Factors

Cost effective ways of upgrading or making improvements to existing wastewater treatments and new technologies that are simple but extremely effective, are in demand. An aging infrastructure means an increased demand for new technologies – but they need to complement and fit within the footprint of current facilities.

For currently employed wastewater treatment technologies, please see Appendix 1.

The Internet of Things/smart/disruptive technology is bound to play a part in the future of wastewater technology, increasing value, precision and automation and providing continual optimisation, while mixed with more 'traditional' treatments.

IoT in the sewage system could support the detection of sources of pollution in real time so that immediate action can be taken. An IoT system in sewers can monitor an entire city, monitor pollution status and identify the worst offenders. Similarly, it can immediately spot serious leakages and prepare treatment plants to deal with excessive loads.

Artificial intelligence can predict a developing water quality issue and recommend measures to resolve it before it happens. This process also can be used to prevent such predictable problems as pump or pipe failures, water losses, and leaks at customer sites.

For the most effective water treatment technologies, the trend is towards a mix of membrane and biological solutions. Recent innovations in the field of membrane filtration are supporting the growth of the membrane filters market in Europe. Several associations, organisations, and societies are actively engaged in the expansion and implementation of membrane technology in various industries, including pharmaceutical, chemical, environmental, and food.

Opportunities for wastewater technology

Looking to the future, new technologies need to embrace superior energy performance, offer circular solutions, focus on improved formulation and processing and be individual – whether in a modular sense to add value to current technologies or literally compact, cost-effective and 'easy' enough for an individual home, street or rural area. The sector is trending towards solutions that are natural and chemical free, and the buzz is all about bio - biomass, biosolids and biofertilizers and the production of materials from wastewater (the circular economy).

The wastewater sector is ripe for a circular economy which can only be achieved through increased global collaboration and research. Wastewater Treatment Plants are no longer considered only for environmental protection and sanitation functions, but also as the starting point for the exploitation of potential resources (including sludge) that now are considered waste streams.

Four notable challenges/opportunities are prevalent from wastewater treatment issues and these are: Pharmaceutical removal, water reuse, capturing energy/gaining value and the removal of microplastics.

Pharmaceutical Removal

The EU has identified pharmaceuticals in waters as a challenging problem since currently, wastewater treatment plants cannot capture the substances efficiently enough. In March of 2019, the European Commission published a communication which proposed a strategic approach to the pollution of water by pharmaceutical substances taking account of the international dimension to the problem and circular economy considerations. More information is still needed to understand and evaluate certain pharmaceuticals as regards their environmental concentrations and the resulting levels of risk.

Recently released research even goes as far as to pinpoint global variations in drug usage based on influent water samples highlighting an increase in the use of methamphetamine in Europe and a key concern involves micro pollutants and the so-called 'cocktail effect', whereby mixtures of single chemical substances individually present at harmless concentrations can combine to pose a risk.

The World Health Organisation (WHO) reports that the weight of evidence from several recent studies points to it being very unlikely that pharmaceuticals in drinking water pose a threat to human health at the low concentrations found, however, it notes that the issue of pharmaceutical residues cannot be ignored. According to a 2012 WHO report wastewater treatments have shown efficacies ranging between less than 20% to greater than 90% for removing pharmaceuticals.

VTT and Aalto University have developed a wood-based cellulose fibre yarn as an affordable solution for capturing pharmaceutical substances—especially ethinylestradiol in contraceptive pills. After some time, the material is collected mechanically from wastewater tanks. It is disposed of by incineration, but it is also possible to separate the pharmaceuticals and reuse the material.

In October 2019, the European Environment Agency published a briefing which stated that more investment is required to improve wastewater treatment plants to meet the challenges of climate change and micropollutants.

There is a rising demand for low-pressure membrane technologies which are said to be the most effective for pharmaceutical removal. Polyethersulfone (PES) membranes are extensively used in the healthcare industry for monoclonal antibodies and vaccine production and for protein separation. Nanofiltration membranes have been an attractive separation process technology employed in separation, concentration, and production of hormones and antibiotics.

A treatment option for pharmaceuticals, trialled with hospital wastewater is the combination of biological systems with sonochemical processes. The biological treatment typically removes macro-components whereas sonochemistry can degrade recalcitrant pharmaceuticals from water.

Water Scarcity and Reuse

From a circular economy perspective, water reuse is a win–win option however, it faces many barriers to implementation ranging from public perception to pricing and regulatory challenges.

It is estimated that more than 200 water-recycling schemes are in operation in the European Union. In December 2019, the EC agreed new rules for the harmonised minimum water quality requirements for the safe reuse of treated urban wastewaters in agricultural irrigation. European Commissioner for the Environment, Oceans and Fisheries, Virginijus Sinkevičius, said: “With this provisional agreement, we are equipping the EU with a powerful tool to tackle some of the challenges posed by climate change. Together with water savings and efficiency measures, the use of reclaimed water in the agriculture sector can play an important part in addressing water stress and drought, while fully guaranteeing the safety of our citizens”.

About 81% of the freshwater used in Europe for agricultural, potable, and industrial purposes is being abstracted from surface water bodies and groundwater. Many industrial and irrigation uses could be satisfied with reclaimed water, but less than 3% of urban wastewater is reused in the whole of Europe. Industry is the biggest abstractor of water in Europe (55%), followed by agriculture (24%). Agricultural use is predicted to increase sharply over the coming years. Landscape irrigation and golf-course watering, often linked to tourism, can also require significant volumes of water.

The global market for water reuse solutions is projected to continue to expand to over 10 million cubic meters per day by 2022. Microfiltration followed by reverse osmosis are the two principal technologies normally employed for the potable reuse of wastewater.

Leakage, particularly in aging water infrastructures, results in the increased use of our natural raw water resources making it a contributing factor to water scarcity. Up to 50% of water resources are being lost through leakage. Advances are required in prediction modelling technologies along with smart solutions for leak detection and prevention to combat these losses however, technology like this will attract high initial investment cost in terms of installation and software licensing. Water utilities can already benefit from predictive and automated leakage repair which will no doubt become smarter, more efficient and cheaper, as the market matures.

Capturing energy/making value from wastewater – Anaerobic Digestion

Anaerobic digestion (AD) is challenging because the treatment performances vary significantly with the technology type, wastewater properties and environmental conditions and a trade-off between the treatment efficiency and other cost and environmental impacts is usually applied.

Recognising sludge as a resource, not as a waste, has made researchers consider the recovery of valuable components from sludge, such as carbon and nutrients. Anaerobic digestion for sludge has huge potential to be leading source of energy and fertiliser with the added environmental benefits of more efficient waste management and emissions reduction. Recognising the circular economy and legislation, the use of sludge as a source of energy is a good alternative for its disposal. The energy that can be obtained from wastewater sludge maybe a sustainable solution to fulfil present and future energy requirements.

The main source of energy from wastewater treatment is the biogas produced by AD, with a content of methane (50-70%) and carbon dioxide (30-50%), and some traces of nitrogen, hydrogen, hydrogen sulphide and water vapour. AD is one of the most applied technologies for biogas generation in WWTPs.

Approximately half the sewage sludge produced by EU member states is spread on land as fertiliser and a quarter is incinerated. Dewatering sludge decreases its weight, which also has an effect on the cost of disposal (cheaper transport costs).

Research has shown that the use of municipal wastewater sludge as a raw material for bioplastics production could be a sustainable alternative to petroleum plastics. Polyhydroxyalkanoates (PHAs) are naturally produced by bacterial fermentation of sugar and lipids and have similar properties as conventional plastics.

Sewage sludge can also be considered a protein source with a protein content of ~61% plus carbohydrates and lipids and the recovery of these macromolecules is said to be very promising, despite the simultaneous recovery of heavy metals.

Power to protein is a research project embracing the concept of wastewater as a resource and investigating the use of wastewater plants to convert the nitrogen from sludge to single cell protein and potentially, also create an energy supply from ammonia extracted from reject water along with hydrogen and carbon dioxide.

Project WOW! is an Interreg North-West Europe project, with the title standing for 'Wider business Opportunities for raw materials from Wastewater'. The consortium of project partners aims to develop value chains for three different raw materials from sewage: cellulose, PHA bioplastics and lipids.

Phos4You is another Interreg North-West Europe project investigating the value of phosphorus removal from sewage sludge and its use in agriculture, energy and new technologies.

Further research is needed into the genetics of the bacteria used in AD plants to see how these could possibly adapt to treat more waste, to treat different types of waste and to extract and add value to the waste. They also need to be 'stable' as waste levels and content (potentially) differs through the life cycle of the plant. Bioreactors that do not require additional oxygen is a growth area and another opportunity to decrease energy costs.

The Removal of Microplastics

Currently, a membrane bioreactor is the most popular technique for high strength wastewater treatment due to its high removal capabilities of the contaminants and it is thought that membrane bioreactor technology could remove microplastics by up to 99.9%.

Biological solutions may not seem a likely choice for microplastics, however more and more fantastic ideas which provide exactly that are emerging globally. Japanese scientists identified bacteria (*Ideonella sakainesis* 201-F6) that eats polyethylene terephthalate (PET), consuming the plastic as a carbon and energy source. In India scientists discovered two strains of plastic-eating bacteria (*Exiguobacterium sibiricum* DR11 and *Exiguobacterium undae* DR14) that can decompose polystyrene. Both strains used polystyrene as a carbon source and created biofilms, paving the way for its natural degradation.

A research team at the Swedish Royal Institute of Technology has developed a nano coating technology which is capable of degrading microplastics. This new technology is revolutionary, being both non-toxic and viable.

Dynamic Membranes are attracting a great deal of both reducing energy consumption and cost in wastewater treatment. Dynamic Membranes are promising technologies for removing low-density, non-degradable particles, like plastics, as they utilise existing pollutants in water to form a filter layer without introducing additional chemicals or other pollutants.

At present, the identification and detection methods of microplastics are incomplete. No standard system has been formed and all kinds of purification detection methods are defective. In addition, there is a lack of identification and detection methods for smaller sizes of microplastics such as nanoplastics. In terms of current technology, the recovery rate is low, and the cost is high.

The major constraint of sedimentation technology in terms of microplastic removal is that the pollutants are not completely removed, they sink or get trapped in sludge, providing a high chance to revert back into the wastewater via leaching or run off.

In the future, it is necessary to propose purification and detection methods for microplastics with high recovery rate, low cost, time and labour saving, and simple operation.

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New challenges facing Europe's wastewater treatment plants present opportunities for improving sustainability
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The Filtration (Granular/Sand Filtration, Adsorption, RO, MF), the fastest growing category of Water and Wastewater Treatment.

TECHNOLOGY	DESCRIPTION	GOOD FOR	PROS	CONS	MARKET SHARE/ GROWTH
Membrane bioreactor	Combines a growth bioreactor with a membrane process	Removing biodegradable compounds, suspended solids, microbial contaminants	Higher quality treated wastewater Costs anticipated to decrease due to growth outlook	Higher associated consumable cost Membranes sensitive to abrasion	21% global – high anticipated growth
Nano filtration/Reverse osmosis membranes	Typically used for ‘polishing’ stages	Small particles	High efficiency Flexible, modular systems Can be automated Low operating temps.	Clogging potential High pressure required High associated capital costs	High anticipated growth
Ultrafiltration/ Microfiltration membranes	Liquid forced though a membrane	The middle range of membrane treatments – optimum set up dependant on incoming water and associated contaminants	High efficiency Modular systems Lower levels of pre-treatment required Relatively cost effective	Potential clogging High pressures Soluble materials won’t be removed Water odour not impacted	Medium to high due to membrane application across other (new) processes.
pH Neutralisation	Common requirement at industrial sites Can be stand alone or part of bigger system Sometimes installed as final stage but equally as first stage to enable treatment	Sites using highly acidic or highly alkaline raw materials	Common/proven efficacy Can be modular	High raw material input Increased salt concentration in effluent	An established tech, uptake already high and utilisation likely to continue
Wastewater Balancing	Commonly involves the installation of an equalisation/balancing tank either in-line or as a side stream May be effective alone to comply with discharge limits		Tried and tested	Large footprint No contaminant removal efficiencies	Steady growth outlook – already common and expected to remain important
Anaerobic Digestion	Converts organic components into biogas which can be used to generate electricity or sold on	Applicable for wastewater with high COD/BOD	Government subsidies available for utilisation Low energy consumption	Tend to be highly sensitive to toxicity	Growth outlook

		Popular in food and drink sector	Gas by-product Low sludge levels Can be a financial asset – payback on investment	Potential for production of dangerous gases High initial investment Start-up is slow	
Chemical clarification	Step 1 – dose of chemicals to take particles out of suspension Step 2 – removal by either sedimentation or flotation	Can take a number of forms in a number of systems	Installation is typically relatively simple Removal efficacy tailored Material recovery possible	Potential odour Clogging/build-up of sludge May not be effective for some materials	Continued importance and wide use are expected Membranes could come to replace sedimentation/flotation
Activated sludge	Air is inserted into sludge via microorganisms causing the sludge to settle and clarified wastewater to be discharged	Widespread use	Can cope with large volumes High energy efficiency Proven technology Cost effective	Large footprint required Large volumes = excess sludge Biological processes can be inhibited Large footprint Odour	Growth potential is linked to membranes and anticipated to be relatively low. Global market share of 10.6% is expected to decrease
Wastewater pre-treatment	Commonly includes the removal of insoluble contaminants prior to further treatment	Depends on nature of wastewater	Proven Simple Offers protection	Little treatment for soluble substances Additional treatment typically required	Steady growth. Use will be maintained.
Chemical oxidisation	Utilises chemical-oxidising agents to convert non-bio contaminants into less hazardous compounds or compounds that are more easily degradable/biodegradable	Typically preferred over other viable bio treatments when waste streams are small Good for chemical or heavy engineering sectors	Inorganic substances Large fluctuations in content are OK Smaller system footprint Can be combined	High energy demand High associated cost Can form other unwanted chemicals	Likely to remain steady
ION exchange	Ions considered to be undesirable are replaced	Offers potential to recover materials so is particularly applicable to metals finishing	Water recovery is possible	Requires prefiltration Bacteria can form Sludge/brine disposal	Growth rate is medium to high as better understanding develops