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UNLOCKING THE POTENTIAL OF WASTEWATER

Using wastewater as a resource while protecting people and ecosystems

INSIDE THIS WHITE PAPER

Wastewater treatment plants as energy recovery facilities
Moving towards an energy neutral water cycle

Considering wastewater as a resource
Reaping the benefits of resource recovery from wastewater

Centralised vs decentralised solutions
Ensuring the most cost-efficient design of wastewater infrastructure

A successful approach to industrial wastewater
Benefits of treating industrial wastewater at the source

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Using wastewater as a resource while protecting people and ecosystems
Version 2.0
Printed in September 2016

Front page photo
Cover photo showing Egå WWTP
Photo: Kontraframe/State of Green

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This white paper is based on the original work from previous versions 1.0 and 1.1 of the white paper "In control of wastewater to protect people and ecosystems" with Pia Klee, Danish Water Forum as editor in chief.

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EXECUTIVE SUMMARY

On a global scale, less than half of all wastewater is collected and less than one fifth is treated. This has led to severe environmental degradation of many inland and sea waters around the world. Increasing water scarcity and population growth underline the importance of treating and understanding the value of wastewater.

Energy producing wastewater treatment plants
Approximately 2% of the world's total energy consumption is used for collecting and treating wastewater. In Denmark, 2-3% of the country's total energy use relates to wastewater. As a result, most Danish wastewater treatment plants have invested in an assessment of different ways to reduce their energy consumption and are increasingly focusing on energy production. As a next step, some water utilities are also looking into recovering the heat from the wastewater before it is discharged with the additional benefit of reducing the temperature impact on the receiving waters.

Using wastewater as a resource
Considering wastewater as a resource is a relatively new perspective. However, today it is widely recognised that the organic content in the wastewater can be a resource for energy production and phosphorus can be used for fertiliser production with several advantages compared to the application of sewage sludge on agricultural land. Finally, the water itself can be cleaned to such high standards that it can be reused in a number of ways – e.g. for flushing toilets, laundry machines or irrigation for crops.

Centralised vs decentralised solutions
Ensuring the most cost-efficient design of an area's wastewater infrastructure is a great challenge. In areas with dense population, the optimal structure tends to be centralised treatment plants whereas in rural areas, which are not connected to the central sewerage system, decentralised solutions are often more attractive.

Treating industrial wastewater
Municipal wastewater treatment plants are generally designed for domestic wastewater and not necessarily equipped to handle industrial wastewater which often contains hazardous substances that may cause problems for biological processes and sludge disposal. Pre-treatment of industrial wastewater at the source can therefore have several advantages. Specifically, treatment can be tailored to the specific industrial pollutants which typically occur in high concentrations in relatively small volumes of wastewater and therefore requires relatively low investment and operational costs.

Find inspiration for your own wastewater projects
This white paper features lessons learned from different Danish stakeholders within wastewater treatment. It is meant to serve as a tool for inspiration for reaping the benefits of using wastewater as a resource.

We hope you will be inspired.

"We need efficient treatment of our wastewater to protect our health and natural environment. The good news is that with the right technology, wastewater can become a valuable resource. For instance, sludge from treated wastewater can be made into a useful source of energy."

Esben Lunde Larsen, Minister for the Environment and Food, Denmark

INDEX

1. Wastewater as a source of clean energy 6
Heading for energy producing wastewater treatment plants and an energy neutral water cycle

2. Resource recovery from wastewater 10
Wastewater treatment plants as resource recovery facilities

3. Effluent requirements as a driver for innovation 13
Treating wastewater to the highest standard to protect people and ecosystems

4. Centralised wastewater treatment 16
Ensuring effective and cost-efficient treatment through centralisation

5. Decentralised wastewater treatment solutions 18
Protecting the environment while keeping water resources in the area

6. Industrial wastewater treatment 20
Treatment at the source is often more efficient for industrial wastewater

7. Denmark knows water 23
If your goal is smart and efficient water solutions, Denmark is ready as your partner

1. WASTEWATER AS A SOURCE OF CLEAN ENERGY

Heading for energy producing wastewater treatment plants and an energy neutral water cycle

Reducing the costs for collection and treatment of wastewater is an important issue for water utilities around the world. In order to achieve this, focus must be on cost efficiency, improvement of the wastewater treatment plants' energy self-sufficiency and possible sale of surplus energy to the grid.

Reduction of energy consumption
On a global level, it is estimated that about 2% of the world's total energy consumption is used for collecting and treating wastewater. In Denmark, 2-3% of the country's total energy use relates to wastewater, and there is a great potential for energy savings and energy recovery in wastewater treatment.

As a result, most wastewater treatment plants in Denmark have invested in an assessment of different ways to reduce their energy consumption. These include implementation of online monitoring and energy management systems, replacement of surface aeration by more energy efficient bottom aerators and different operational approaches.

New focus towards energy self-sufficiency
In the recent years, Danish water utilities have moved beyond simply focusing on reducing energy consumption, to also focusing on energy production. The first goal is typically to become energy neutral, and the second goal is being able to sell excess electricity and heat to the local electricity and heating companies.

Some of the largest water utilities are already well on their way. In Denmark's second largest city, Aarhus, the Marselisborg WWTP produced 30% more electricity than the amount consumed by the plant itself in 2015. At the same time the treatment plant produced 80% more heat than it consumed, resulting in a total net energy production of just above 150%. In Odense, Denmark's third largest city, the Ejby Mølle WWTP achieved similar levels of total net energy production. As a next step, the water utilities in both cities are now looking into recovering the heat from the wastewater before it is discharged with the additional benefit of reducing the temperature impact on the receiving waters.

"Energy recovery is now a strategic goal for all major utilities and becoming an energy neutral water utility is within reach. After several years of energy optimisation, we are now able to produce 50% more energy than we use on our most efficient wastewater treatment plants."

Lars Schrøder
CEO, Aarhus Water

Solutions depend on plant design and context
More and more wastewater treatment plants in Denmark are upgraded with anaerobic digestion of sludge and/or co-digestion with organic waste products and they utilise the produced biogas to generate electricity and heat. The optimal solutions depend on the individual plant design and the possibilities for either internal use or external sale of the produced electricity or heat. The tipping point for which the implementation of anaerobic digestion is financially viable depends on the development of new technologies and changes in the price structure for purchase and sale of electricity and heat. In Copenhagen, a new technology is currently under implementation which allows for upgrading biogas to a quality which is similar to natural gas or vehicle fuel.

Heading for an energy neutral water cycle
By introducing new technologies to reduce energy consumption and improve energy production, it is the goal that the utility companies can provide an energy neutral water cycle. In this scenario the energy production from the utility's treatment plants is able to cover the energy consumption related to its groundwater extraction, water treatment, water- and wastewater transport as well as wastewater treatment. In 2015, Aarhus Water demonstrated a 90% net energy production for the water cycle in Marselisborg catchment area (Aarhus city centre).

Benchmarking and innovation lead to lower costs
The innovation of new wastewater treatment optimisation and cost-efficient solutions for both the construction and operation of infrastructure is largely driving by the fact that Danish water utilities are subjected to mandatory benchmarking on operational parameters and cost efficiency across the water sector. Innovation projects are often based on collaboration across governmental bodies, water utilities, consulting companies, technology suppliers, universities and research institutions.

Achieving 153% energy self-sufficiency at WWTP, Aarhus, Denmark

Over the past five years, the water utility Aarhus Water has put great focus on energy savings and energy production. At its Marselisborg WWTP, the utility has implemented energy-saving technologies such as an advanced SCADA control system, a new turbo compressor, sludge liquor treatment based on the anammox process, as well as optimised the fine bubble areation system. This has resulted in a reduction in power consumption of approximately 1 GWh/year which corresponds to about 25% in total savings. During the same time period, the energy production has been improved through implementation of new energy efficient biogas engines (CHP), resulting in an increase in electricity production of approximately 1 GWh/year. Furthermore, a new heat exchanger has been installed with the aim of selling surplus heat to the district heating grid, which represents approx. 2 GWh/year. In 2015, Marselisborg WWTP had a total energy production of 9,628 MWh/year and an energy consumption of 6,311 MWh/year, equivalent to a net energy production of 153%. Most of the installed technologies have a payback time of less than 5 years.

(Courtesy: Aarhus Water)

Construction of two new thermophilic digesters, Copenhagen, Denmark
From 2013 to 2018, the wastewater utility BIOFOS will increase the digester capacity to a total of 30,000 m^3 at Denmark's largest municipal wastewater treatment plant Lynetten. During the project, BIOFOS will construct two new digesters with a capacity of 6,000 m^3 each. The aim of the project is to ensure a more flexible and optimised operation. Future scenario projections show that Lynetten will receive higher amounts of sludge and therefore requires more capacity to meet this increased demand. By increasing the capacity, Lynetten will be able to produce more biogas to be injected into the Copenhagen city-gas network and thereby reduce CO_2 emissions produced by traditional methods of gas production. BIOFOS is collaborating with the two Danish consulting companies, Rambøll and EnviDan, on design, preparation of tender packages and supervision during the construction phase. During the design phase, the project group has worked towards a project which focuses on key aspects such as operational cost, high quality, low maintenance and health and safety during both the construction phase and in the daily operation.

(Courtesy: Rambøll, EnviDan, BIOFOS)

Maximising the value of wastewater, Odense, Denmark
In many countries, water and wastewater services are seen as public goods paid for by the state. However, in Denmark and in other member states of the European Union the 'polluters-pay-principle' applies to both domestic and industrial users, which means that the cost of wastewater collection and treatment must be covered by the water tariffs. Wastewater collection and treatment costs are typically twice the size of the water abstraction and supply costs, which means that cost-efficient solutions are imperative to ensure affordable wastewater treatment for water users and polluters.

In the City of Odense in Denmark, the largest wastewater treatment plant – with a capacity of 385,000 person equivalents (PE) – has achieved a degree of electricity self-sufficiency of more than 110% through optimisation of the plant's existing infrastructure. Further optimisation opportunities have been identified in cooperation with a number of consulting companies, which will enhance nutrient reuse and maximise biogas extraction for additional heat and electricity production.

(Courtesy: VCS Denmark)

Becoming energy self-sufficient, Esbjerg, Denmark
In Esbjerg, the fifth largest city in Denmark and an important port city, one of the city's wastewater treatment plants was in recent years optimised and expanded to a hydraulic capacity of 64,000 m^3/hour and sludge-related capacities for 160,000 person equivalents (PE) resulting in substantial increase in energy consumption. However, by additional investment in sludge digestion tanks and by utilising the produced biogas to generate electricity the plant is now self-sufficient in energy.

(Courtesy: NIRAS)

2. RESOURCE RECOVERY FROM WASTEWATER

Wastewater treatment plants as resource recovery facilities

Traditionally, wastewater has been considered a liability. Meeting increasingly stricter standards for wastewater discharge also increases the costs of treatment. Utilising resources in the wastewater can prove an important step in the opposite direction.

Considering wastewater as a resource is a relatively new perspective, however today it is widely recognised that the organic content in the wastewater can be a resource for energy production, the nutrients - especially the phosphate – can be used for fertiliser production, and the water itself can be cleaned to such high standards that it can be reused in a number of ways – e.g. for flushing toilets or laundry machines.

Utilising organic content
As described in the previous chapter, organic material in wastewater can be separated and utilised for biogas. This has been standard procedure in larger wastewater treatment plants for a while, and new water treatment technologies and more efficient equipment for combined power and heat production have increased the potential. Organic content can be saved for energy use in biogas production if new carbon saving processes for nutrient removal are introduced. Denmark has vast experience in optimising the use of carbon, and is now also gaining know-how in nutrient recovery.

Phosphorus recovery from wastewater sludge
Phosphorus is a scarce resource with great value for the agricultural sector. Phosphorus is accumulated in the wastewater sludge and in internal side streams and if treated properly, it is possible to change this into a controlled harvesting of a pure fertiliser. The recovery of phosphate for fertiliser enables a multitude of possibilities for sludge handling, not wasting the valuable phosphorus to end up in low quality form as ashes or mixed with heavy metals and micro pollutants from wastewater.

The phosphorus product struvite has been approved in Denmark as a fertiliser product. A full-scale development plant in Aarhus currently forms the background to increase the current P-recycling from approximately 25% to 50% and a similar plant is planned to be built at two other WWTPs in the Aarhus area. Once these are completed, the total phosphorus recovery throughout the catchment area is expected to be increased to approximately 165 tonnes P/year or approx. 3.6 tonnes of struvite fertiliser per day.

Benefits of using struvite fertiliser compared to sewage sludge
The solution of recovery of struvite as a pure mineral phosphorus fertiliser offers several advantages in comparison to the application of sewage sludge on agricultural land:

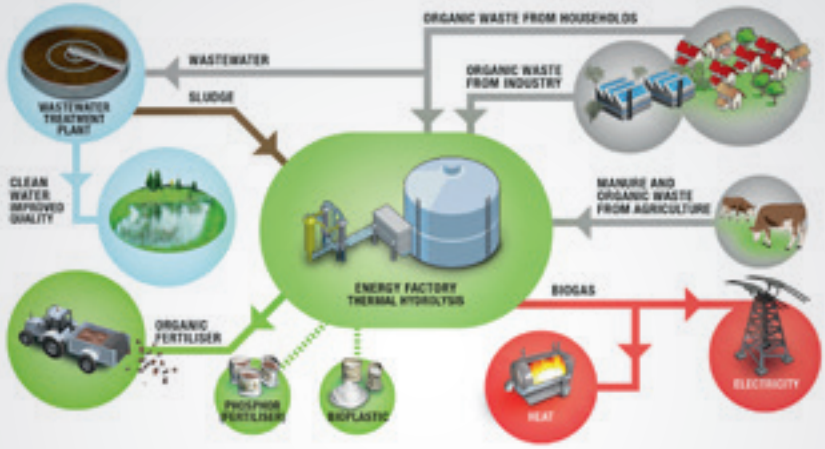
- Environmental benefits: Struvite is significantly cleaner than the sewage sludge in terms of heavy metals. The content of the typical problematic metals such as lead, cadmium, nickel, chromium copper and zinc is a factor of 20-100 times lower in relation to the content of phosphorus.
- Reduced risks of groundwater contamination: Phosphorus from wastewater can be utilised for agriculture without risking a contamination of soil and groundwater with the accumulation of heavy metals and other harmful substances to the environment, which makes it possible to carry out subsequent groundwater exploitation in the same area.
- Greater flexibility in terms of usage and storage: Struvite is much more flexible as a fertiliser as the material is concentrated, comes in a dry form and is possible to store for longer periods of time.
- Economic benefits: Struvite can be sold at a high price (up to EUR 335 per tonne)
- Ready-to-use as fertiliser: There is no need for further processing as the material is ready to use and can be mixed with other mineral fertilisers if there is a need for changing the level of potassium or nitrogen.
- Better suited for fertiliser use: Sludge from wastewater treatment plants, which has recovered phosphorus, have a lower content of phosphorus relative to nitrogen. This fact makes it better suited for fertiliser use. If the P:N-relation is too high, ammonia will have to be added in order to compensate for this.
- Low solubility: Struvite has a low solubility, making it suitable for depot fertiliser where the phosphorus content is released slowly in line with the needs of the plants. This is an advantage for fertiliser spreading without danger of dissolution into groundwater or surface water.
- Lower cost: Sludge from P-recovering plants, which is low on phosphorus, can be used as a bio-fuel without it resulting in a loss of phosphorus to ashes. The cost of regaining phosphorus from ash is 5 to 10 times higher than extraction as struvite from wastewater.

Struvite based P-recovery is the state-of-the-art for phosphorus recovery from wastewater. The technology is still under development and Danish wastewater utilities and companies are working on developing even more efficient process solutions.

Phosphorus recovery from wastewater, Herning and Aarhus, Denmark

In 2015, the water utility Herning Water Ltd. opened the largest P-recovery plant in Denmark, which recovers phosphorus from a concentrated side stream in the wastewater treatment plant. For several years, the WWTP suffered from struvite scale buildup in its sludge and wastewater pipes, causing problems for the dewatering process of sludge and biogas production. In addition to solving the problem, Herning Water wanted to exploit the potential of recycling the struvite into agricultural fertiliser. A solution based on controlled precipitation of struvite was therefore designed, and a full-scale recovery plant of the phosphorus compound struvite was built based on previous test results from Aarhus Water at its plant Aaby WWTP. At both plants, the struvite is precipitated as a 'ready-to-use fertiliser' and sold to a fertiliser company. An official approval of the product as commercial fertiliser has been obtained for the struvite produced at both the Herning and Aarhus plants under the name PhosphorCare™. The operational savings at the treatment plants and the expected revenue from sale of struvite is expected to result in a payback time of 7 years.

(Courtesy: Herning Water, Aarhus Water, Stjernholm, Grundfos, Norconsult, Suez and SEGES)



Resource recovery for the future, Billund, Denmark

Billund BioRefinery (BBR) is a water reclamation plant with integrated waste and wastewater treatment. BBR is producing clean water, energy for the local public heat and power grids, as well as organic fertiliser for the surrounding agricultural area. The wastewater catchment areas consist of combined and separate sewer systems, and the waste is made up of sorted organic waste from households and local industries. The WWTP-line is optimised with biological processes and advanced online control to minimise energy consumption. The processing for waste and sludge include shredding, separation, hygienisation, double co-digestion with an intervening thermal ExelysTM hydrolysis, dewatering the residues and removing ammonia by an annamox process. All processes are optimised by an advanced on-line control system, STARTM. Outlet nutrients (N, P and COD) have been reduced corresponding to a quarter of the level required by Danish legislation, and the plant produces a 200% energy surplus relative to the plant's own consumption. In total, the implementation of new technologies has an expected payback time of 9 years. The project has been financially supported by the Danish Eco-Innovation Programme and the Danish Water Sector Foundation (VTUF).

(Courtesy: Billund Vand A/S and Krüger A/S)

Wastewater for irrigation, Malta

Assisted by Danish wastewater experts, the Republic of Malta in the Mediterranean Sea has implemented a new wastewater infrastructure. It aims at reusing the effluent for irrigation and for industrial purposes. Today, treated wastewater is considered a useful resource in Malta and the irrigation systems ensure a significant increase in agricultural production during dry periods. The project included an upgrade of one wastewater treatment plant with a capacity of some 17,000 m^3/day and the construction of two new treatment plants to treat sewage from most towns and settlements on the country's two islands, Malta and Gozo. Each of these plants has a capacity of 45,000 person equivalences (PE) and about 50% of the effluent will be reused for irrigation and second class industrial water.

(Courtesy: COWI A/S)

3. EFFLUENT REQUIREMENTS AS A DRIVER FOR INNOVATION

Treating wastewater to the highest standard to protect people and ecosystems

In many countries, decades of uncontrolled wastewater discharge have resulted in severe environmental degradation of both inland and coastal waters. Stricter regulatory standards for both treatment efficiency and effluent quality are important tools for reversing this trend.

Collected but failing to meet standards

Worldwide, it is estimated that only one fifth of all wastewater generated from households and industry is adequately collected and treated. In Europe, approximately 70-80% of the generated wastewater is collected and subjected to secondary treatment. Still, only about 50-60% of wastewater discharges comply with the required quality standards due to inadequate capacity, operational performance or design of the infrastructure.

Regulation as a driver for development

The environment has been a key focus area in Denmark for a long period and some of the oldest wastewater treatment facilities were established more than 100 years ago and today, 95% of all wastewater is treated. Denmark was among the first to take major steps in minimising the adverse impact from the cities' wastewater discharge to the aquatic environment. The approach has been to use novel technologies and not just move the pollution away from the cities but treat the sewage water from the cities to an appropriate standard. This has enhanced the liveability in the Danish cities and made the surrounding areas more attractive.

Geographically, Denmark is challenged by the lack of major water bodies for discharge of pollutants from the cities. As a result, the environmental aspect has been important for a long time and has led to stringent regulation implemented since the 1980s, with the Danish standards for discharge to sensitive waters being further strengthened during the 1990s. Much of the legislation passed in Denmark has been taken up almost in its full content by the European Union and today, Denmark is subject to the EU Water Framework Directive. However, the Danish regulation is in many aspects more stringent than the general EU requirements. From the beginning, the legislative requirements and standards have been based on a specific evaluation of the recipient with the aim of ensuring vast improvements of the water quality in the surrounding water bodies.

"Denmark has, after decades of environmental challenges, created a strong regulatory framework to minimise the impacts from wastewater discharge. Finding solutions to our own challenges has made us one of the leading nations in wastewater treatment with high discharge standards, resulting in better water quality, more liveability in Danish cities and their surroundings."

Anders Bækgaard, CEO, VCS Denmark

Polluter pays principle

To complement the regulatory framework, a discharge tax has been implemented which means that the polluter (in this case the wastewater treatment facilities) has to pay a tax on every kilo of discharge of the three key parameters; organic matter (BOD), total phosphorous (P) and nitrogen (N). The result has been a very innovative and progressive optimisation strategy for the water sector in Denmark.

Operating beyond the discharge requirements

Today, Danish treatment plants of all sizes are generally operated well below the discharge requirement as this has proved to be both economically beneficial to the wastewater utility and to the environment. This shows that regulation can be a productive driver for innovation and excellency.

Back in late 1980s and early 1990s, the Danish approach led to the construction of biological WWTPs throughout the entire country – even for very small plants. Since then these plants have been constantly optimised and expanded. The result has been a substantially improved aquatic environment with many cases of water quality enabling salmon breading in rivers and creeks – even in very densely populated areas. The recreational value of the Danish water bodies has also been improved and in many cities it is now possible to swim in the inner city harbours.

Towards climate neutral wastewater treatment, Odense and Aarhus, Denmark

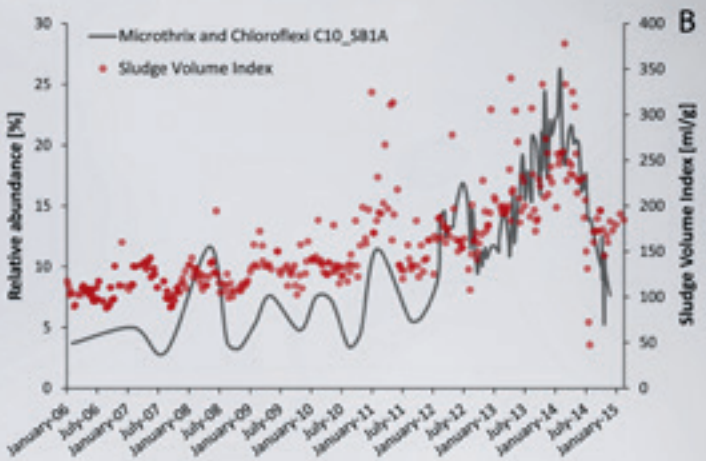
During the last decade, there has been a strong movement towards reducing the cost and climate impact from wastewater treatment, primarily through energy savings and increased energy production through anaerobic digestion. From a climate perspective, it is also relevant to focus on bringing down greenhouse gas emissions, including minimising N2O emissions from wastewater treatment as this typically contributes to 20-50% of the total climate impact from wastewater treatment. A unique N2O sensor technology has therefore been installed at Ejby Mølle and Marselisborg WWTPs. The sensor can detect the N2O concentration online in the process and the emission of N2O can be calculated real-time through verified emission models. Furthermore, the online control strategies for reducing N2O have been developed and tested in control campaigns. As unbalanced energy savings and increased energy production can lead to an increased N2O emission, this can actually result in a net negative effect on the climate. This new technology enables wastewater treatment plants to move beyond energy neutrality to 'climate neutrality'. The solution has been implemented at several other Danish WWTPs.

(Courtesy: Unisense Environment, DHI, VCS Denmark, Aarhus Water with financial support from VTUF and the Danish Eco-Innovation Programme)

Tracing contaminants to the source with SorbiCell, Viborg, Denmark

A new, patented environmental sampling method, SorbiCell, efficiently monitors water quality and enables tracing of hazardous chemicals in wastewater to their source, including hydrocarbons, chlorinated solvents, pesticides and heavy metals. The challenge for the utility Viborg Energy was that toxic chemicals threatened biological processes in their wastewater treatment plant. Further, toxic chemicals were accumulated in sewage sludge, eliminating the option of recycling of the waste and increasing the cost of disposal. Conventional sampling methods use single spot samples at one point in time, or use expensive and power consuming sampling stations poorly suited for remote locations. The solution with SorbiCell allows for continuous monitoring in sewers and drainage systems for a period of 1-2 weeks, while average discharge concentrations are obtained in this period. This method helped Viborg Energy and numerous other water companies in Denmark to trace the source of e.g. metal or organic contamination and reduces their costs of sludge disposal.

(Courtesy: Sorbisense A/S)



Understanding microbial communities in engineered systems is essential for process optimisation, Aalborg and Aarhus, Denmark

Aalborg University has established the MIDAS database which provides information about function and distribution of the key organisms in activated sludge in Danish WWTPs. A survey of microbial community composition is conducted every year in 50 WWTPs using advanced DNA sequencing technology. The data is used for surveillance and optimisation of plant operations as changes in community composition are often reflected in plant performance. Aalborg West WWTP has experienced long-term problems with sludge settling due to overgrowth of filamentous bacteria. Using community composition data, problematic bacteria were identified to be Microthrix and previously unknown filament C10_SB1A belonging to phylum Chloroflexi. In addition, control measures were developed and are currently being implemented in the plant, which will also be tested in other plants at Aarhus Water. The fast and cheap 16SrRNA gene sequencing will, in the future, make it possible to perform 'online' analyses of microbial population where a list of all the important players in activated sludge will be provided in less than a day to be integrated into process control.

(Courtesy: Center for Microbial Communities - Aalborg University, Aalborg Kloak AS and Aarhus Water)

4. CENTRALISED WASTEWATER TREATMENT

Ensuring effective and cost-efficient treatment through centralisation

Stronger environmental legislation and increased public awareness of the importance of proper wastewater treatment have led to centralised and more efficient treatment in many regions. Other factors driving the centralisation of wastewater treatment include consolidation of the water sector with bigger water utilities and an increased demand for cost-efficient treatment and resource recovery.

Building a cost-efficient infrastructure

In some regions, sewerage networks and treatment facilities have reached a coverage of almost 100%. However, in many other regions there is still a massive need for further expansion of sewer networks and for construction of new or upgrading of existing treatment plants. Ensuring the most cost-efficient design of an area's wastewater infrastructure is a great challenge.

In areas with dense population, the optimal structure seems to be mainly large centralised treatment facilities as increased demands of energy self-sufficiency and resource recovery requires larger units. In rural or semi-rural areas, the most cost-efficient structure tends to be decentralised with smaller local treatment plants and low-technology solutions. This general model, however, is being challenged from many sides. Rapid urban growth, especially in developing countries, may require a cluster approach to maintain sewer networks of manageable size. Furthermore, water scarcity calls for increasing reuse of wastewater in local areas. New technologies, such as compact treatment units or different membrane technologies, are rapidly becoming competitive for households, buildings and industrial districts.

In Denmark and other countries, centralised wastewater treatment, where wastewater is pumped from minor towns and villages to the nearest bigger town, have become very common over the past 5-10 years. The main driver for the development is an increased demand for cost effective solutions with focus on reduced operational costs especially related to reduced labour and maintenance costs.

"Centralised treatment is currently more efficient and it is more feasible to apply solutions that recover energy, phosphorus and other valuable resources from wastewater. At smaller plants, this is too costly and too complex."

Ole Godsk Dalgaard, Project Director, Water and Environment, COWI A/S

Advanced treatment opportunities

In Denmark, the centralised treatment plants initially used simple biological treatment to decompose the organic components in the wastewater. Although the biological treatment was developed and optimised to provide almost complete breakdown of organic substances, the end products and other pollutants still caused severe environmental degradation to the receiving water bodies. This led to the development of new tertiary treatment technologies for removal of substances like nitrogen and phosphorus by biological or chemical methods.

The latest development includes very energy efficient wastewater treatment and more plants are in fact becoming net producers of both electricity and heat. Furthermore, some WWTPs have been designed for phosphorus recovery. At present, it is only feasible to apply solutions that recover energy, phosphorus and other valuable resources from wastewater at larger, centralised wastewater treatment plants. At smaller plants, these processes are too costly and too complex.

Structural analysis of wastewater infrastructure, Aarhus, Denmark

To develop the most cost-efficient wastewater infrastructure, Denmark's second largest city Aarhus conducted a thorough analysis of the current treatment system. Initially treatment took place at 17 small and large treatment plants. However, an analysis revealed that a more centralised structure where wastewater treatment is carried out at just two large treatment plants would be more economically and environmentally advantageous in the future. Implementation of the new structure is now gradually taking place and the initial focus is on phasing out smaller treatment plants where operational costs are relatively high and the possibilities for utilising the wastewater as a resource are not financially viable.

(Courtesy: Aarhus Water and COWI A/S)

Reducing energy costs for centralised wastewater treatment, St. Petersburg, Russia

Centralised treatment requires the wastewater to be transported over a certain distance. In many locations, this is associated with high costs for pumping systems. With five million people, St. Petersburg is the second largest city in Russia. One of its major wastewater treatment plants has an inflow of 1.5 million m^3/day of wastewater. The plant, established in the 1970s, had very high energy costs partly caused by overload of existing pumps when the flow exceeded their capacity of 3,500 m^3/hour. Even though the plant remained operational, the maintenance and energy costs were high. To solve this, renovation of the sludge return pumping station was carried out and four new Grundfos pumps were installed in 1998, followed by another eight pumps in 2000. All of these pumps are 65 kW heavy-duty sewage pumps with a free passage of 125x163 mm. The renovation of a sludge pumping station led to such a remarkable reduction in energy and maintenance costs that the technicians at the plant literally thought the electricity meters had broken down.

(Courtesy: Grundfos)

Construction of new centralised WWTP, Rezekne, Latvia

Deliberate internationalisation strategies of Danish wastewater companies have carried Danish expertise into the world, and today most activities of Danish contractors and engineering companies lie outside Denmark. An example of this is Rezekne, Latvia, where a new fully automated wastewater treatment plant was designed and constructed by the Danish contractor, Per Aarsleff. The aim of the project was to improve the water quality of the Baltic Sea as wastewater in this region is discharged to the river Daugava which ends up in the Baltic Sea. The contract included all civil, mechanical and electrical/SCADA works as well as commissioning, training and testing of all equipment. The treatment plant has a capacity of 52,300 PE and the operation is automatic and controlled by SCADA. As part of the project, a pre-treatment section with mechanical equipment and aerated sand trap was installed as well as tanks for biological treatment for N and P removal and SS tanks for settling of sludge and solids. Dewatering of sludge is carried out means of a centrifuge. The effluent is treated to a quality which complies with EU Directive 91/271/EEC.

(Courtesy: Per Aarsleff)

5. DECENTRALISED WASTEWATER TREATMENT SOLUTIONS

Protecting the environment while keeping water resources in the area

There are many economies of scale to be achieved from centralised treatment. However, in areas which are not connected to the central sewerage system, decentralised solutions are often more attractive. As water scarcity becomes an increasing problem, treating wastewater locally can contribute to keeping water resources in the area.

The term 'decentralised wastewater treatment' is often used to describe treatment of wastewater that is not discharged to a municipal treatment plant but takes place onsite and/or in cluster systems for treatment and disposal of wastewater from dwellings and businesses. Decentral wastewater treatment takes place at widely different scales, from clusters within a mega-city to scattered individual households in rural areas.

Strengthening treatment in rural areas

Decentralised treatment solutions are mainly applied in rural areas or other areas which are not connected to the municipal sewerage system, such as university campuses, industrial parks or resorts. Since 2004, the Danish wastewater treatment strategy has strengthened its focus on villages and scattered households in rural areas. The need to protect groundwater aquifers or surface waters, which are important drinking water sources and sensitive to nutrient pollution, has led to development of a range of new solutions for decentralised treatment. At the high-tech end of this range are prefabricated mini-treatment units for households or small villages. They are typically compact purification systems based on biological processes, mostly confined in tanks and reactors that are covered to prevent spreading of unpleasant odours. At the other end of the range are low-tech biological sand and gravel filters designed for discharge to surface water or for infiltration of treated wastewater into the soil.

Reusing water resources in the area

Planning for water supply and considering wastewater a resource rather than a problem may postpone costly investments and give greater flexibility when water shortages occur. Today, treating wastewater to a level of drinking water quality is possible with advanced oxidation processes (AOP) and different membrane technologies. However, treated wastewater is typically used for purposes in which a lower quality is sufficient such as street cleaning, watering of parks and irrigation for crops. In agriculture, low-technology or partial treatment, for instance in constructed wetlands or reed beds, may be adequate for at range of uses, including irrigation of cereals or tree crops that do not go from farm to fork.

Decentralised versus centralised treatment in cities

As ever-expanding cities around the globe have to serve more and more people, there is a risk that multiple sewer systems will grow to unmanageable sizes or require huge pumping costs. A number of existing wastewater treatment plants are already close to reaching their full capacity. The rapid urban growth makes decentral solutions attractive in order to maintain a manageable size of sewer networks, which takes into account the topography for gravity drainage and avoid escalating pumping costs. The cluster approach is for instance attractive in cities with large differences in service levels between the urban centre and surrounding shanty towns or satellite cities as a gradual upgrading of water supply.

Despite the benefits of decentralised solutions, it is also important to be aware that wastewater treatment plants located within cities can be difficult to manage due to risk of foul smell from treatment basins and heavy transport required for disposal of sludge. In addition, the increasing value of land often makes it financially attractive to relocate treatment plants outside the city. Nevertheless, if available space for a wastewater treatment plant becomes a limitation, decentralised plants are attractive solutions to sustain urban progress. Looking ahead, a myriad of solutions combining central and decentral concepts is thus expected, based on studies determining which combination of approaches is the optimal solution.

Decentralised solution for luxury hotel, Mombasa, Kenya
In East Africa, there is an increasing demand for high-quality decentralised wastewater treatment. Fresh water supply is scarce and reuse of the treated wastewater increases the available water resources. An example is the wastewater treatment systems installed at the luxury hotel English Point in Mombasa. The systems treat the wastewater to a quality of which the water safely can be reused for toilet flushing and watering of the hotel lawns. To maximise the use of the surface area available for hotel buildings the system was installed in the hotel basement. As a result, it was crucial that the system chosen delivered treatment that limited the noise and odour to a minimum. A similar system was installed in the high-end hotel Ramada Beach Resort in Tanzania.
(Courtesy: BioKube)

City hall treatment solution, Nonthaburi Thailand
In 2008, the municipality of Nonthaburi outside Bangkok installed their first own sewage treatment plant. The decentralised system treats the wastewater from the local town hall and discharges the treated wastewater to the neighbouring park, where it contributes to keeping a constant water level in a scenic lake. Since the treatment system is noise and odour free, the city hall placed their outdoor restaurant on top of the treatment plant – so far without any complaints from the guests. This demonstrates very well, the low level of odour and noise of the wastewater treatment process, as an open air public restaurant is placed on top of it.
(Courtesy: BioKube)

6. INDUSTRIAL WASTEWATER TREATMENT

Treatment at the source is often more efficient for industrial wastewater

Municipal wastewater treatment plants are mainly designed to remove easily degradable organic substances and nutrients which are the major constituents of domestic wastewater. However, in many countries the sewer network and treatment plants often also receive wastewater from industrial production.

Industrial wastewater differs a lot
Wastewater from food processing companies is generally well suited for centralised treatment since it is often rich in easily degradable organic compounds, which provide nutrients for the growth of microorganisms and thereby enhance the biological processes. In fact, some treatment plants actively encourage discharge of waste from food processing industries because it enables them to increase the biogas production and thereby generate more energy, as well as improves the biological removal of nitrogen and phosphorous.

"Municipal wastewater treatment plants are designed for domestic wastewater and not necessarily for industrial wastewater, which not only pollutes but may even cause problems for biological processes and sludge disposal. Treatment of industrial wastewater at the source can have several advantages."

Per Elberg Jørgensen,
Urban and Industry Water
Treatment Specialist, DHI

Wastewater from manufacturing industry, on the other hand, has a much more complex composition and often includes substances that do not respond to biological treatment or which may hamper the growth of microorganisms and therefore interferes with the biological treatment processes or makes the sludge unsuitable for use in agricultural fertilisers. In addition, some toxic compounds may jeopardise the occupational health and safety of the utility's staff while corrosive compounds may damage the sewers and pumping equipment. In these cases, it may be advantageous or even mandatory to pre-treat the industrial wastewater at the source before discharging it to the municipal sewerage system or to have full treatment before discharging it directly to the water recipient.

More efficient to treat at the source
Treatment of industrial wastewater at the source has several advantages. First and foremost, treatment can be tailored to the specific industrial pollutants which typically occur in high concentrations in relatively small volumes of wastewater and therefore requires relatively low investment and operational costs. More importantly, it may be possible to recycle or reuse wastewater internally in the production after partial treatment or to recover and reuse raw materials or chemicals. Prime examples are the recycling of dyes used in textile production or metals used in metal plating, where up to 90% of the used water, dyes and metals may be recovered, thereby reducing the discharge of wastewater accordingly. In many countries where wastewater discharge fees are graduated according to pollution load, investment in decentralised wastewater treatment may have a very short payback time.

Methods for decentralised treatment
Industrial pollutants, which require specialised treatment processes, include non-degradable or slowly degradable organic compounds, fat, grease, oil, heavy metals and toxic organic compounds such as pesticides and pharmaceuticals. A number of specialised processes for removal of industrial pollutants can be applied at the source, including neutralisation, heavy metal precipitation, membrane filtration, activated carbon filtration, chemical oxidation, ultra-violet disinfection, evaporation, crystallisation and more.

Hospital wastewater and water reuse
In recent years, special attention has been paid to the discharge of hospital wastewater to the public sewer network. This type of wastewater contains a complex mixture of medicine residues and other substances that are hazardous to both human health and the environment. Nevertheless, hospital discharge to the public sewer network is seldom regulated. In a number of European countries, including Denmark, this situation is changing so pre-treatment or full treatment of hospital wastewater at the source will be required in near future. Removal of the critical pollutants from hospital wastewater will usually require extensive and advanced treatment methods resulting in high-quality effluent. This makes it possible to reuse the treated water which again can reduce the hydraulic load on the sewerage network and treatment plants.

Treating hospital wastewater, Herlev, Denmark
Hospital wastewater is a complex mixture of disease bearing pathogens, medicine residues and other hazardous substances which presents a risk to utility staff, public health and the environment. Technology suppliers have collaborated with one of Denmark's biggest hospitals, Herlev Hospital, to implement a full scale innovative wastewater treatment solution. The full-scale plant has been in operation since May 2014. The plant is based on an innovative combination of the technologies: Membrane bio reactor (MBR), ozonation, granulated activated carbon (GAC) and UV treatment. Hazardous pharmaceuticals, estrogenic activity and pathogens are efficiently removed, resulting in an effluent which can be discharged directly to the local stream or reused as cooling water at the hospital. The cost evaluation shows total operation and maintenance cost of EUR 1.45 per m^3 and a simple payback time of 8 years based on sewer tax savings.

(Courtesy: DHI and Grundfos)

Reuse of laundry wastewater through Forward Osmosis, Singapore

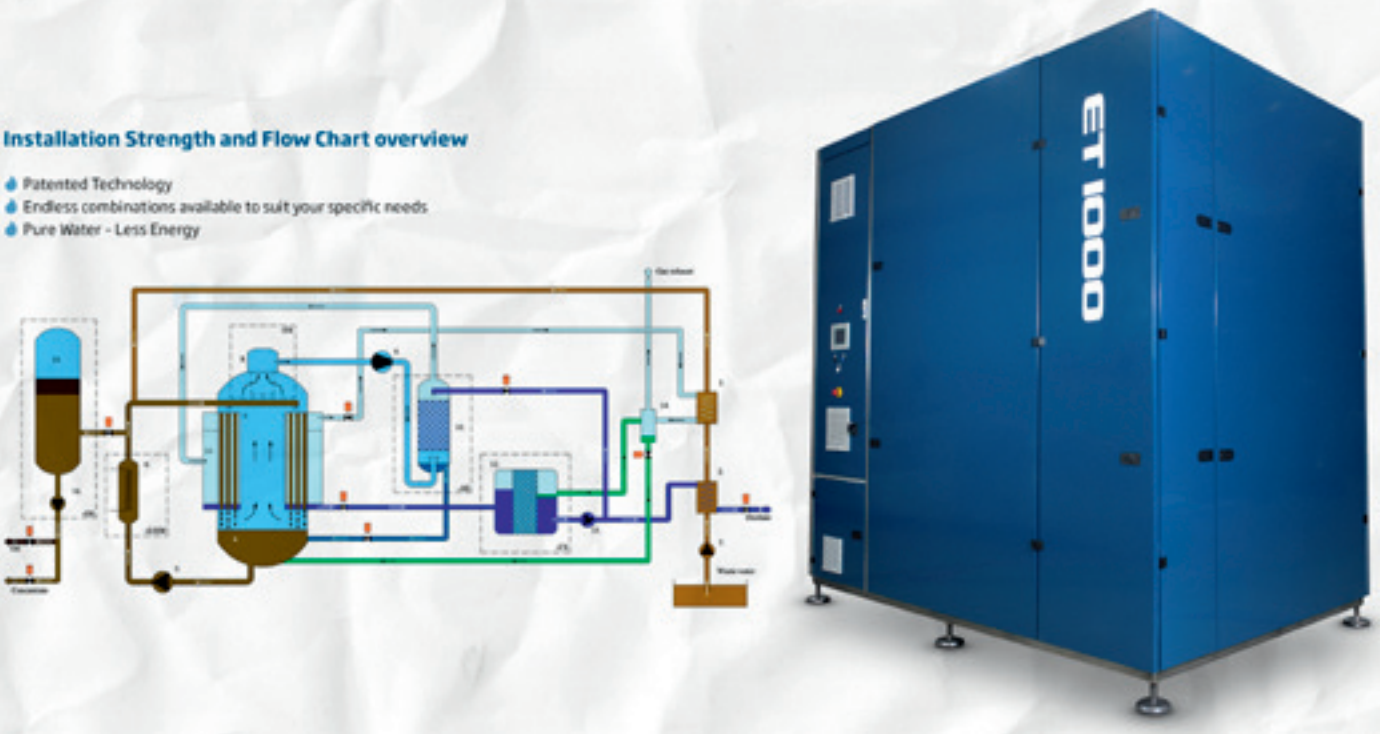
The company Orchid Laundry wanted to test bed the use of the Aquaporin Inside™ Technology for dewatering wastewater from a pre-wash step of a petroleum industry's uniform/coverall washing process and simultaneously reduce the company's need for freshwater in other washing processes. Aquaporin Asia designed and tested a lab scale Forward Osmosis process using concentrated laundry detergents as a draw solution to reduce wastewater, while diluting detergents for use in the laundry process. No high-pressure pumps or equipment were needed in such a system, reducing both operating expenses and capital expenditures. A range of detergents were tested as draw solutions for optimised water flux, and tests were run to determine the osmotic driving force and water flux capability, as well as identifying potential fouling issues in the system. The project showed the potential for Aquaporin forward osmosis membranes to be used in a process to cost-efficiently reduce wastewater volumes significantly, while enabling direct reuse of the clean water produced. The project was supported by a research grant from the Singapore National Research Foundation.

(Courtesy: Aquaporin, DHI, NEWRI and Singapore Membrane Technology Centre at Nanyang Technological University)

Reuse of 95% of industrial wastewater from metal machining company, Horsens, Denmark

The metal machining company, AAOsteel, specialises in deep draw, stamping and cold forming of steel. The company used to dispose more than 1,200 m³/year of process water from their alkaline automatic rinsing line. The annual costs for disposal of process water to an outside company was constantly increasing, surpassing EUR 100,000. In addition, the company faced high expenses for soft water. To solve this challenge, an Envotherm ET350 plant with E•MVR Technology was installed to process the wastewater in a way that reduces the need for disposal to less than 5%. The remaining 95% of distilled water is of such high quality that it can be recycled directly into the company's production process. Oil content has been reduced to less than 10 ppm and conductivity to less than 40 µS/cm. The investment was paid back in less than 2 years.

(Courtesy: Envotherm and AAO Steel A/S)



7. DENMARK KNOWS WATER

If your goal is smart and efficient water solutions, Denmark is ready as your partner

Water is an increasingly scarce resource in most parts of the world and we need to rethink how we use it. Denmark holds a long tradition of integrated water management and is committed to take responsibility and contribute to solving the major global water challenges.

A long tradition of sustainable water management
As awareness about sustainable water practices has increased, Denmark has spent the past decades building expertise within water efficiency and water management. Today, our tap water is as pure as the finest spring water, water loss in our pipelines has been reduced to less than 8%, wastewater is treated efficiently with a strong focus on energy and resource recovery and the water in our capital's harbour is clean enough to swim in.

The knowledge we have about water resources, security and efficiency is no coincidence. Successive governments have addressed our country's limited natural resources and the Danish water sector holds a long tradition of water utilities, technology providers, consulting companies and universities working jointly together to promote integrated solutions for efficient and sustainable water management.

A shared water vision for the future
The close collaboration between multiple stakeholders has put Denmark at the forefront of research, technology development, know-how and best-practice in integrated water management, urban drainage, water supply, wastewater treatment as well as governance and ensuring public awareness and support for water policies.

Denmark is prepared to take responsibility in solving the world's major water challenges and has ambitious plans for its water sector. A water vision for 2025 has been created through dialogue between the Danish water sector and the Ministry of Environment and Food with the intention of developing Denmark's position as a water hub for intelligent and efficient water solutions. The aim is to create solutions which will increase access to clean water and sanitation, promote efficient use of water resources, improve the competitiveness of water consuming industries, lead to a cleaner global environment and protect cities from floods and storm surges.

As a country, we see great opportunity for mutual benefit in the transfer of knowledge and we aim at turning global water challenges into opportunities for sustainable growth.

Explore water solutions online or experience them live in Denmark
We invite you to explore the newest Danish water solutions, policies and news online at www.stateofgreen.com/water. You can also visit Denmark on a State of Green Water Tour where you can experience innovative water solutions first-hand and take advantage of the lessons learned by leading Danish companies and utilities.

For more information about State of Green Water Tours, please visit:
www.stateofgren.com/tours

"Danish water companies, utilities and organisations have shown that by working together, it is possible to create more innovative solutions which lead to added value for both their customers and society as a whole. This is a great example of how Denmark contributes to finding solutions to the major water challenges the world faces."

Esben Lunde Larsen, Minister for the Environment and Food, Denmark

the international water association

Join us in Copenhagen for the IWA World Water Congress & Exhibition in 2020
Denmark is proud to host the IWA World Water Congress & Exhibition on 18-23 October 2020. Proposed congress topics are "Water for smart liveable cities", "Water - Energy - Food Nexus" and "Recruitment and career development in the water sector". The proposed topics address future water challenges all over the world. Before, during and after the conference, a united Danish water sector looks forward to demonstrating smart water technology, system solutions and discussing governance and policy in order to secure resilience in the future in towns, basins and cities around the world.
Read more at www.iwa2020copenhagen.dk

Learn more about Danish water solutions, find more cases from around the world and connect with Danish expertise at:

stateofgreen.com/water

State of Green is a non-profit, public-private partnership founded by:

Confederation of Danish Industry

DANISH ENERGY ASSOCIATION

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