# *CLEAN TECH Made in Denmark*

## *Case Stories and Company Profiles*

*"Transition towards a green economy is a must. We can no longer afford to continue on the unsustainable track, we are on. Most of the case stories presented in this book focus on novel methods to minimise the negative impacts of modern life. Denmark has never claimed to be a paragon of virtue. We have built much of our present clean tech know-how out of need. I hope that the spread of technologies may help others to choose a more sustainable track as their economy grows"*

*Ida Auken, Minister for the Environment*

*"Water and wastewater treatment, abatement of air pollution, environmental assessment and consultancy are core competencies of our clean tech companies. Much of their efforts are focused on developing cost-efficient and resource-efficient novel solutions to well-known environmental problems. Denmark is a small country. Our contributions inevitably will be modest compared to the scale of challenges. Nonetheless I hope you will find them significant, when reading the case stories in this book"*

*Pia Olsen Dyhr, Minister for Trade and Investment*

*Clear Air*

*Clean Water*

*Clear Advice*

Danish Environmental Technology Association

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CLEAN TECH Made in Denmark

*Danish Environmental Technology Association*

# *CLEAN TECH*

## *Made in Denmark*

*Clear Water*
*Clean Air*
*Clear Advice*

*- There she sat, glazing through the clear water*

Hans Christian Andersen
The Little Mermaid

# CLEAN TECH

## Made in Denmark

*Case Stories and Company Profiles*

*Forewords by*

*Ida Auken, Minister for the Environment*

*Pia Olsen Dyhr, Minister for Trade and Investment*

*Danish Environmental Technology Association*

Clean Tech Made in Denmark

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## Front cover

*The Little Mermaid left her usual place close to Copenhagen Harbour in 2010. That year, she was busy in Shanghai. Sitting in the middle of the Danish Pavillion at the world exhibition EXPO 2010, she acted as an ambassador for Danish clentech. Her pavillon was designed by Bjarke Ingels Group, BIG. The architecture made her a symbol of Danish achievements in water and wastewater management. One of the companies presented in this book, Skjølstrup and Grøndborg, designed her temporary aquatic environment, see page 109.*

*Now she is back at her usual location, and in fact, she is glanzing into amazingly clear water. Most metropolitan harbour waters are heavily polluted. Copenhagen Harbour, due to foresighted decisions and effective environmental technologies, has become so clean that the water is fit for bathing. Kids leaving school and people working and living in the centre of the city go for a swim in the Harbour Baths (page 62-63) .*

*"When other large cities begin to demand bathing water in their harbours, our technology will help them reach the goal" says Theis Gadegaard, Krüger. Case-stories pages 62-65.*

*Photo: Iwan Baan.*

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# Strong potentials for sustainable solutions

*CLEAN WATER, CLEAR SKIES and a healty environment are matters of growing concern. Control of lethal and devastating air pollution needs to be high on the agenda in all countries. Freshwater resources are increasingly scarce. Large parts of the populations, particularly in fast growing urban areas, are in dire need of effective sanitation and wastewater treatment. Assessment and mitigation of the environmental impacts of economic activities are indispensable to sustainable development. Climate change accentuates the need for sound management of water, wastewater and energy resources.*

*DANISH COMPANIES have something to offer in these fields. We are told that people raise their eyebrows when they hear about Danish achievements such as water savings and water resource management, monitoring and remote control, air- and water purification, biological wastewater treatment, flow control, filter technologies, membranes, catalysts, sensors, and a wide range of software tools...*

*Based on high environmental standards, science and engineering, some of the companies presented in this book have developed strong positions in air pollution control and the water sector years ago. New companies have emerged more recently. Some of them present high-tech and bio-tech solutions to long known problems. Others are based on entrepreneurship and innovative spirit.*

*Many of our member companies act as consultants and specialised advisors. Based on multi-disciplinary competencies, experience and expertise, often with a holistic approach, they assist customers assess the possibilities, obtain effective and durable solutions, and make the most of their means.*

*THE NEEDS TO IMPLEMENT environmental technologies are plentiful. The financial means may not be so. Fortunately, a common denominator of the solutions presented by our member companies seems to be optimisation and cost efficiency. Protecting the health and improving the environment need not be unaffordable. On the contrary, efficiency gains and savings made on energy, water and other resources largely outweigh the additional expenses.*

*Generally speaking, the return on investment in novel environmental technologies is surprisingly fast. Strict environmental standards should not be seen as a luxury, but rather as means to protect the health of people and care for their environment while at the same time avoiding waste and loss of resources, spurring innovation and consolidating the economy.*

*The list of cases does in no way pretend to be exhausive. Hopefully they will serve merely as eye openers.*

*Jørn Jespersen*
*Director*
*Danish Environmental Technology Association*

## ABOUT US

The objective of the Danish Environmental Technology Association is to put advanced solutions to global environmental problems high on the political agenda. We want Denmark to be, and to remain, a front-runner in the development of novel, effective technologies in this field. We work to raise awareness of environmental challenges and technological potentials among policymakers, authorities, knowledge institutions, and the public. Responsible policies and stringent regulations, along with support for high quality research and development, will spur the innovation. High domestic standards secure a healthy environment, clean water, clean air and a rich, diverse nature for ourselves and our descendants. In turn it makes us able to contribute significantly to global sustainability through international cooperation and trade.



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# We have to do more with less

*NOT LONG AGO green business and green transition were not considered real politics but garnish. This approach has changed with the global, financial downturn experienced in recent years as more and more businesses as well as politicians are realising that we can no longer afford to continue on the unsustainable track we are on.*

*Most economic activities make use of or put pressure on natural resources such as water, clean air, minerals, materials, biodiversity or energy.*

*Thus transition towards a green economy is a must.*

*AN IMPORTANT pillar in a green economy is economising with resources. Wasteful production must be avoided, we must adjust consumption to real needs, abate pollution, protect health and the environment, and maximise reuse, recycling, and recovery of valuables from waste streams.*

*In short, we have to do more with less.*

*I AM PROUD to say that Denmark has something to offer for this purpose. Most of the case stories presented in this book focus on novel methods to minimise the negative impacts of modern life.*

*Denmark has never claimed to be a paragon of virtue. We have built much of our present clean tech know-how out of need. I hope that the spread of technologies may help others to choose a more sustainable track as their economy grows.*

*In Denmark's case the need for environmental regulation has shown to be a driver for growth. A combination of ambitious targets and intelligent regulation spurs innovation and create new opportunities. Export of clean technologies now accounts for more than 10 percent of the total Danish export. A number expected to increase in the years to come.*

*TO JUMP into a sustainable future we must have the courage to set the bar high. In my ministry and the entire government we strive to support research and development that pave the way for novel, effective and cost efficient green technologies, for the benefit of citizens as well as businesses.*

*We also support the necessary cooperation between public authorities, utilities, organisations, businesses and research institutions, both here and abroad.*

*We hope that you will find the selection of Danish clean tech solutions presented here interesting and attractive.*

*Ida Auken*
*Minister for the Environment*



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# Green trade and mutual cooperation

*SEWER PROBLEMS may not be the obvious choice of subject for a dinner conversation. Nonetheless the supply of water and the management of wastewater are matters of urgent concern to the majority of mankind.*

*Air pollution is a matter of equally serious concern – particularly to the fast increasing part of the world's population that are living in urban areas.*

*By 2030 it is expected that half of the world's population will live in regions with water shortage while on the other side, due to climate change, flooding and sewer overflow is expected to become more frequent and devastating.*

*Water pollution and poor wastewater treatment degrades the water resources and destroys coastal and freshwater life in many areas.*

*Air pollution is a serious health hazard to millions of people, shortening life expectancy with several years in many major cities. These global challenges have to be met by very extensive mitigation measures without compromising progress in other areas such as food supply, housing, health, energy, education, communication, transportation and basic consumption.*

*FORTUNATELY Denmark is in a position to contribute to the solution. Water and wastewater treatment, abatement of air pollution, environmental assessment and consultancy are core competencies of our clean tech companies. Much of their efforts are focused on developing cost-efficient and resource-efficient novel solutions to well-known environmental problems and the demand for climate adaptation. Denmark is a small country. Our contributions inevitably will be modest compared to the scale of challenges. Nonetheless I hope you will find them significant, when reading the case stories in this book.*

*FORGING A STRONG LINK between the global demand for green solutions and the core competencies of Danish companies is a preoccupation of mine. It is evident, that green trade and mutual cooperation need to be scaled up massively to meet global demand.*

*I am well aware that the emerging economies are now taking the lead, compared to older economies like ours. I also know that excellent scientists, brilliant engineers and ingenious developers are found all over the world.*

*In my opinion, nevertheless, this book demonstrates that in some areas we have cutting edge expertise and offer clean tech solutions that are second to none.*

*My government finds it utmost important to maintain, vitalise and further develop these competencies which build on many years of experience combined with innovative thinking.*

*THIS BOOK FOCUSES on privately owned companies. Many of their products however have been developed to meet demands from public utilities and with important input from public research institutions.*

*To enhance such synergies we strive to establish binding partnerships across sectors and borders between the public sector, research institutions and businesses.*

*In my ministry we would be more than happy to assist you in getting all the information and support you need to find the best and most relevant Danish partners for your venture, be it turnkey or tailor made installations, consultancy or service for your local implementation.*

*Pia Olsen Dyhr*
*Minister for Trade and Investment*



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*Cleaning the air*

# A DEMANDING TASK

*Topsøe's catalysts for the abatement of nitrogen oxides in flue gases from power plants are extremely efficient*

Four fifths of the air is nitrogen. Whenever something is burned, some of the nitrogen combines with oxygen to form nitrogen oxides, NOx. The emission of nitrogen oxides is a major global pollution problem, with substantial negative impacts on health and the environment.

Removal of nitrogen oxides from exhausts and smoke (flue gases), is a complicated task. Imagine for example a gas-fired power plant that uses up to 100,000 cubic meters of natural gas in an hour. The exhaust of flue gas at high temperature, high pressure and high speed is several hundred cubic meters per second.

### Dating at the surface of a catalyst

If gaseous ammonia is added to the stream of flue gas, it will combine with the nitrous oxides to form nitrogen and water vapour – two harmless substances that are already plentifully present in the air.

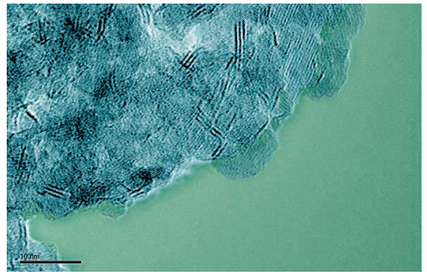
This happens at the surface of a catalyst. But how do we make sure that all the molecules of nitrogen monoxide and nitrogen dioxide actually get in touch with an ammonia molecule right at the surface of the catalyst?

We could make something like a huge sponge with an enormous amount of tiny holes covered internally with our catalyst. But then again: Wouldn't it require a lot of extra energy to push the flue gas through such a huge sponge?

### Topsøes solution

What we really need is a highly permeable structure with a very large inner surface covered with a very efficient catalyst. This is what Topsøe has achieved with the DNX®series of catalysts for removal of nitrous oxides. The catalyst (vanadium and tungsten) is finely dispersed at the surface of a ceramic fiber-reinforced titanium oxide carrier that looks like a stack of corrugated cardboard.

Left: DeNox catalysts for turbines



Right: Surface of the catalyst, nanophoto

## *The technology:* SELECTIVE CATALYTIC REDUCTION

A very effective way to reduce or remove NOx from flue gases is by the injection of gaseous ammonia, $NH_3$. The ammonia will react with nitrogen oxides to produce elemental nitrogen and water vapour. In the presence of a catalyst, the reaction occurs at temperatures in the range of 200°C – 500°C. This method is called Selective Catalytic Reduction, SCR.

The SCR DeNOx process is by far the predominant choice of technology. It has been applied to a variety of applications since the 1970s including flue gases from boilers, refinery off-gas combustion, gas and diesel engines, gas turbines and chemical process gas streams.

The SCR catalysts are most commonly vanadium-titanium based but zeolite-based catalysts exist for operation at high temperature, 500°C – 600°C, in e.g. gas turbine or diesel engine exhaust. To provide a large gas contact area with a minimum pressure loss, the catalysts are provided as elements which contain a large number of parallel channels.

Haldor Topsøe has developed and marketed a series of unique SCR catalysts based on a fiber-reinforced ceramic titanium dioxide substrate which is impregnated with the active metals. The highly porous walls ensure high NOx conversion and excellent resistance to sulfur and other contaminants in the exhaust gas. The catalysts are manufactured in different formulation and geometries to cater for different applications.

In a properly designed SCR system, NOx removal rates well in excess of 95 percent can be achieved. More than 800 SCR catalyst systems with catalyst from Haldor Topsøe are in operation in the USA, Europe and Asia.



HALDOR TOPSØE
CATALYSING YOUR BUSINESS

Haldor Topsøe is dedicated to catalysis, and the catalyst technologies developed by Topsøe is used by a wide range of industries all over the world

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Catalyst installation at powerplant

If you look closely at the surface in a microscope or even in an electron microscope, you will find that the inner surface is extremely wrinkled and porous, providing each unit with a large void which provides many sites where the catalytic reaction can take place.

These features make the DNX® catalyst series for gas turbines far more efficient than similar competing catalysts.

### Science-based innovation

This achievement is based on nano-science, materials research, chemistry, physics, and practical engineering.

"It is an excellent example of how we, at Topsøe, use our basic scientific research and knowledge to improve technologies", says Joakim Reimer Thøgersen, Vice President of Topsøe's Research & Development Division.

Topsøe retains 40 percent of the world market in this technology, and expects an increase of sales as a result of new natural gas discoveries, and particularly the exploitation of shale gas in the United States.

This catalyst is also effective in the removal of carbon monoxides, and volatile organic compounds (VOC's) from the flue gases.

### Abatement of air pollution from ships

Significant air pollution comes from ships. In principle, the International Maritime Organization, IMO has made decisions about strict standards for nitrogen oxide emissions. If the Emission Control Areas are implemented as expected, most new vessels built from 2015 and onwards will have to be equipped with systems for nitrogen oxides removal.

Topsøe is ready to supply shipbuilders with catalysts and technologies specially designed for ships.

"We have been preparing for this since 1980, and we have installed the system on Californian and Swedish vessels. In the 1990s, we were the only company to do so, and the market was not large. Now we are in the process of making agreements with ship engine manufacturers", says Joakim Reimer Thøgersen.

## Nitrogen oxides

Nitrogen oxides, NOx (NO and $NO_2$), are formed when fuel is combusted at high temperatures with excess air present. The emissions are harmful to health and the environment in many ways.

When exposed to sunlight, the NOx reacts to form ground-level ozone. Combined with other pollutants, they cause the health-threatening yellowish smog in urban and industrial areas. Nitrogen dioxide in itself can cause inflammation of the airways and lungs. NOx also contributes to acid rain, and the ensuing forest death and destruction of coastal and fresh-water life.

A large part of the nitrogen oxides come from fossil fuel energy production and energy use in manufacturing industries. The European Environment Agency has estimated the costs of damages to health and the environment resulting from nitrogen oxides pollution from power plants and industry to be € 15-39 billion per year.

»We cannot afford to ignore these issues« says Professor Jacqueline McGlade, EEA Executive Director.

European Environmental Agency: Revealing the costs of air pollution from industrial facilities in Europe, Technical report No 15/2011.

# TAMING THE FLOW

*FORCE Technology uses Computational Fluid Dynamics to guide the flue gas and improve the performance of catalysts to control air pollution*

Winds behave in a turbulent way. All air streams do. Inside the tubes and ducts, the flue gases at a power plant whirl and curl on their way from combustion to the smokestack.

Who cares?

FORCE Technology does. They analyse the flow of flue gases, using clusters of computers. The flow is made visible on screen and in transparent plastic models. It is a very complicated task, but it is an important part of the fight against air pollution.

### Demanding conditions

Devastating air pollution is a serious problem, particularly in China. During the current five-year plan, the Chinese government has called for reduced emission of nitrogen oxides. Many Chinese power plants currently install catalysts to meet these new requirements.

Catalysts can remove more than 90 percent of the hazardous nitrogen oxides. To obtain this effect, however, ammonia has to be mixed evenly into the flue gases, and the mixture of ammonia and nitrogen oxides must reach the entire surface of the catalyst in a uniform stream. The task of FORCE Technology is to make sure that these conditions can be met.

"Too little ammonia will prevent the cleaning from taking place. Too much ammonia will add just another source of pollution: Ammonia emissions. Furthermore, deposition of dust can spoil the entire process", explains Head of Department Kristian Lykkemark.

"Typically, the catalyst supplier issues a guarantee for 90 percent or 95 percent removal of nitrogen oxides – on the condition that the specified criteria regarding flow and ammonia distribution are fulfilled. Our job is to design the ducts to meet the criteria. We guarantee the flow, pressure, temperature and blending required."

### Guide vanes change the flow

"The flue gases must move at equal speeds across the section of the duct where the ammonia is injected. Subsequently the blend must be evenly spread", Kristian Lykkemark says.

The flow can be changed with curved wings known as guide vanes. The question is where precisely to place the vanes? How many? How big? Which angle? Which shape?

Many people's health may depend on the answers provided by FORCE Technology.

"We use clusters of computers with fluid dynamics software to calculate the temperature, pressure, speed, and flow of flue gases through the ducts. In the computer model, we can change the position of ammonia nozzles, alter the shape, and insert different guide vanes. In this way we are able to test and optimise the design before the vanes are actually manufactured and installed", tells Kristian Lykkemark.

### Models close to reality

Computational Fluid Dynamics (CFD) is applied in all areas where flow needs to be understood, such as weather forecasts and aerodynamics. FORCE Technology uses a commercial and internationally recognized CFD software as in-house development platform for adaptable models.

"We develop the models to make sure that what we get in the end is actually what we expected in the design phase", says Kristian Lykkemark. "The better you can model reality, the better the actual unit will perform in real life".

### Dust can change it all

In many ways the CFD flow-models are superior to traditional transparent Plexiglas models, as they produce a coherent total picture.

FORCE Technology, however, still builds scaling plastic models between 1:15 and 1:10 to investigate the deposition of dust, as scale models are currently the best method to investigate dust depositions.

Dust that settles in the ducts during changing boiler loads can change the flow. Deposits of dust can even compromise the function of the catalyst.

### Eager to improve

In China as well as in other emerging economies, the number of coal fired power plants has been rapidly growing for many years. The air pollution has worsened accordingly.

Now, catalysts are installed at all new Chinese power plants and retrofitted for many of the older ones.

"Our Chinese partners are eager to reach the level obtained by other industrialised countries. They are moving fast and they are very willing to listen, learn and implement the clean technologies as fast as possible. We can hardly keep pace", says Kristian Lykkemark.

FORCE Technology provides advanced technological services to many industries, assisting them improve their performance and meet environmental targets

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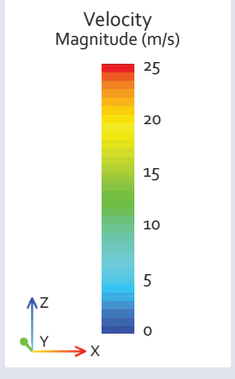
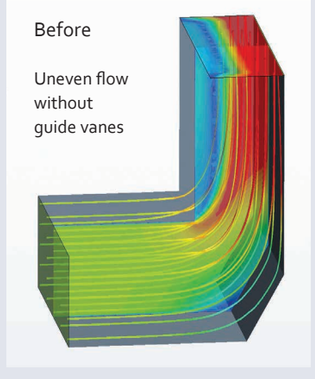
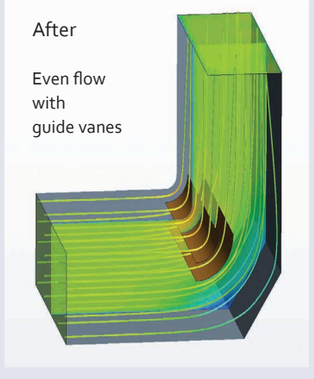
Scaling models are used to visualise the entire process and for deposit tests

## *The Technology:* COMPUTING THE WHIRLS OF FLUE GASES

Up until fifteen years ago, FORCE Technology had to rely only on scaled plastic models to examine the flow of gases in ducts. Today, Computational Fluid Dynamics does an even better job for the most part. Fluid dynamics is the scientific description of liquids and gases in motion. They move in a chaotic way, and the mathematical algorithms used to calculate them are demanding.




Computers, if they are big enough, can actually calculate the motions and visualise the flow quite accurately.

Commercial suppliers and Universities have developed the software, used by FORCE Technology, to compute the flow.

Computional Fluid Dynamics is a strong tool compared to spot metering (measurement in a single point) because the dynamics of the entire system is seen on the screen. Based on knowledge gained through theoretical understanding and many years of experience, FORCE Technology calibrates the models to come close to reality.

## *The Chemistry:* CATALYSIS

Ammonia is a compound of nitrogen and hydrogen. Injected in hot flue gases, it vaporises and combines with nitrogen oxides at the surface of a catalyst. The result is two harmless substances, water and free nitrogen. The efficiency of the process depends on the substances being present all over the surface of the catalyst in appropriate concentrations as well as adequate temperature and pressure.

*Cement Industry*

# PREVENTING AIR POLLUTION

*FLSmidth's gas suspension absorber removes pollutants from flue gases in a cost-efficient way*

Cement plants in many countries are looking for ways to reduce their pollution, as required by tightened emission regulations. FLSmidth serves the cement industry, along with other industries, with a range of technologies to remove the pollutants in a cost-efficient and reliable way.

"The world's cement industry is dominated by a number of large, transnational companies, and they have their own environmental guidelines. Usually they require their plants in all countries to meet identical standards, unless the country has stricter demands, and they prepare for even stricter emission requirements in the future", says Product Marketing Manager Mimi Sofie Stabell at the head office in Copenhagen. The emissions tolerated from each cement plant are quite small, compared to standards a generation ago.

## Norwegian SO2 abatement

HeidelbergCement owns two cement plants in Norway. They wanted to reduce emissions of $SO_2$ , sulfur dioxide, by 400 tonnes a year at their plant in Brevik., which is a minor town close to the capital Oslo. The reduction was required in order to comply with the protocols to the International Convention on Long-Range Transboundary Air Pollution known as the Gothenburg Protocol. The Brevik plant uses different raw materials. Only some of them causes the plant to exceed the limits for $SO_2$ emission. The plant therefore needed a flexible solution.

After reviewing potential technologies the plant decided to install FLSmidth's gas suspension absorber, the FLS-GSA™.

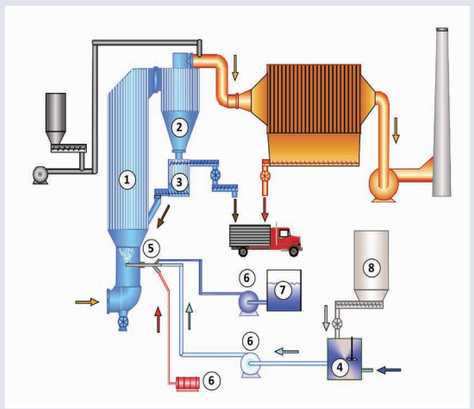
In order to keep dust emission at an acceptable low level the FLS-GSA at the Norcem Brevik plant is followed by a modern fabric filter from FLSmidth. This technology is capable of delivering emission below 2.5 mg/Nm3.

## High performance, low operation costs

This semi-dry scrubber system has exceeded its designed performance. Emissions of $SO_2$ are reduced by 97% and hydrochloric acid with 95%. The system has also been proven able to reduce emissions of mercury by more than 90%. At present there is no environmental requirement to remove mercury, but that may well happen in the future.

"These results demonstrate that the system is able to meet even the most stringent of present and expected future regulations. The performance is similar to, and in some cases even better than, what can be achieved in wet scrubber systems, which are more complex to operate and more expensive", says Karsten Poulsen, General Manager for Research & Development.

## *The Technology:* GAS SUSPENSION ABSORBER




FLSmidth's gas suspension absorber removes acid compounds of SO2, HCl, and HF from flue gases in a cost-efficient way. It also reduces mercury and other heavy metal emissions.

In the bottom of the reactor (1) the flue gas is blended with lime slurry (8 and 4) that is injected with pressurised air through a nozzle (5). Additional water can be injected to adjust the temperature (7).

A very high concentration of finely pulverized (fluidised) lime whirls around in the reactor. It makes intimate contact with the acid constituents in the flue gas and absorbs them. SO2 reacts with the lime to form calcium sulfite and calcium sulfate (gypsum). Hydrochloric acid forms calcium chloride, and hydrofluoric acid forms calcium fluoride.

In one or more cyclones (2) 99% of the entrained dust and absorbent is separated from the flue gas stream. The flue gas continues through a dust filter to the stack. The recovered absorbent is recycled (3). The entire system is automatically monitored and controlled to maintain optimal temperature as well as feed of lime, recycled media, and activated carbon.



FLSmidth's fabric filter technology installed at Holcim's Ste. Genevieve cement plant in USA

FLSmidth's Air Pollution Control team supplies technologies to reduce emissions from a wide range of industries

*Company Profile page 96*

## Low operational costs

Thanks to the FLS-GSA technology, the system is efficient while retaining low operation costs, he says. A high absorption rate is obtained with a low usage of lime. Maintenance costs are also low and reliability is high, due to sturdy, hardwearing components and few moving parts.

"Calculating the return on investment they realised that the additional expenses to install our solution instead of traditional injection of dry hydrated lime, would be earned back again within a relatively short period of time", Karsten Poulsen says.

## Identical technology in Thailand

Convinced by the performance and the cost-efficiency, Siam Cement Public Company Ltd. has ordered similar equipment for three cement lines at their Thungsong plant in Thailand.

"Our business is based on the fact that authorities in most countries gradually raise the environmental standards. This is also the case with Siam Cement", says Mimi Sofie Stabell. "We use the same technology and components in different countries, but each of our systems are tailor-made. At Siam Cement, it is designed to comply with new environmental legislation, decided by the Thai government".

FLSmidth is a leading supplier of equipment for the removal of pollutants from cement industries. Half of the world market for these technologies is in China. Together with a shareholder, FLSmidth has started a company to market and sell air pollution control products to the cement industry in China. This company combines local presence and relations with global technologies and resources.

The GSA-technology is applicable for the removal of $SO_2$ in many other industries. FLSmidth has recently received orders for similar systems at steelplants in China and USA, and a pulp & paper plant in South Africa.

FLS-GSA at Siam Cement plant in Thungsong, Thailand

# HOW TO STOP ACID RAIN

*Catalysts from Topsøe turn highly damaging air pollution into a widely used commercial product: sulphuric acid*

Thirty to forty years ago, acid rain was an urgent environment problem in the United States and Europe. Trees were dying in Central Europe and the eastern North America. Lakes and waterways were acidified. Historical buildings and monuments were damaged, and the health problems in the most polluted areas were alarming.

### Topsøe: Part of the solution

Sulphur dioxide from industries and power plants was a major cause of the acid rain and the air pollution.

Today, the problem is under control in Japan, North America and Europe. Since 1970, the emissions have been substantially reduced. Catalysts and technologies from Topsøe played an important role in this achievement.

In other parts of the world, the atmospheric pollution with $SO_2$ and acid rain are still serious problems.

### Topsøe's know-how

When the awareness of the problem grew, and the authorities realised that strict regulations were necessary, Topsøe's know-how and experience in the manufacturing of sulphuric acid was taken into use to combat air pollution. Sulphuric acid is a widely used chemical, particularly in the fertiliser industry. 230 million tonnes are produced each year, worldwide. In the industry, sulphur dioxide ($SO_2$) is oxidised to sulphur trioxide ($SO_3$) by means of a catalyst. Subsequently, different methods are used to produce sulphuric acid from sulphur trioxide and water: $SO_3 + H_2O \rightarrow H_2SO_4$.

### 99 percent recovered

Topsøe made its first catalyst for production of sulphuric acid in 1944, and is currently the world's leading supplier of catalysts in this area. In the 1980s, Topsøe further developed the catalysts and also developed a unique condenser which produces high grade concentrated sulphuric acid from waste streams of sulphurous gases.

More than 99 percent of the hazardous sulphur content is recovered and transformed into a product of commercial quality. The heat is recovered and dirty by-products are avoided, because the process works with wet gases. This technology is widely used to clean flue gases with high sulphur content, often created at oil refineries, in the petrochemical industry, the metallurgic industry, metal roasters, the steel industry (coking), coal gasification, the cellulose industry (viscose) and the power industry.

Since 1985, more than 120 plants have been contracted to use the special Topsøe Wet Sulphuric Acid (WSA) condenser, and more than 600 sulphuric acid plants use Topsøe's catalysts.

### The SNOX™ technology

The Wet Sulphuric Acid process can be combined with catalytic nitrogen oxide removal (see page 10) in Topsøe's SNOX™ process.

This technology is an advantageous option, particularly if there is need for power and sulphuric acid as well. Instead of producing each of them separately, the production can be combined and fuels with high content of sulphur, which are elsewhere phased out to avoid air pollution, can be used for this purpose.

Six SNOX™-plants have been contracted. Three of them are in operation. The fuels applied are coal, petroleum coke and oil residue, respectively.

### Science and engineering

Topsøe's ambition is to be second to none in catalysis and its implementation. The company strives to stay at the cutting edge, by means of fundamental long term research combined with practical application.

"We are unique in that we are both an engineering company and a company that develops and manufactures catalysts", says Joakim Reimer Thøgersen, Vice President of the Research & Development Division. »Our scientists have the scientific and technical competencies that enable us to figure out how the catalysts, the materials and the processes can be constantly improved«.

Topsøe owes its position to synergies between research, development, process design, engineering, catalyst production and sales, he says.

"Our research and development is focused according to feedback from industrial practice. We are capable of integrating all aspects from fundamental knowledge to practical implementation".

HALDOR TOPSØE
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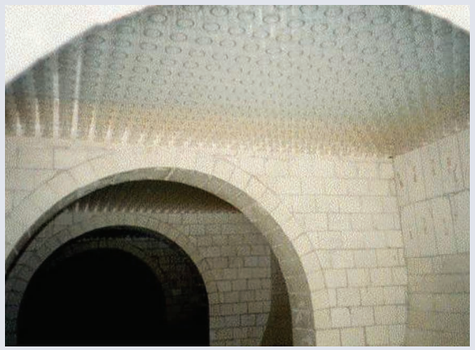
Haldor Topsøe is dedicated to catalysis, and the catalytic technologies developed by Topsøe are used by a wide range of industries all over the world

*Company Profile page 111*

## *The technology:* CATALYSTS TURN HAZARD INTO SALES PRODUCT

**WSA process:** The first step in treating sulphurous waste gas streams is to convert the feed gas to $SO_2$ gas, through combustion or heating. In the next step $SO_2$ is converted to $SO_3$ by contacting the gas with Topsøe's sulphuric acid catalysts, the VK-W series, specially designed for operation in wet gasses. When cooled, part of the $SO_3$ gas reacts with water vapour in the gas to form sulphuric acid vapour. In the third step, the gaseous sulphuric acid and the remaining $SO_3$ is converted to liquid sulphuric acid in a condenser (see picture).



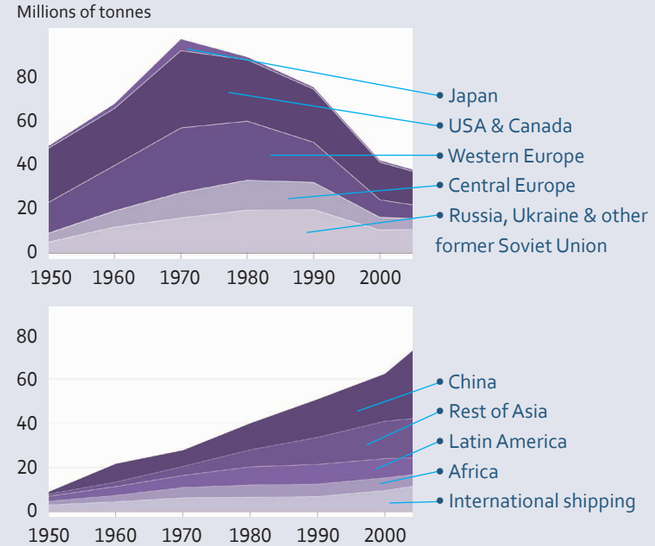
The process gas passes through vertical glass tubes, which are cooled on the outside by atmospheric air. Thereby the acid condenses and can be removed as concentrated sulphuric acid of a commercial quality.

Typically 99.0 – 99.9 percent of the sulphur is removed and recovered. Excess heat is exported as superheated high pressure steam. Drying of the feed gas is not required in the WSA process, meaning that formation of dirty, dilute acid is avoided.

**SNOX™ process:** The WSA-process can be combined with catalytic removal of nitrogen oxides and used for cleaning of flue gases from combustion of high-sulphur fuels.

**VK series of catalysts**: Topsøe's catalysts for conventional dry gas sulphuric acid plants are optimised for energy efficient operation. A range of catalyst types including caesium-promoted catalysts with high activity at low temperature ensure extremely low sulphur dioxide emissions.

## Emissions of sulphur dioxide



# CLOSED LOOPS IN THE PAPER INDUSTRY

*FLSmidth's electrostatic precipitators help cleaning the air and recycling the chemicals effectively in the production process*

Rizhao is a seaside city in the Shandong Province, China, with a population of 2.8 million. The city's pride is "Blue Sky, Blue Sea and Golden Beaches". Approximately 20 million tourists are attracted there each year by the pleasant climate, the cultural heritage, the water sports, and the sand beaches.

### "A charming eco-city"

Rizhao, however, is far from being a quiet tourist resort. It is a busy boomtown with plenty of heavy industries. The port's cargo handling grows by 20 percent each year. Industries close to the port include iron & steel, energy, petrochemicals, grain- and food processing, woodworks, automobile engines and parts, shipbuilding, and pulp & paper.

In spite of this, Rizhao is listed as one of the top ten air quality cities of China. It has been awarded the title "National Model City of Environmental Protection" by the Chinese Ministry of Environmental Protection (formerly SEPA). "We want to build an eco-city", the municipal authorities proclaim. One of the world's largest pulp & paper plants is situated near the port and close to the city centre. Hundreds of thousands of tonnes of pulp, paper, and paperboard are produced from wood chips which arrive from Sumatra, Indonesia.

The plant's owner, Asia Pacific Resources International, APRIL, proudly claims that its waste gas and waste water treatment systems are among the most advanced in the world. The level of air pollution is well below the standards required by the authorities.

FLSmidthhas supplied equipment to remove dust from the flue gases at this plant.

### Capturing the dust

The dust is captured in electrostatic precipitators. FLSmidth has installed more than 4,000 such precipitators in different industries around the world. Based on this experience, each new electrostatic precipitator is specifically designed to fit the local conditions and achieve low emission levels.

Computational Fluid Dynamics (CFD) is used to calculate the flow pattern inside the filter in order to obtain an optimal distribution of the flue gases and utilise the 100% of the installed area of the collection plates inside.

The precipitator is controlled by microprocessors to achieve a fast response to process variations within the plant. The electrodes are designed to fit the specific working conditions at each plant, and the equipment is designed to reduce the need for maintenance and repair.

### The dust is recycled

The electrostatic precipitators also help to recover the chemicals which are used in the plant. The precipitators delivered by FLSmidth treat the flue gases that are created in the world's largest recovery boiler and in two large lime kilns.

The calcium carbonate contained in the dust from the lime kilns is recycled to make more lime for the production process.

The recovery boiler is a furnace where the non-fibre fraction of the raw material (wood chips) is combusted. The boiler has a capacity of up to 7,000 tonnes per day. The soda contained in the dust from this combustion is recycled to make more pulp.

Rizhao by night.
Two of FLSmidth's electrostatic precipitators are on top of the building

FLSmidth

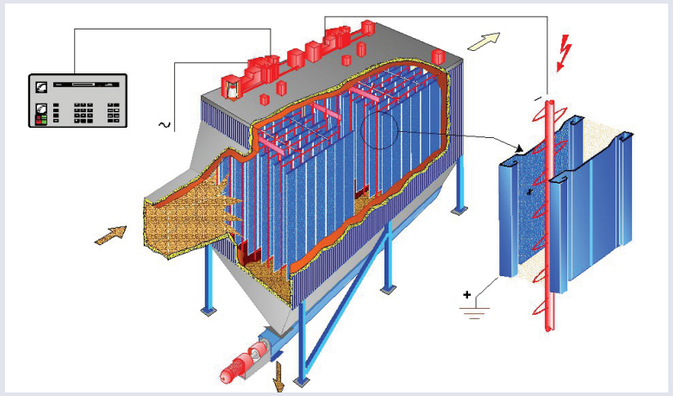
FLSmidth's air pollution control team supplies technology to reduce emissions from a wide range of industries

*Company Profile paage 96*

## *The Technology:* ELECTROSTATIC PRECIPITATOR

Electrostatic precipitators (ESP's) are used to remove dust from large volume of gases produced in industrial processes.

The flue gas is diffused into a steel-case. The airborne dust flows through the case between rows of electrodes (red) and collecting plates (blue). The electrodes are connected to a high voltage transformer. The collecting plates are earth-connected.



When a high voltage is applied, the electrons will move from the electrodes to the dust particles and charge them negatively. As a result, the particles are attracted by the collecting plates. The particles gather at the surface of the collecting plates and fall to the bottom of the steel case where they are removed.

FLSmidth has developed the COROMAX® pulse system that can add an extra high voltage at extremely short pulses of 75 microseconds. The base voltage and the extra pulse add to a total peak of 140 kV.

The voltage and the current can be adjusted independently to suit operating conditions. This feature reduces power consumption by almost 30 percent and emissions by half.

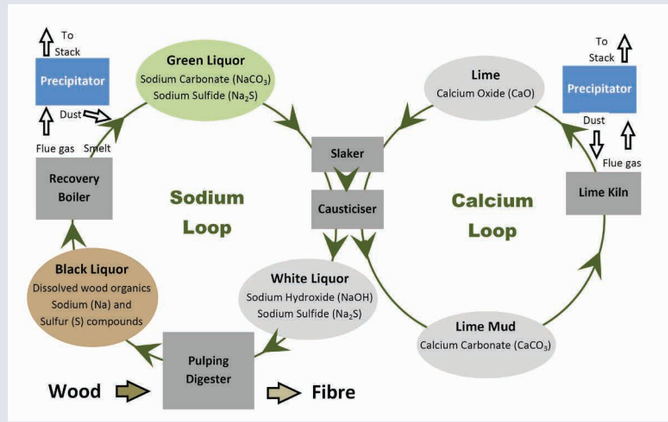
## RECYCLING OF PULPING CHEMICALS

The first step in paper production is pulping: Wood chips are boiled in a **pulping digester** with soda, "white liquor". Then the cellulose fibres which are used to make paper, are collected by washing and filtering. The remaining "black liquor" contains the degraded part of the wood chips along with useful chemicals.

The black liquor is concentrated in evaporators and combusted in the **recovery boiler**. The resulting hot steam is used to generate heat and power for the plant. In the bottom of the boiler, the chemicals are recovered as molten salts (smelt). The dust recovered in the **precipitator** also contains a part of the valuable chemicals. Combined, they are used to make "green liquor".

Before the liquor is ready to use again, however, the sodium carbonate has to be altered to sodium hydroxide (caustic soda). This is done by adding burned lime. In the **slaker** the lime reacts with water to form calcium hydroxide. In the **causticizer** the sodium and the calcium switch places. The result is new white liquor for pulping – and lime mud.

The lime mud (calcium carbonate) is burned in **lime kilns**. The dust in the flue gases from this high temperature burning is recycled to the kilns.



# TAKING CLEAN TECH TO A HIGHER LEVEL

*If you know precisely what you are doing today, chances are you will be able to do even better tomorrow*

Accurate and reliable measurements are indispensable tools to meet tightening environmental requirements.

FORCE Technology continuously develops and improve the methods to measure emissions, such as hazardous particles in engine exhaust and fossil carbon in flue gases.

### Reducing marine air pollution

Air pollution from ships is a growing concern. The International Maritime Organisation has prescribed a stepwise reduction of emissions. Particularly low emission limits apply to the Emission Control Areas established in North American and European waters.

The shipping companies can meet these requirements by using cleaner fuels or by cleaning the exhaust gases. "Financially it can make sense to clean the exhaust flue gas instead of using cleaner fuels", says Thomas Rosenørn, FORCE Technology.

### Measuring the emissions

MAN Diesel & Turbo is a major supplier of ship engines. According to MAN, around 48,000 ships, transporting more than half the world's commercial goods, have MAN's engines on board. FORCE Technology assists MAN in measuring the emissions from diesel engines equipped with scrubbers which remove sulphur from the exhaust.

The measurements take place at MAN Diesel & Turbo test facilities in Copenhagen and on board the cargo vessel Ficaria Seaways.

### Size matters

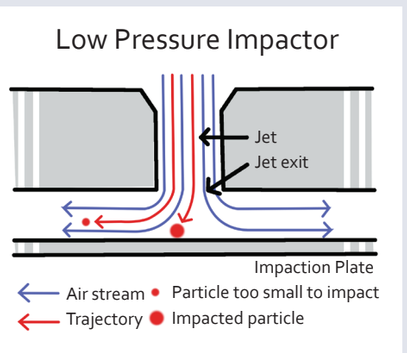
"We take samples in different parts of the exhaust circuit and replace with: we are able to not only measure the total amount of particulate material, but also to collect and count them by size and to perform size resolved analysis of physico-chemical parameters of the collected fractions", Thomas Rosenørn says.

Measuring only the mass of particles or the opacity of exhaust samples does not tell much about health hazards. The number of very small particles is much more important. Ultrafine particles penetrate deep into lung tissue, and their combined surface is large, just as the combined surface of chopped onion is large compared to the surface of one whole onion.

### Unexpected particles

FORCE Technology uses similar methods to measure the emissions of ultrafine particles from natural-gas-fired combined heat and power plants. "Theoretically, you would expect nothing but water and carbon dioxide from combustion of natural gas. That is, until you consider that the engine has to be lubricated. Some of the lubricants are combusted and particles are formed. We help in minimising that problem", says Thomas Rosenørn.

## *The Technology:* MEASURING PARTICLES




Soot and particles from the combustion of fuels are harmful to health, and ultrafine particles are especially dangerous. Therefore it is important to measure the size of the particles exhausted.

A Low Pressure Impactor sorts the particles according to their size. A sample of exhaust is sucked through tiny holes facing plates (see Figure). Larger particles impact and stick to the impactor plate due to their inertia while smaller particles follow the air stream.

The air stream continues through progressively smaller holes. This accelerates the jet speed, and successively smaller particles are collected. The particles are charged and the number of particles collected on each individual impactor stage is determined by an electrometer. Subsequently the particles on the impactor foils can be analyzed using electron microscopy or chemical analysis.

The concentration of particles of different sizes can also be examined with a Differential Mobility Analyzer. This method is based on the physical principle that the time it takes a charged particle to traverse an electric field depends on its size.




FORCE can determine the emission of fossil carbon from measuring the flue gases. The method used is radiocarbon dating, known from archeology. The isotope carbon-14 is only present if the fuel is not fossil based

FORCE Technology provides advanced technological services to many industries, assisting them improve their performance and meet environmental targets

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### Measuring fossil carbon

Another innovation by FORCE Technology is a method to measure the emission of fossil carbon from waste incineration.

Waste is increasingly used as a fuel to produce heat and power. As of January 2013, the major waste incineration plants in Denmark and Sweden are required to measure their carbon emissions.

"Combustible waste contains a mixture of fossil and non-fossil products", says Karsten Fuglsang, FORCE. The fossil carbon, e.g. in plastics and paints made from mineral oil, is at least 100,000 years old. It contributes to global warming and is not a part of the current natural carbon cycle.

Biogenic carbon, e.g. in organic waste and paper, has been accumulated in plants and other organisms in recent times. It is considered a renewable energy source.

### Carbon-14 dating of the flue gas

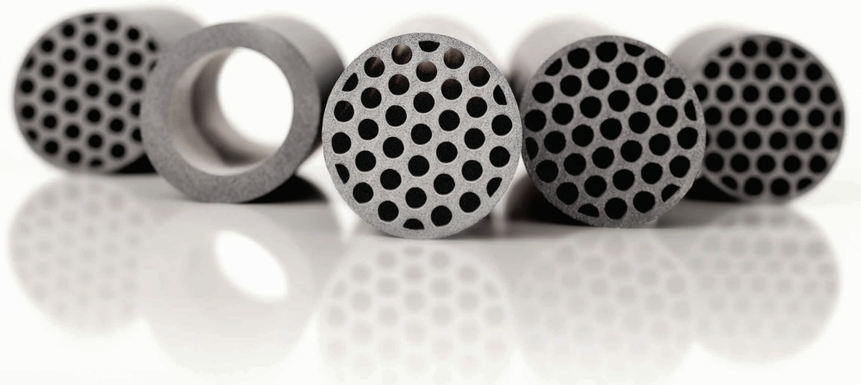
"Our method is based on carbon-14 analysis", says Karsten Fuglsang. "Biogenic carbon contains the isotope carbon-14. In fossil-derived carbon, the share of carbon-14 is negligible due to the radioactive decay of the isotope through the years".

"We collect a sample of $CO_2$ from the stack gas, analyse it and compare the carbon-14 content with the content expected from combustion of 100 percent biogenic carbon. In this way, we can determine the share of fossil $CO_2$ accurately."

Such accurate measurements are important because carbon taxes, emission allowances and national greenhouse gas inventories are based upon them.


FORCE measures the particle emissions by size and by volume

# KEEPING THE SKY BLUE



LiqTech provides higly durable ceramic membranes for filtration and air pollution control

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*LiqTech's ceramic membranes are preferred by many motor companies and suppliers of filters for retrofit of older diesel engines due to their high durability and flexible design*

Exhaust from diesel engines is a threat to the health of millions of people. The demand for efficient filters to remove lethal particles and other pollutants is rapidly growing all over the world.

LiqTech ceramic filters are made solely from silicon carbide. They are suited for the filtration of liquids as well as cleaning of exhaust gases. A substantial part of the filters are supplied as original parts to the motor industry or used for retrofitting of older diesel engines.

LiqTech filters are found in trucks and buses, passenger cars, off-road vehicles, locomotives, marine vessels and generators.

### Outstanding durability

"Next to diamonds, silicon carbide is one of the strongest and most durable materials in existence", says Sales Manager Brian Petersen.

"LiqTech's core competency is to process this very hard and strong material. It is difficult to modify and manipulate silicon carbide, but we are good at it. We have even developed a special technique to combine several layers of silicon carbide with different size of grains and pores".

High porosity and high durability make LiqTech's membranes the filters of choice for many demanding applications, including passenger cars and off-road vehicles.

Off-road engines have traditionally had no filters when leaving the factory. This is about to change. As health authorities realise that particle emissions are very harmful to public health, the legislation is gradually being tightened.

"For instance, Switzerland has decided that all diesel engines must be fit with particle filters. Tractors and construction machines are not accepted anymore without retrofit of filters", says Brian Petersen.

### Adaptability

Compared to large scale manufactures of ceramics, LiqTech is a flexible and dynamic, smaller company. "We are able to meet the special needs of customers, even if they want only a limited number of specially designed filters", says Brian Petersen.

"The durability of our product combined with our expedient adaptability is our competitive advantage", he adds.

If, for example, a Chinese motor company needs a minor part of their engines to meet high European or North American standards rather than average Chinese standards, LiqTech can quickly design and manufacture small series of tailor-made filters for them, he explains.

### Low Emission Zones

The demand for filters is growing at a higher rate than the motor industry itself, because emissions standards are being raised all over the world.

California has been a clean air pioneer for decades. Five-year warranties are required for filter effects, and the fines are high if the filters do not work properly at vehicle inspection. These requirements are strong incentives to choose durable materials, and LiqTech has thereby gained a significant market share.

LiqTech has also provided many filters to the suppliers of retrofit equipment required for vehicles driving in Low Emission Zones. Such zones have been established in London and a large number of other European cities.

### Wide use of different filters

LiqTech filters can be shaped, coated and combined in many ways to meet the diverse demands. "Retrofit of filters is especially important to the occupational health in mining and other activities, where the employees are exposed to exhaust from indoor machinery", he adds.

Other areas of increasing concern are stationary generators and power engines on board ships in port and vessels in rivers and canals. LiqTech manufactures specially-designed filters for all such purposes.

To complete the product series, LiqTech has also developed filters with catalysts to remove nitrogen oxides, hydrocarbons, and carbon monoxide from exhaust gases.

## *The Technology:* STRONG BUT POROUS

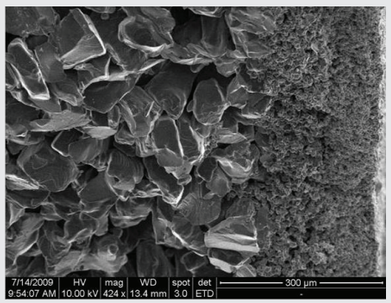
LiqTech ceramic membranes are made solely from silicon carbide. Temperatures above 2,400 degrees Celsius are required for the casting and extrusion of this extremely hard and stable material. The resulting cylinder with inner canals is very durable and resistant, yet highly porous (above 45 percent).

The inner surface can be coated with one or more layers of the same material, with different grain- and pore-sizes. It can also be covered with catalysts. These technologies make it possible to adapt the ceramic carrier for many different purposes.

Motor companies face two conflicting demands: One the one side, high fuel efficiency is good for the climate because of low carbon emissions. On the other side, high filter efficiency is good for the health and the environment.

A filter inevitably creates some resistance to the flow of exhaust gases. The motor must use some of the fuel to create the energy required to overcome the backpressure.

LiqTech focuses on the development of filters with an even greater porosity. High porosity means low backpressure and thus better fuel economy.



# Lifeguard at the Tailpipe

*Dinex's exhaust systems for trucks, busses, vans and off-road machines are life-saving technologies*

Millions of people are exposed to health hazards such as lung cancer, respiratory and cardiovascular diseases du to the exhaust from diesel engines.

Fortunately, modern filters and catalysts, if properly made, installed and maintained, can remove the hazardous substances.

### Dinex supplies the solutions

To protect the health of people, the authorities in Europe, USA and Japan have gradually raised their emission standards. Countries in other parts of the world tend to implement similar standards. Dinex can equip new and older heavy duty vehicles to meet even the highest of these emission standards.

Dinex specialises in the development, manufacturing and distribution of complete exhaust systems and emission technologies, from turbo to tailpipe, for trucks, busses, vans and industrial machines with diesel engines. In this field, Dinex is Europe's leading supplier. Among the customers are large manufactures such as Volvo, MAN, Mercedes, Caterpillar and John Deere.

### Advanced technology centre

"Obviously high emission standards are important to our business", says Dinex's Sales Director, Torben Pagh.

Since 2006, standards have been so demanding that when diesel engines are optimised to reduce one sort of emission, they may generate emissions of another sort. Therefore the engine and the after-treatment of exhaust must be handled as an integrated whole.

"This means that Dinex is now a very important partner for the engine-manufacturers. Our technology centre is equipped to test and validate all types of exhaust systems and emission levels. We can not only offer the technology, but also all the engineering work needed to develop, test and validate them", says Torben Pagh.

"This is especially relevant to customers in areas such as Asia, Latin America and South Africa, where emission control regulations have only been implemented recently.. To them we are a partner who can play an important role as counterpart to their in-house engineering throughout the engine manufacturing process", Torben Pagh continues. Unlike other suppliers, Dinex manufactures 95 percent of all the parts needed in-house, including the ceramics and the coatings of the filters.

The head office, the Technology Centre, and some of the production is in Denmark. The rest of the manufacturing takes place in Germany, UK, Latvia, Russia, Turkey, China and USA.

"We are the first in our segment of the market to manufacture the same equipment in all parts of the world. The ability to act globally while producing and delivering locally is important to our customers in the automotive industry; they demand global presence", says Torben Pagh.

### Retrofit of filters and catalysts

Many cities have established low emission zones. Typically, trucks and busses are prevented from driving there, if they are not equipped to meet the same emission standards as new vehicles.

Dinex has a broad variety of complete solutions to retrofit filters and catalysts to all major brands and models of trucks and busses. The units are designed to be fully interchangeable with the old exhaust system, making the fitment cost very low compared to other available systems.

### Certified for all relevant countries

Contrary to the emission standards, retro-fit legislation is country specific.

"Each country has different rules and approval procedures, but Dinex particulate filters are certified in all countries that have established low emission zones in Europe and elsewhere", says Torben Pagh.

A bus can take passengers to Berlin this week, London next week and Copenhagen the following week, without problems.

### High standards pay off

"The extent of retrofit needed depends on how high the authorities place the bar, and there are good reasons to raise it", he says. "The overall costs of stringent rules in low emission zones are more than compensated for by the health costs saved – not to mention quality of life". This statement is confirmed by numerous scientific studies. »It is a proven fact that the socio-economic benefits from retrofitting particulate filters for heavy diesel vehicles and vans is very large in comparison to the costs«, says Kaare Press, environmental engineer at the Danish Ecological Council.

Dinex supplies exhaust systems and low emission technologies for commercial diesel vehicles and industrial machinery

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## *The Technology:* REDUCING LETHAL EXHAUSTS

The exhaust from diesel engines contains many dangerous substances, such as nitrogen oxides, carbon oxide, hydrocarbons and particles. Some of them are poisonous, others are carcinogenic. Combined, they contribute to smog formation.

Ultrafine particles are the most lethal part of the exhaust. In 2010, a study commissioned by the European Environmental Agency concluded that fine particles are associated with almost half a million premature deaths in the European Union.

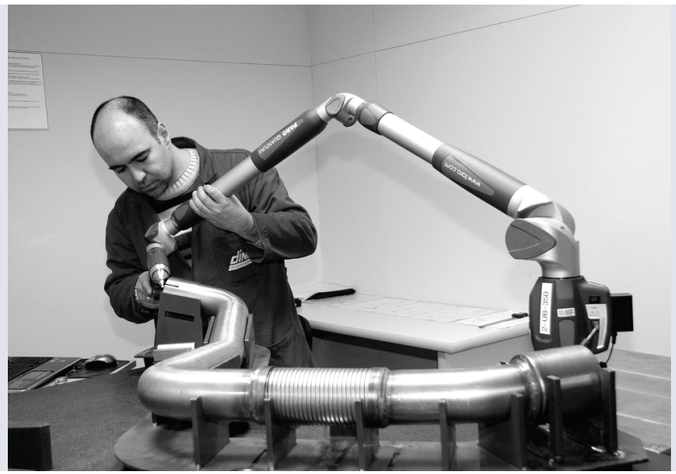
The emission standards have been significantly tightened. Typically the allowed emissions from trucks, busses and other heavy duty vehicles sold today are 5 to 10 times less than the emissions from vehicles purchased ten years ago in Europe and the USA.

The next European standard, EURO VI, enters into force in 2014. This will decrease allowed emission of particles by half. Emission of nitrogen oxides will additionally be cut to a fifth.

Dinex has the competencies needed to make vehicles meet the highest standards in Europe, Japan as well as the United States.

Particles are removed with coated ceramic filters. Nitrogen oxides are removed by way of selective catalytic reduction.

By retrofitting filters and catalysts, e.g. DINOx® equipment, older vehicles can thereby meet the high EURO VI emission level.



# CATALYSING THE WAY FORWARD

*Improved catalysts for diesel vehicles can benefit not only people's health and the environment, but also the climate as well as the economy*

Manufacturers of diesel engines have reached a barrier. For the benefit of economy and climate, fuel consumption and $CO_2$ emissions can be reduced e.g. through better control of the fuel injection.

However, if the manufacturers choose to do so, the emissions of nitrogen oxides, NOx, will grow, to the detriment of health and the environment.

If, on the other hand, they choose to optimise the engines in order to minimise emissions of nitrogen oxides, the engines will use more fuel.

### Highly efficient catalysts are required

Many automotive manufacturers and their suppliers therefore concentrate on developing engines that use as little fuel as possible, while leaving the NOx-problem to the effective purification of the exhaust gases.

This solution requires catalysts and technologies that are very efficient. On the other hand, it opens a new perspective. Instead of looking for a decent compromise, the manufacturers can go for a quadruple dividend:

The more the catalysts ability to eliminate NOx can be improved, the more the fuel consumption can be reduced, to the benefit of the economy, the climate, the health and the environment as well.

### Supply of original equipment

Topsøe has supplied approximately 200,000 catalysts for diesel engine exhaust treatment, mostly in Europe, but also in China and Brazil. The catalysts ensure that vehicles can meet the highest emission standards.

Topsøe works with original equipment manufacturers to develop the exhaust systems. Customer engines are used in bench tests for optimising catalysts and system design, in collaboration with the customers.

"Automotive is a relatively new business area for us, but we expect a substantial growth in the coming years", says Joakim Reimer Thøgersen at Topsøe's Research & Development Division.

## *The technology:* AUTOMOTIVE CATALYSTS FOR DIESEL ENGINES

Emissions from diesel engines are decreased by different means:

- NOx (nitrogen oxides) are removed by catalysts, which are either vanadium-titanium-based or zeolite-based. Urea is injected upstream within the catalyst, and hydrolyzed by the hot exhaust gas.
- The excess ammonia is removed by an ammonia slip catalyst, typically platinum-based.
- The soluble part of particles is burned by an oxidation catalyst and by the vanadium SCR catalyst, if present.
- The insoluble part of particles is trapped in a particle filter. An oxidation catalyst is located upstream in the filter to burn the trapped soot.

These catalysts are used in different combinations in trucks and busses, in cities and on highways, in non-road equipment and vehicles, in locomotives, and in-shore vessels.

Topsøe has invented a unique catalyst, where the ceramic substrate is corrugated and impregnated with the active metals, vanadium and tungsten.

The ammonia slip catalyst can be zone coated on the same substrate. The highly porous walls ensure high NOx conversion and excellent resistance to sulfur and other contaminants in the exhaust.




HALDOR TOPSØE
CATALYSING YOUR BUSINESS

Haldor Topsøe is dedicated to catalysis, and the catalyst technologies developed by Topsøe are used by a wide range of industries all over the world

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### Automotive: High demands

"Principally, the catalysts and technologies are the same as those used for heavy industrial equipment, but vehicle equipment is even more demanding", he says.

It fits well with Topsøe's core competencies: applied science, innovation and technology improvement. Topsøe strives to develop catalysts that are more robust and compact, with even larger inner surface and longevity than those used in industries, power plants and ships.

### In-house manufacturing

Topsøe manufactures all catalysts in-house. The DNXR-catalyst, which is used by several truck and bus manufacturers in Europe, is produced at a fully automated plant according to the superior international standards TS16949 and ISO14000.

"In collaboration with our heavy duty vehicle customers, we have embarked in developing entire new exhaust systems in our own engine-lab", Joakim Reimer Thøgersen says.

### Retrofit of older vehicles

Topsøe also supplies equipment to retrofit catalysts and particle filters to heavy duty vehicles, which were manufactured before the emission standards were elevated. The NOx abatement is obtained by adding urea to the exhaust. In this process, the ammonium in the urea combines with nitrogen oxides to create harmless elemental nitrogen and water vapour.

It is very important that the urea is applied in exactly the dose required. Topsøe has developed an advanced urea injection algorithm to ensure that the digital urea dosing pump is controlled automatically, according to the operation of the engine. The result is a high NOx-conversion with a low release of excess ammonia.

The system for NOx control provides a high NOx conversion, in the range of 70-90 percent. In addition, the unburned hydrocarbons from the engine are reduced by around 80 - 90 percent and particulate mass is reduced by 20-40 percent.

## *Climate Change and Pollution*

To protect the climate, we have to use less fossil fuel. To protect health and the environment, we have to limit air pollution. But what if engines that use less fuel, pollute more, while engines that pollute less, use more fuel?

Road transport is an important source of greenhouse gases, as well as of air pollution. Transport volumes and mileages are growing all over the world. Until now, it has proven very difficult to limit the growth or to shift the transport mode from road to rail and waterways. It has also proven difficult to find and promote more sustainable fuels for the replacement of diesel, particularly for trucks, busses and other heavy duty vehicles.

Presumably, in the foreseeable future, the most viable solution is technology that improves energy efficiency while removing pollutants from their exhaust.

# CLEAN TECH

# CATTLE BARN

*A new concept for handling manure in cattle sheds drastically reduces the emissions of ammonia as well as the odour from large scale dairy produce*

Foto: Anita Corpas

Modern dairy cows produce a lot of milk, but they certainly produce a lot of manure too! The ammonia evaporating from this manure can seriously harm the natural environment.

The Danish Institute for Agri-Technology and Food Innovation, AgroTech, has assisted the construction and civil engineering company, MT Højgaard, in addressing this problem through the development of a new concept for cattle housing, OdourGuard.

### An open challenge

If ammonia from several hundred cows is allowed to escape into the environment, it acts as an airborne fertiliser. Eventually it will disturb the natural eco-balance in nearby lakes and streams. Vulnerable heath- and moorlands are particularly affected.

If the cows were in closed buildings, the ammonia could be collected by way of traditional ventilation. Today, however, most farmers prefer housing loose cattle in open sheds. Such housings lie open to the wind, which makes it difficult to control the ventilation. In seach of a solution, AgroTech arranged an innovation workshop. "Milk producers, experts, and process consultants from AgroTech and MT Højgaard were invited to contribute new ideas on how to create the best housing ever for dairy cows", says Niels Henrik Lundgaard, AgroTech.

The best ideas were collected, evaluated, prioritised, and later used to develop the new livestock building concept. "At first, we considered using solid floors, which could be automatically scraped to remove the manure. This solution, however, would leave the cows on wet and slippery floors. We realised that slatted floors are better for the health and welfare of the animals", says Erling Friis Pedersen, MT Højgaard.

At slatted floors the manure falls through the gaps between the slats onto a second solid floor from where it is scarped and flushed away.

With liquid manure being collected beneath the cows and windows open above them, the best solution found was vacuum ventilation under the floor. In this way the ammonia vapour is caught at the earliest possible stage.

### Far ahead of the competitors

This concept was thoroughly tested. A full scale model was built, and Agro Tech undertook comprehensive measurements. The conclusion was that this sort of ventilation could remove at least 75 percent of the ammonia vapour and half of the odour. MT Højgaard expect 90 percent of the ammonia to be removed. "In any case, we are far ahead of our competitors," says Erling Friis Pedersen. "The second best technology currently available is acidification. This method requires much energy, and its efficiency levels are only at 40 percent".

MT Højgaard recieved the European Business Award for the Environment for the invention in 2012. The first building to use the new concept was put into use in May 2012.

### Thorough verification

AgroTech is now in the process of testing the performance of the new concept in real life. The measurement program is extensive, and the testing is done in accordance with the VERA standard, Verification of Environmental Technologies for Agricultural Production.

"The VERA-test applies to all countries within the European Union, and the results found by AgroTech will be the official figures for the performance of our concept", says Erling Friis Pedersen.

When the documentation is accomplished, he expects the authorities to permit larger herds than currently allowed at farms utilising the more traditional types of cattle housings.

### Self-learning software

An improved indoor climate is part of the project's objectives. Dairy cows require good air quality, ventilation, and standard temperatures above 7 degrees Celsius.

The ventilation provided under the floor improves the air quality for animals and people as well. The rest of the ventilation is natural: Warm air rises from the cows and escapes through the windows at the ridge of the roof.

AgroTech found that the bulk of measurement data which was collected to develop the new concept were also useful in improving the ventilation system.

"Statistic data analysis is one of our core competencies", says Niels Henrik Lundgaard. "Our experts discovered patterns in the data, which are now part of the SmartFarm software that is used to control the temperature, humidity, $CO_2$-content, light, odour and ammonia-ventilation".

AgroTech A/S provides advice and technological services to the agricultural sector, horticultural nurseries, and food producers

*Company Profile page 86*

## *The Technology:* AN 'AIR CURTAIN' CAPTURES THE AMMONIA

The unique feature of MT Højgaards patented OdourGuard concept is ventilation beneath the floor. The manure falls through slots in the floor into trenches from where it is washed away. Air ducts are placed at each side of the trenches. Fresh air is blown in from one side of the trench. At the opposite side, a slightly stronger vacuum extracts the air. This ventilation creates an 'air curtain' above the surface of the slurry. The ammonia vapour is taken away with the air stream. Some of the ammonia vapour above the floor is also drawn away by the vacuum.

Trials conducted by AgroTech have proved that the novel system removes at least 75 percent of the ammonia and about half the odour.

The ammonia is thereafter recovered as ammonium sulfate in a filter system.

As a side-benefit, the data from the air quality measurements made were found to be useful in improving the computerised control of the indoor climate. The software is 'intelligent' and self-learning. By utilising outdoor wind and temperatures, it calculates the optimal opening of the ceiling windows.

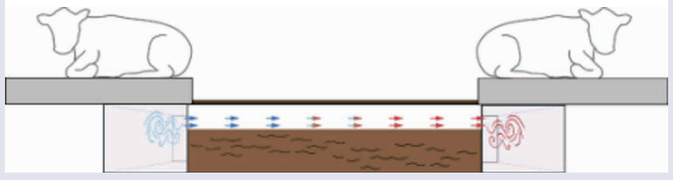


Photo: Jens Bertelsen

# A FAREWELL TO BAD SMELL

*Odious exhaust from food industries and commercial kitchens can be a nuisance for the neighbours. JIMCO's technology reduces the odours to almost zero*

The Danish company Daloon produces ready-made Chinese spring-rolls and sell them in the millions. Daloon knows all about frying, but they didn't know how to get rid of the sticky fat that clung to the hoods and ducts of their ventilation system. The fat leaked out of the hatches on top of the roof. Fatty acids damaged the paint of the employee's cars.

A Fire Officer inspecting the plant said: "Sooner or later you will have a fire here. It's merely a question of time. The fat will self-ignite".

### It worked perfectly well

JIMCO's founder, Jimmy Larsen, came to their rescue. In 1993 he installed his first air-cleaning device at Daloon's plant. It worked perfectly well. The grease disappeared like dew in the morning sun. Soon the inner surfaces of the vents were clean and nice.

Jimmy Larsen is a plumber by profession. He knew about ventilation and he was enthusiastic about his invention.

"But at the time", he admits, "I really didn't know why the unit worked so well".

In absence of technical documentation, he had a hard time convincing customers other than Daloon. The hesitant scepticism, however, faded away when Daloon ordered another and even bigger unit, being very content with the performance of their first unit.

Another early customer of JIMCO's was a nearby fried onion plant. The bad smell was a nuisance to the local community. and the owner of the plant, Danisco A/S, was required to remove 90 percent of the odour, or else face the risk that the municipality would shut down the facility.

### Performance guarantee

This time, Jimmy Larsen had to gamble. Calculations indicated that his device could probably remove 91 percent of the odour, but at the time, he could not be sure. The owner, however, demanded a no cure no pay guarantee.

"I made a bet and took the risk of losing my money", he says. The day the lab test result arrived, he was proven correct: The odours were reduced by 97 percent.

Today JIMCO's technology is well proven and extensively documented. JIMCO does not hesitate to issue guarantees.

"To make our customers feel safe and comfortable, we always guarantee performance – on the conditions that the evaluation is made by an independent lab and the payment is deposited in a secure manner", Jimmy Larsen says.

JIMCO's devices are constantly being further developed and adapted to a broad variety of applications and customer needs in the food industry, catering firms, commercial kitchens, private households, and institutions.



JIMCO supplies air-treatment units for some of the biggest chains in the world, including McDonalds, Marriott, Hilton, Scandic Hotels, and Danish Crown.

### Every third french fry

McCain Foods is the world's largest manufacturer of frozen French fries and potato chips. One of every three fries around the world is a McCain fry. The odour problems caused by McCains 50 manufacturing facilities are worldwide as well. The plant in Scarborough, UK, tried to get rid of the bad smell through the utilisation of a wet scrubber system. After two years, they had to recognise, that the problem persisted. Facing growing complaints and the risk of closure they asked JIMCO: Can you guarantee removal of 92-93 percent of the odour? JIMCO said yes and got the order. McCain Foods got what they had asked for.

"The treatment of 32,000 cubic meters of exhaust air per hour has worked well for three years now. We are ready to assist McCain meeting EPA requirements elsewhere", Jimmy Larsen says. JIMCO's patented technology has many advantages compared to other methods, Jimmy Larsen notes. Some of them are very energy-demanding, some are very space-demanding, and others are less efficient.

### Many different applications

Today the technology is adapted for a wide variety of purposes. Contaminated freshwater and heavily loaded wastewater can be purified with JIMCO's technologies.

The air cleaning devices are designed to improve indoor air quality and remove odours and micro-organisms. They come in a variety of different sizes, fit for improving indoor climate in living rooms as well as large office buildings and other workspaces.

Cleaning of bad smelling used cars and containers is also part of the activities.

Depending on the doses, the technique is also able to sterilise the air in food processing areas, vegetable storages, hospitals, and many other places.

JIMCO A/S provides air- and water-purification equipment, helping industries and private households to solve odour problems and improve indoor climate

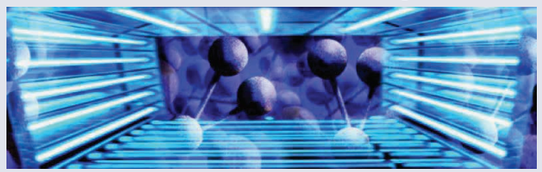
*Company Profile page 100*

## *The Technology:* 'COLD BURNING' OF ORGANIC COMPOUNDS

In Nature, the ultraviolet sunrays have a purifying function. Confined to the interior of vents, ducts and cleaning devices, artificial short wave UV-C radiation does an equally brilliant job purifying air and water. Odour binding proteins are split to pieces, micro-organisms are killed, and oxygen $O_2$-molecules combine to form ozone, $O_3$, in concentrations high enough to oxidise the undesired organic compounds.

The process is known as photolytic oxidation or 'cold burning'. In short, it removes odours, fat, oil, micro-organisms, volatile organic compounds, and other organic remnants. The remaining dust and wax is harmless and biodegradable. Dependent on the doses, the technology can even be used for sterilisation. If handled correctly, the remaining ozone is well below the threshold value.

The JIMCO patented technology also avoids the undesirable formation of nitrogen oxides, which would inevitably occur if conventional high voltage equipment (corona discharge) were used, because four fifths of ambient air is nitrogen.



# BACTERIA AND FUNGI

*Organic removal of odours makes waste treatment and recycling acceptable to the public*

Many foul smelling industries perform recycling activities: Municipal waste is transformed into fertile soil through composting. Wastewater sludge and food wastes are used to make biogas. The remaining sludge can be used as a fertiliser. Dead animals and slaughterhouse waste are sources of useful proteins, fats, greas and biodiesel. And in fact the World Renderers Organisation claims to represent "the world's first recycling business".

Bad odours, however, are likely to hamper the public acceptance of such useful activities, particularly in urban settings.

### Pleasant smell

The BBK biofilter was developed to solve these problems in an efficient, organic and economically feasible way, without creating new waste problems, says Arne Poulsen, the owner and CEO of BBK bio airclean.

"People say that the air coming from our biofilters smells like moist soil on a forest floor", says Arne Poulsen, the owner and CEO of BBK bio airclean. He is proud of the pleasant scent, which is the result of many years of "hard work, studies and persistence". Serene walks through the woods are not exactly what people generally associate with sewage treatment, waste composting, biogas production, treatment of dead animals, rot and decay.

### Feeding the micro-organisms

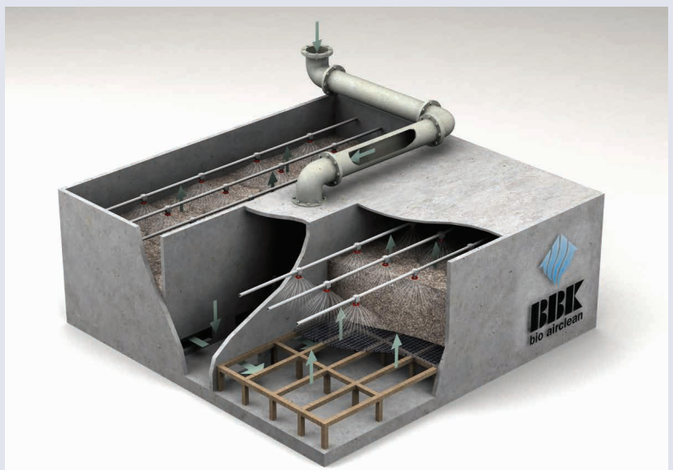
In a biofilter, the polluted air passes through humid filters containing micro-organisms that use the malodorous compounds in their own metabolism. They "eat" the odour.

BBK has improved this technology to such a degree, that the otherwise heavy odours are barely detectable.

Most other biofilters are made from random plant residues. They are likely to collapse and clog in a few years. BBK-filters are made of completely composted organic material and lightweight clay products. "We tested different materials again and again until we found a very porous and homogenous combination that remains stable, and allows air to be evenly distributed to the entire surface. Our filters have a proven durability of more than ten years", Arne Poulsen confidently says.

## *The Technology:* ADVANCED BIOFILTER

The biofilter is an enclosed system. The air containing malodorous compounds and volatile organic compounds passes through the filter media. When the odorous compounds meet specifically selected micro-organisms, most of them are decomposed into carbon dioxide and water. How much time the air has to be detained in the filter depends on the complexity of the odorous compounds; typically it is 25 – 35 seconds.




The filter consists of fully composted organic material plus Leca and moler. Leca is lightweight burnt 'bubbles' made up of marine clay. Moler is a geologically unique mixture of clay and algae shells, found in Northern Jutland.

The filter media is first pasteurised to eliminate bacteria, fungi etc. Then it is inoculated with specific micro-organisms that are specifically selected to digest the odorous compounds consistent from each type of industry.

The filter is kept humid with a sprinkler system, the acidity is controlled by adding sodium bicarbonate (known as baking soda) if appropriate, and the temperature is moderated to be viable to the micro-organisms.

BBK inspects and regulates the function of the filters at least once every three months. If necessary, the filter is cleaned and flushed with new micro-organisms.



# CONSUME THE ODOUR

BBK biofilter at the world's largest biogas plant, Måbjerg Bioenergy

Many other biofilter producers blend their filter media with sludge from a wastewater plant. It is a convenient source of active micro-organisms. "In this way, you get millions of micro-organisms. However, most of them will fight each other or do nothing to remove the odours", Arne Poulsen explains.

### Specially selected micro-organisms

Instead, BBK has worked closely with micro-biologists to identify strains of bacteria and fungi that are specifically suited to remove the odorous compounds from each type of industry.

A high concentration of relevant micro-organisms results in high efficiency. The BBK-filter is able to remove more than 95 percent of the odorous compounds, at constant rates.

If the micro-flora deteriorates, it can be re-established by flushing the filter with a concentrate of the relevant micro-organisms.

### Control is the key

"The key issue is to control the micro-biology", says Arne Poulsen. "We pasteurise the filter to eliminate undesirable microorganisms prior to inoculating it with the specifically selected ones".

The filter system is designed to maintain a suitable temperature. The humidity is controlled with a sprinkler. The acidity is kept moderate by adding sodium bicarbonate (baking soda) to the water if necessary.

The retention time of air in the filter depends on the compexity of the odours. Typically, it is in the range of half a minute. The filters can be made to treat airflows from 500 to several hundred thousand cubic metres per hour.

### No discount

The features of the BBK-solutions do not come for free. The initial costs of purchase are high, compared to other suppliers. The customers, however, earn their money back thanks to the durability and efficiency of the filter, says Arne Poulsen.

"Making business with us, a discount solution is not an option", he says. "We use high quality components only, and we would rather lose an order than compromise on the quality". The contracts always include warranties and regular service.

BBK biofilters are made from fully composted, stable material, blended with lightweight burnt clay. The micro-organisms are specially selected.

BBK bio airclean

BBK bio airclean A/S designs, produces and maintains biological filters for removal of malodorous compounds in the exhaust air from organic industries

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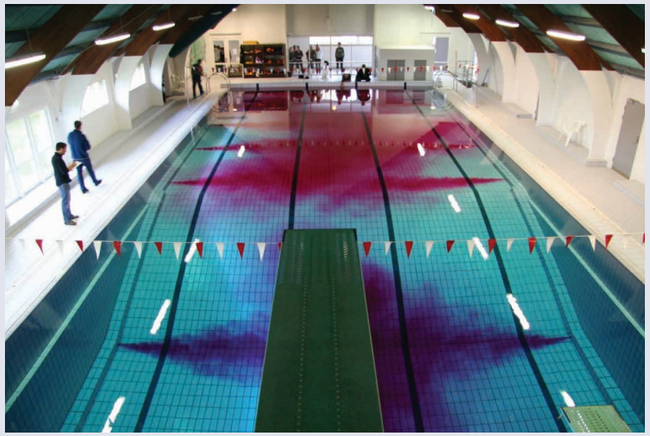
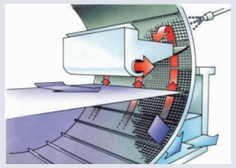


## *Technology:* THE inBLUE CONCEPT

Circulation: By means of hydraulic computer models and full scale testing, the circulation of water in the pool is improved. The position of inlets and outlets is optimised to ensure that all of the water is circulated. The impurities are swiftly removed, and the chlorine is better distributed. On top of this, the new design saves energy, because lower pump pressure is needed.



Drum sieve

Filtering: Traditional sand filters are cleaned by pumping water backward through the filter only once a week or once a fortnight. Meanwhile, chlorinated by-products are constantly formed as the skin cells and other particles captured by the filter are constantly surrounded by warm, chlorinated water.

Therefore, inBlue uses Hydrotech drum sieves instead. The cylinder sieve is regularly washed by high-pressured water, within a timeframe of less than one hour. More than 90 percent of the particles are removed and led to the sewer within hours.

Other filters, such as membranes, are applied according to circumstances.

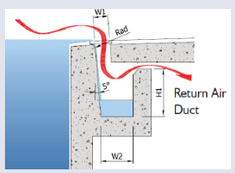
Stripper

Stripper: The hazardous chlorinated by-products are gases. In a specially designed stripper, much of thes gas is removed.

The water trickles down metal plates and gases, such as chloroform, escape to a stream of air moving upwards along the plate.

The gasses escape to the outdoor air instead of reaching the basin where they would escape to the air at the surface of the pool.

Ventilation




Ventilation: With conventional ventilations principles, the hazardous gases gather at the surface of the pool because they are heavier than air. With the inBlue concept the surface of the pool is better ventilated in order to remove the remaining volatile by-products.

# SAFE SWIMMING

*By-products from the disinfection of swimming pool water is suspected to cause asthma – particularly among small children*

Most people are acquainted with the unpleasant 'chlorine odour' in swimming pools. In fact, it is not the chlorine itself that smells. It is the by-products formed when the chlorine breaks down the impurities in the water.

These by-products, especially chloroform and chloramines, can cause red eyes, discomfort and acute asthma attacks.

### 'The chlorine hypothesis'

Ten years ago, the Belgian pediatric doctor Alfred Bernard submitted the hypothesis that the steep rise in childhood asthma observed over the past decades is caused, at least partly, by chlorine compounds contaminating the air of indoor swimming pools.

Today, a great deal of studies indicate that chlorinated by-products are more harmful than previously believed. As a consequence, the health authorities have tightened limits and regulations.

The Federal Environment Agency of Germany now advises parents to refrain from swimming with children aged 0-2 years, if allergies often occur in their family.

### The inBlue concept

To minimize the problem, the Danish engineering company Skjølstrup & Grønborg has invented an entirely new concept for swimming pools.

The impurities are swiftly circulated away from the pool by way of a much improved circulation system.

The new filter system washes the impurities into the sewer within hours. In this way, the formation of additional chlorinated by-products is avoided.

New ventilation principles remove the remaining by-products from the surface of the water where the swimmers breathe.

With the inBlue concept, less chlorine is needed for disinfection, and the consumption of water and energy is halved. The investment level for inBlue technology is approximately the same as required for high standard conventional equipment. Operational costs, however, are lower, due to a reduced consumption of water and energy.

### Science-based solution

The inBlue concept is based on re-thinking the entire water treatment process.

»We are scientists and our solution is based on research«, says Ole Grønborg at Skjølstrup & Grønborg. »We took a holistic view and asked ourselves: Where do the contaminants come from? Can we do the whole thing in a different way, to avoid the harmful substances and obtain clean and healthy water and good, comfortable indoor climate as well«?

»When we swim, we leave skin cells, urine, sweat, cosmetics and other impurities behind us. The chlorine breaks these compounds down, but it takes some time, and in the process the harmful by-products are formed«, he says.

### Worst for the babies

»The water looks clean and clear, but the chlorinated by-products escape to the air at the surface of the pool water, which is exactly where swimmers breathe«, says Ole Grønborg.

»The impact of this is particularly high for babies in the pool. Their lungs and airways are newly developed and they are positioned with their nose right at the surface, which unbeknownst to most, consists of extra warm water with lots of chlorine and contaminants for an hour or more«.

### No need for asthma medication

The first customer to uilize the new technology was Bernstorffsminde Private School, where young elite swimmers are educated.

»Of the 20 swimmers currently attending the school, six had sports asthma upon arrival. None of them have used their asthma medication since«, says the school's Vice-Principal Rene Nielsen.

So far, approximately 30 swimming pools have been built or renovated in accordance with the inBlue concept. The concept is now in the process of being standardized.

inBlue COM

HEALTHY POOL TECHNOLOGIES

The inBlue concept is developed by Skjølstrup & Grønborg, an innovation engineering company specialised in science based water treatment

*Company Profile page 109*

# *Ballast Water Treatment*

# ALIEN SPECIES NO ENTRY

**DESMI Ocean Guard A/S**
*- ballast water treatment systems*

*DESMI Ocean Guard has developed a highly efficient system for the elimination of living organisms in ballast water.*

*Company Profile page 105*



*The spread of living organisms through the ballast water from ships is a threat to local marine life, fisheries and health.*

The world trade is growing, and more than 80 percent of the world's goods and commodities are conveyed by ships. In the process, billions of tonnes of water are moved from one port to another. Water is pumped into the ballast tanks to stabilise the ships when they are emptied, and discharged when they are loaded.

### A serious threat

The use of ballast water is indispensable to ensure the safe operation of ships, but it is a serious threat to global biodiversity. Some the organisms living in the ballast water survive the voyage and establish fast growing populations in their new environment. Such invasive species can disturb the ecological balances, and be devastating to local marine life, fisheries, infrastructure and people's health. The impacts are often irreversible.

The threat was recognized by the international community through the adoption of the Ballast Water Management Convention of the International Maritime Organization, IMO, 2004. According to the IMO, discharge of ballast water causes a new such invasion to take place somewhere in the world every nine weeks. When the convention enters into force, 50,000 – 70,000 ships will have to install ballast water treatment systems.

### IMO compliant in all water types

DESMI Ocean Guard has developed an efficient and cost effective system to eliminate organisms in ballast water. The water is filtered and treated with UV irradiation and ozone. No chemicals are added.

"We have been able to demonstrate that our system performs in all water salinities, fresh, brackish and sea water, and at all temperatures from 0 degrees Celcius and up", says DESMI Ocean Guard's CEO Rasmus Folsø.

The system can be scaled and configured according to the needs of each vessel. It is available in containers ready for plug in, or as components to be installed where space is available. The delivery and installation onboard may be done with practically no interruption of the ship's normal operation. The energy consumption is low, and it is adapted to the available power supply onboard.

### It works in freshwater too

The unique feature of the DESMI Ocean Guard technology is that it efficiently eliminates living organisms even in turbid and coloured freshwater. This is very important, because many major ports, such as Shanghai and Rotterdam are situated in river estuaries.

"If the treatment of ballast water does not comply with required standards, even in ports with such challenging conditions, it may result in fines, detained ships and costly replacements", says Rasmus Folsø.

### The choice of technology

To avoid harsh and risky chemicals, DESMI Ocean Guard decided to use ultraviolet radiation (UV-light) and moderate oxidation with ozone for the treatment of the water.

"We considered many possibilities and decided to use low pressure UV-lamps in the UV-reactors", says Rasmus Folsø. The low pressure lamps generate 30 percent UVC-light. The corresponding figure for medium pressure UV-lamps is only 18 percent. In addition, the low pressure lamps allow for a compact design. The UV-light only has to penetrate a few centimetres of water. This is important because fresh water is often very opaque.

After leaving the UV-reactors the water is mixed with a moderate amount of ozone, created by the UV-lamps. The ozone is an efficient disinfectant regardless of the colour and murkiness of the water.

The system has been tested and proven effective in all salinities, including fresh water. It is type approved by Lloyds Register of Ships and fully complies with the requirements and guidelines adopted by the IMO. It is also in compliance with the US Coast Guard discharge standards which were published in june 2012 and will enter into force from December 2013.

Partners:

**A. P. Moller – Maersk**
One of the world's largest shipping companies

**DESMI**
Leading provider of pumps for the marine industry

**Skjølstrup & Grønborg**
Specialised in sophisticated water treatment

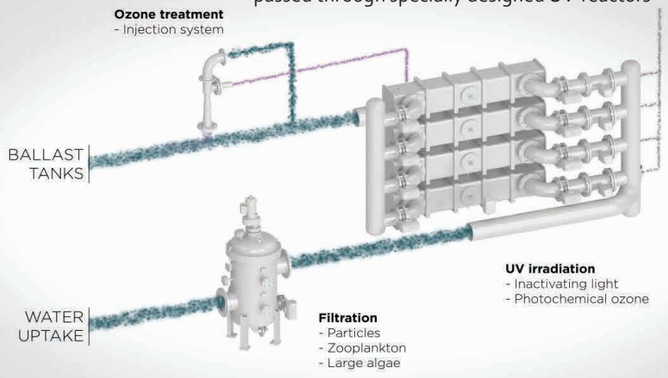
## *The Technology:* EFFECTIVE USE OF UV-RADIATION

The ballast water is first filtered by a 30 micron (3 hundredths of a millimetre) self-cleaning filter. This filter removes the vast majority of organisms larger than 50 micron.

The next step is UV Irradiation, which kills most of the remaining organisms. The water is passed through specially designed UV-reactors equipped with low pressure ultraviolet (UV) lamps. Each reactor has a flow capacity of 100 cubic metres of sea water per hour, or 75 cubic metres of freshwater. Built-in sensors measure the salinity, and the flow is automatically regulated.

The final step is ozone treatment. Each UV lamp is surrounded by a quartz tube. Air is drawn through the gap between the lamps and the quarts sleeves. Ozone is formed when the oxygen molecules in the air are hit by UV-rays. This ozone is mixed with the water leaving the UV-reactors. Ozone is a highly effective disinfectant, even in turbid water. The concentration is kept high enough to deal with the organisms that were not hit by UV-radiation, but low enough to present no risk to the crew or the ship, such as corrosion of tanks, pipes and pumps.

In spite of this treatment, some organisms may survive and grow inside the ballast tanks during long voyages. The water is therefore treated once again before it is discharged.

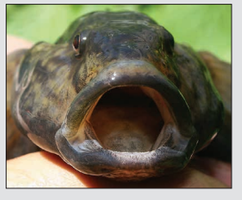



## INVADERS FROM THE SEA

The Comb Jelly was introduced to the Black and Azov Seas in the 1980s. It reproduced rapidly, depleting zooplankton stocks. The anchovy and sprat fisheries were wiped out. An estimated US$ 200 million annually were lost. In 1999 the species was further introduced to the Caspian Sea through the Volga-Don Canal, here again with devastating impact on fisheries and marine life.

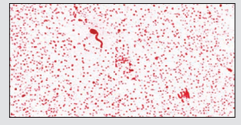
The Zebra Mussel, is native to the Black Sea. It has been introduced to Europe and North America. It fouls hard surfaces in mass numbers. Water intake pipes, sluices and irrigation ditches are blocked. Estimated costs in the USA: US$ 500 – 1,000 million between 1989 and 2000. The Golden Mussel was introduced in Argentina in 1991. It spreads through the Plata river basin system at a rate of 250 kilometres per year, damaging fisheries, hydropower plants and other infrastructures. It is now close to the famous tropical wetlands, the Pantanal.

The Chinese Mitten Crab is found in densities exceeding 10,000 per square metre in the San Francisco Bay. It is also common in the Thames area. It preys on native fish and invertebrates, and undermines river brinks and dykes. The crabs are seen in large numbers during their spectacular migrations. They are feared in areas with native crab fishery.



The Round Goby has spread from the Black, Azov and Caspian Seas to the Baltic Sea and North America. It competes for food with native fishes and preys on their eggs and young.

Toxic algae may form algae blooms. They can devastate marine life and foul beaches. Consuming contaminated shellfish may cause severe illness in humans.



Vibrio Cholerae. Some cholera epidemics appear to be directly associated with ballast water.

Invaders from The Sea, a BBC-IMO documentary, can be seen at Youtube.

# TINY HOLES WITH A GREAT EFFECT

*Cleaned water pass through LiqTech's ceramic membranes at an astonishingly high rate*

As the world's oil wells mature, more and more oily water is produced along with the remaining oil. Some of the water was already there from the beginning, beneath the oil. However, more and more water also intrudes from the surroundings over time. Finally, oil companies have a custom of injecting water into the wells to force the last remnants of oil to the surface.

Discharge of oily water is harmful to the environment, and the authorities in many countries are now tightening the legislation.

### Membranes are better than centrifuges

Oil companies therefore need efficient technologies to separate oil from water. Traditionally, they have used centrifuges called hydro-cyclones. To some extent, oil can be separated from water by a hydro-cyclone, because water is heavier than oil. The process, however, is not very efficient, nor is it very stable.

Membranes with ultra-fine pores can easily produce much better results. Some of the membranes, however, have been too expensive until now, while others have been too unefficient or instable.

This has changed with the development of LiqTech's membranes, made of silicon carbide. Thanks to the unique properties of this material, the porosity of LiqTech's membranes is very high. The flow of liquid through the pores is five to ten times higher than for similar ceramic membranes. Compared to membranes made from polymers, the overall performance is up to 40 times better.

"People just don't believe it is true, when we present our test results at international fairs and conferences", says Sales and Marketing Coordinator Daniel Sereth Larsen at LiqTech.

On top of this, the extremely hard material is chemically inert and mechanically very durable.

### LiqTech membrane at work in the North Sea

The first full scale installation for the filtering of oily water was delivered to an offshore oil platform in the North Sea, by the Danish company Semco Maritime.

The pore size of the LiqTech membrane being used for this purpose is 0.04 micron (thousandth of millimetres), which means that the membrane easily removes all particles, solids, and oil down to a concentration far below 5 milligrams per litre. In fact, 99 percent removal of oil (down to 0.2 mg per litre) has been obtained in tests. The filter is approximately one meter long with a diameter of 14.6 centimetres. The surface of the many channels inside the ceramic is large, in the order of eight square meters. The flow of filtrated, purified water through each square metre of surface is up to 1,200 litres per hour.

## *The Technology:* VERY HARD, YET HIGHLY POROUS

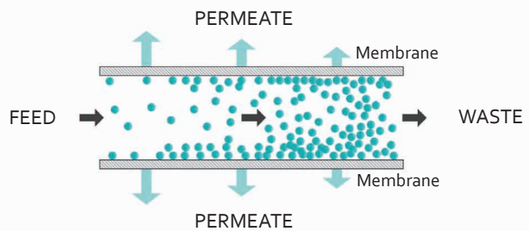
LiqTech membranes are made solely from Silicon Carbide, which is one of the hardest and most durable man-made materials. The porosity is very high, approximately 45 percent. The membranes withstand harsh chemicals, high temperatures, high pressure, and mechanical stress. The shape of the ceramic is a cylinder with parallel flow channels extended through the element. The number of channels vary according to the application. The inner surfaces of the channels are coated with one or more layers of silicon carbide with different grain and pore size.

In this way the desired combination of pore size, inner surface and flux is obtained in one monolithic structure, made from one material.

In cross-flow filtration the liquid to be filtered flows into the channels under pressure (Black arrow, left). Much of the liquid penetrates the pores of the membrane (blue arrows); cleared liquid is collected at the outer surface of the cylinder. In the remaining liquid, the concentration of impurities increases (blue dots).

LiqTech supplies membranes with pore sizes ranging from 0.04 to 10 micrometres. Due to the high porosity, the flux is higher than for any similar membrane.

CROSS-FLOW FILTRATION






### Reuse of treated wastewater

LiqTech's membranes are suitable for a wide range of other applications. One example is filtration of wastewater. When the water leaves a traditional wastewater treatment plant, it is not entirely clean. It still contains impurities and contaminants. Usually it is discharged into rivers, lakes, and seas, leaving the final treatment to Mother Nature.

If, instead, it is passed through ceramic filters, it can be transformed instantly into a valuable resource for watering, irrigation, cooling and industrial processes. This is an attractive option, particularly where water is scarce.

Recently, the ultra-filtration membrane was approved for liquid sterilisation. "Besides drinking water, we see a huge potential in biotech and food & beverage applications", says LiqTech CEO Lasse Andreassen.

### Many promising applications

The filters can be used to produce drinking water from the surface water of lakes and rivers, and for pre-treatment of seawater prior to desalination. LiqTech membranes are also used to treat pool water, coal mine tailing ponds and protein recovery.

Other promising applications are the treatment of hospital wastewater and of ballast water to avoid the risk of invasive species in marine environments.

An on-going project in China is testing the use of membrane filters to secure safe drinking water, free from bacteria and with very low risk of viruses.

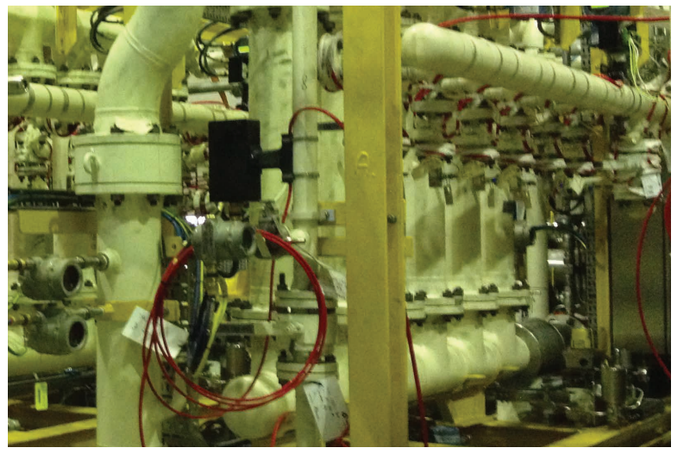
LiqTech membranes are also used to treat pig manure. Ultra-filtration can separate the troublesome livestock manure into reusable water and nutrient-rich dry matter, ready to be used as fertiliser.

Daniel Sereth Larsen expects LiqTech filters to be much more commonly used in the future. Large scale production will lower the cost of purchase.

### High flux maintained

Any filter may be clogged, especially if the water is slimy, but LiqTechs membranes can withstand cleaning with harsh chemicals, strong oxidisers, and high pressure.

LiqTech has developed a special back-flush system to maintain high flux: The Back Pulse Hammer induces block pulses at high frequency back through the membrane in order to keep the surface and the pores clean.



LiqTech filter installed at an offshore oil platform

LiqTech INTERNATIONAL

LiqTech provides higly durable ceramic membranes for filtration and air pollution controlv

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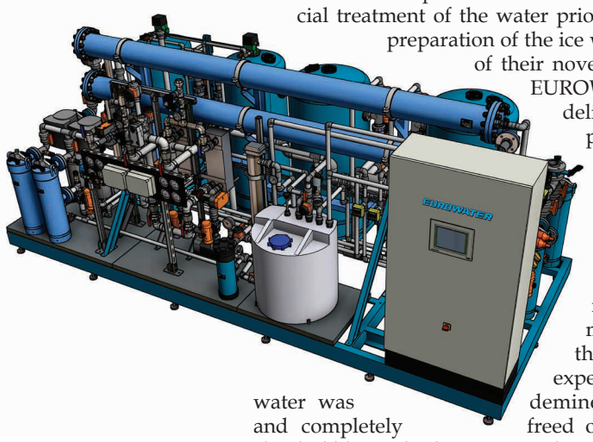
# PURE WATER – PERFECT ICE


*Fast ice is a very sophisticated technical specialty. A Danish company provides a basic technology for the Olympic Winter Games*

The ice stadium in Sochi, Russia, is ready for the Olympic Winter Games to take place in 2014. The ice for this rink is made in Denmark. Well, not exactly, but the water for preparing the ice is processed at a plant made by the Danish company EUROWATER. The water to be used for generating such ice must be very clean indeed.

### Water for the fast track

Milliseconds count in speed skating. When Kazakhstan won the bid to host the 2011 Asian Winter Games, they decided to build a large ice stadium in Astana. The task to create the fastest ice possible was entrusted to Bertus Butter and Marcel Boukens – two renowned Dutch specialists in the field. Special treatment of the water prior to the preparation of the ice was one of their novel ideas. EUROWATER delivered a plant for treating the water to the exact quality requirements of the Dutch experts. The demineralised water was and completely freed of particles, bubbles and salts. Apparently it worked well:




Nine continental records were set during the Games, and the water treatment, according to Marcel Boukens, played a substantial role in making the ice rink a "fast track".

### No malfunctions tolerated

For the Winter Olympic Games in Sochi, EUROWATER has supplied a similar plant. The plant was produced and mounted on a frame at EUROWATER's factory in Denmark.

As always, the Olympic Games are prestige projects. Certainly, the organisers would not like to have their events disrupted by technical malfunctions. Therefore, they requested a thoroughly tested and entirely reliable plant. Fortunately, this is one of EUROWATER's core competencies.

Additionally, the plant has been designed for low consumption of water and energy.

### They come in many combinations

EUROWATER supplies special water treatment plants for various purposes to utilities and industries in many countries. The company's strength is its technical knowledge, long experience and wide range of well proven standard equipment.

In most cases, the customers' demands can be met by frame mounting a combination of EUROWATER's standard components. The plants can also be custom-made to fulfil specific requirements. In any case, most of the components are original parts, manufactured at EUROWATER's own factory.

The range of products include pressure filters, activated carbon filters, deaerators, dealkalisers, softeners, dosing pumps, membrane filters, chemical and electronic removal of salts, and disinfection.

If temporary water supply is needed, it is possible to rent a container unit at short notice. It is ready for operation as soon as the water pipes and power cords are plugged in.

### Extremely pure water

Many reverse osmosis units have been supplied, in particular to treat water for use in steam boilers, and to provide demineralised process water for industries. Reverse osmosis removes 98 percent of the salts. The rest can be removed by ion exchange or electro-de-ionisation. EUROWATER supplies these technologies to customers who need ultrapure water, such as hospitals, pharmaceutical companies and electronics.

Breweries, soft drink producers, distilleries and food industries often need water with very specific qualities. In such cases, EUROWATER designs individual plants for filtering, softening, and demineralising of the water.

EUROWATER strives to minimise the environmental impacts and to avoid unnecessary consumption of water and energy. An example is the newly developed reverse osmosis plant, RO-PLUS.

EUROWATER provides technologies for almost any kind and grade of water treatment. The company has more than 75 years of experience in the field

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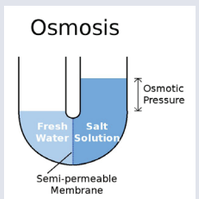
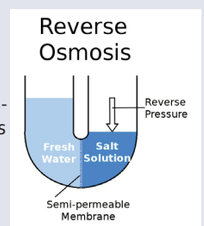
## REVERSE OSMOSIS

Semi-permeable membranes for osmosis have pore sizes about 0.0001 microns (a micron is a thousandth's of a millimetre). Water molecules are very small; they can pass through these pores. Larger molecules and ions cannot.

At one side of the membrane is pure water. At the other side is water with a solution of some salt. The water molecules will move through the membrane towards the saline side, attempting to make the concentration of salts more equal. This process is called osmosis. It stops when the pressure becomes high enough to make up for the unequal concentrations.



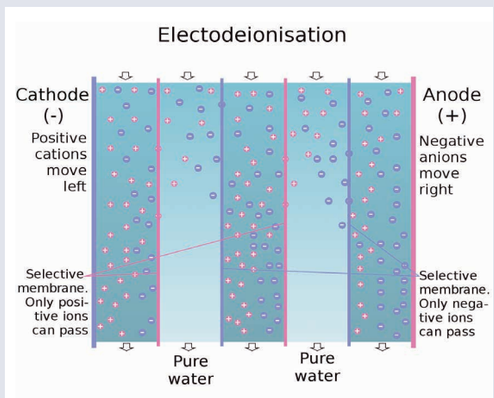

The process can be reversed by putting the solution under excess pressure. Due to the pressure, the water molecules will move to the other side of the membrane. The result is purified, demineralised water.




## REMOVAL OF IONS

When mineral salts are dissolved in water, they separate in positively and negatively charged ions. Consequently, the salts can be removed chemically by binding the ions to other ions. This technique, called ion exchange, is used i.e. to soften water.

Salts can also be removed with electro-de-ionisation, EDI. The water flows through channels divided by selective membranes which are alternately permeable to positive or negative ions only. The positively charged ions move left toward the negative cathode. The negatively charged ions move right towards the positive anode. None of them, however, can pass more than one membrane before they are trapped by the next one. In this way the ions are concentrated in every second channel.



# THE PERFECT WATER FILTER

*Bio-mimetic membranes that imitate Nature's way of filtering water have the potential to revolutionise the world's water treatment*

In the course of evolution, the cells of living organisms have perfected their ability to purify water. Natural proteins, called aquaporins, are superior to any man-made filter technology.

The Danish cleantech company, Aquaporin, has made a filter that copies Nature's method.

### The plumbing system of cells

Aquaporin molecules are part of the membrane that covers the surface of living cells. They form pores in the membrane, known as 'water channels'.

Water molecules can pass swiftly through the channels, but only in single file, one by one. Larger molecules and electrically loaded molecules cannot pass through.

The aquaporins were discovered in 1992 by the American molecular biologist Peter Agre and his colleagues. Peter Agre has called the aquaporins "the plumbing system of the cells". He received the 2003 Nobel Prize for the discovery.

### Teflon-coated water channels

"Imagine a channel internally coated with Teflon", says Mark Perry, a biophysicist who joined Aquaporin A/S in 2007 and now works as COO of Aquaporin Asia Pte. Ltd. "As soon as the water has entered the channel, it passes very quickly. There is very little resistance. On the other hand, the selectivity of the channel is extremely high. Virtually nothing else can pass the channel. The result is 99.999995 percent pure water."

One of the scientists that has explored the function of aquaporins is the Danish biophysicist, Morten Østergaard Jensen.

His computer simulation of water passing through the aquaporin channel inspired himself and his friend Peter Holme Jensen to found Aquaporin A/S in 2005.

### 'Artificial kidneys' on an industrial scale

In human kidneys, aquaporins are working very hard. Each day more than 150 litres of water are filtered and purified by the kidneys and reabsorbed by our body.

The efficiency of this built-in biological filter is much higher and less energy demanding than any mechanical water filtration or purification yet invented.

"Our objective is to produce 'artificial kidneys' on an industrial scale", says Mark Perry.

### Bio-nanotechnology at work

Synthetic aquaporin membranes have the potential to revolutionise the world's water treatment. However, the road from idea to practice has been paved with demanding challenges. After seven years of concerted research and development efforts in biotechnology, nanotechnology, and engineering, Aquaporin has launched its 'first generation' bio-mimetic membrane.

"It doesn't unfold the full potential, but it is very efficient and sufficiently effective to be marketed", Mark Perry says.

### Singapore venture

Since 2009, the new technology has also been developed in a 3 million US$ Environment & Water Industry (EWI) funded project, in collaboration with DHI Singapore and Singapore Membrane Technology Centre (SMTC) under the NEWRI institute of Nanyang Technological University.

"The ultimate aim of this project is the desalination of water. We contributed with four years of research results. In return, Aquaporin A/S is the majority owner of Aquaporin Asia", says Mark Perry, who is the Chief Operating Officer at Aquaporin Asia.

### Special applications

At present, the technology is too expensive to be used for desalination of seawater and ordinary filtration. Instead, Aquaporin is in the process of marketing the membrane for special applications where highly efficient water purification is of great value, such as hospitals, medicine, the pharmaceutical industry, and others. One such application is the place in the world where a bottle of potable water is more scarce and expensive than anywhere else: In manned spacecrafts.

AQUAPORIN

Aquaporin is a biotech company where the scientists strive to create some of the world's most efficient membranes for water filtration

*Company Profile page 87*

## *The Technology:* MOLECULAR PUZZLE


Extract some aquaporin proteins from the cell membranes of a spinach plant. Mix them carefully with biocompatible molecules until you have a formulation that resembles the membranes of living cells.

Now spread the formulation on the surface of a micro-porous filter membrane, cover it well, and ensure that the formulation remains at the surface, even when you flush water through the filter.

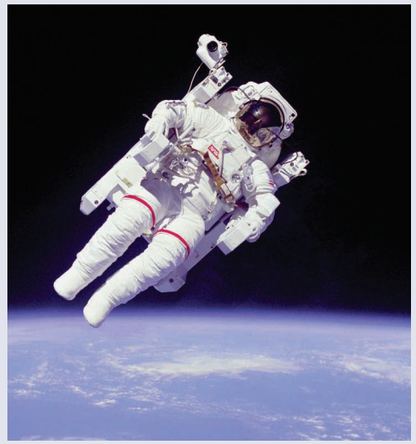
This is the recipe for making an Aquaporin Inside™ membrane.

Sounds simple? Well, it is not. Every single step in the making of the membrane was completed only through the hard work of a team of scientific specialists in the fields of molecular biology, biochemistry, biophysics, chemistry, and engineering.

The 'bio-mimetic' membrane must imitate nature's cell biology – which was developed through millions of years - in an industrially suitable way.

Among thousands of possible combinations, the team had to find the matrix of large biocompatible molecules best suited to incorporate the aquaporins in bio-mimetic membranes. They also had to find a 'glue', suited to make the formulation stick to the supporting substrate. Finally the whole thing had to be integrated at the surface of feasible micro-pore membranes.

## Astronaut urine transformed into potable water



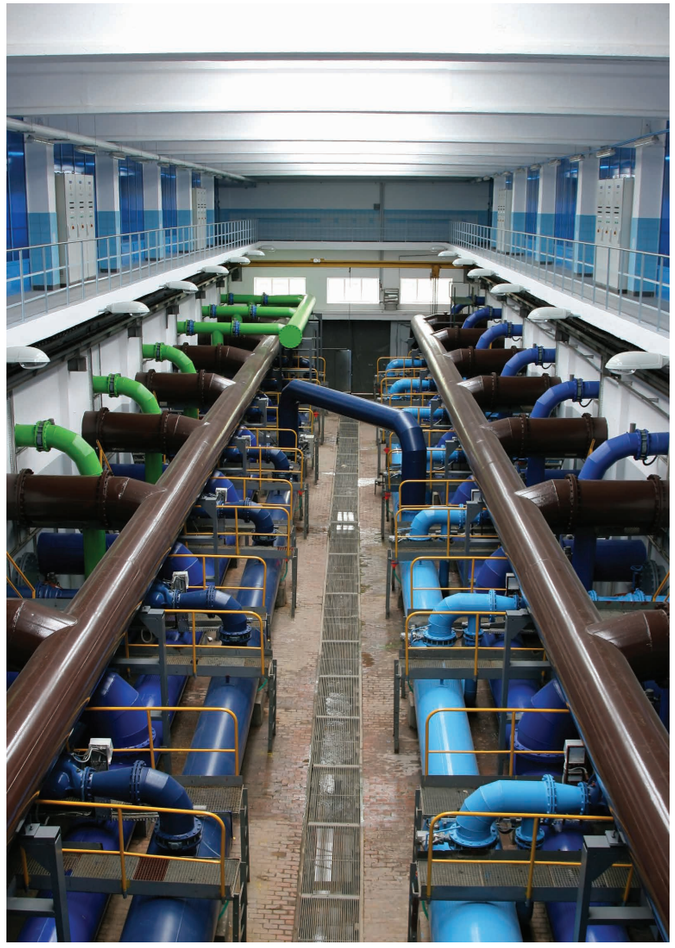
In outer space, a bottle of water is really expensive. It costs about US$ 20,000 to put a litre of water into orbit. No wonder the American Space Agency, NASA, is looking for ways to reuse yellow water (urine) and other body liquids of the astronauts instead.

The Aquaporin Inside™ membrane has been tested at NASA's facilities. According to the head of NASA's Advanced Human Support Technology Research Group, Michael Flynn, the membrane comes very close to fulfilling the requirements. It performed better than similar membranes that were previously tested. The urea was almost totally rejected.

Aquaporin A/S is now participating in a project with NASA Ames in the design of a lightweight filtering bag that may be tested in a spaceflight next year.

*Key to savings and secure water management*

# CONTROL THE FLOW



*The water network management system developed by 7-Technologies is used by more than 1.500 cities to avoid the waste of water, waste of energy, waste of money and waste of time*

There is really no point in increasing the production of clean and safe drinking water if much of it gets lost in transition to the consumers. In a world of rapid urbanisation and water scarcity, it is increasingly important to utilise existing water resources efficiently.

Usually, water utility companies are in good control of their water sources and waterworks. This part of their activities, however, represents only one fifth of their total capital investments.

The water network management system help them controlling the remaining 80 percent. The distribution network is often a mixture of modern and older, and in some cases obsolete, pipes.

### Accurate modelling

The hydraulic computer modelling system was developed by 7-Technologies, a Danish subsidiary of Schneider Electric. When fed with data, it can simulate the performance of an entire network. The data required are digitalised maps of the network, reservoirs, pipe dimensions, pump capacities, supply pressure, flow rates, and billing system information on usual consumption patterns.

With real-time data from the utility's supervision and control system and strategically positioned sensors, the system can calculate what the flow and pressure at any critical point in the network should be. The user interface translates this complex information into a simple decision making tool. It can be used to overview the system and operate it in a cost-efficient and environmentally friendly way.

### Optimal use of water and energy

Without this ability to calculate and monitor performance and consumption in real time, the operator would have to play it safe and maintain excessively high pressure in order to be sure of continuous supply even at peak hours. Using the water network management system, the pressure can be lowered to an adequate optimum. Optimal use of reservoirs, valves and pumps and optimal regulation of flow and pressure leads to better service at lower operating costs. If pressure is increased to compensate for water losses, the leakage and the risk of further leakages increase too. It is a vicious circle. Lowering the pressure reduces the risk of leakage. Leakages in specific zones can be detected and pinpointed by comparing current water flow in a time period of known minimum consumption with data from the same period in recent weeks. Leakage alarms can automatically be triggered at a predefined threshold. In this way, much costly and complicated digging and repair can be avoided and the remaining necessary renovation can be rationally planned and prioritised.

Further savings of water and energy can be obtained with the optional Pressure and Pump and Reservoir Optimisation modules. The modules combine the above mentioned data with external data such as weather forecasts, varying power prices and other operational costs.

Typically the return on investment is less than two years, because of reduced electricity consumption and reduction of leakage. The $CO_2$ emissions are reduced by 10 – 20 percent.

### Logging, warning, planning

The system continually logs the operation activities. Extensive documentation is available to staff members and to regulatory authorities on demand. The reliability of supply is strengthened because the system can warn the operator of any event that may impact the volume, pressure or quality of water. It is easy to perform 'what-if'-analyses of any contingency, thereby avoiding errors.

The system is also a unique tool for planning and design. Based on known performance, the consequences of different choices can be evaluated before expensive construction works are decided.

7-Technologies has developed software for management of water networks, district heating networks, and industrial automation

*Company Profile page 108*

## *The Technology:* SIMULATING THE REAL FLOW

On the screen, the entire network and each part of it can be monitored with the network management software. The tool can be handled by non-specialist members of staff.

Behind the screen, complicated math is at work. Calculating the flow and pressure in water pipes may sound like ordinary work for water supply engineers.

Actually computer simulation of entire distribution networks is a very demanding task. Advanced hydraulic modelling algorithms are required.

The Technical University of Denmark has a good reputation in hydraulics and the software developers at 7-Technologies are highly skilled hydraulic experts with an average of 20 years of experience.

Unlike other modelling tools, used for static analyses and planning, this system uses real-time data, enabling operators to make proactive, dynamic decisions. Optional add-on modules further optimises leak detection and provides advice for cost-effective regulation of production, pressure, and pump operation.

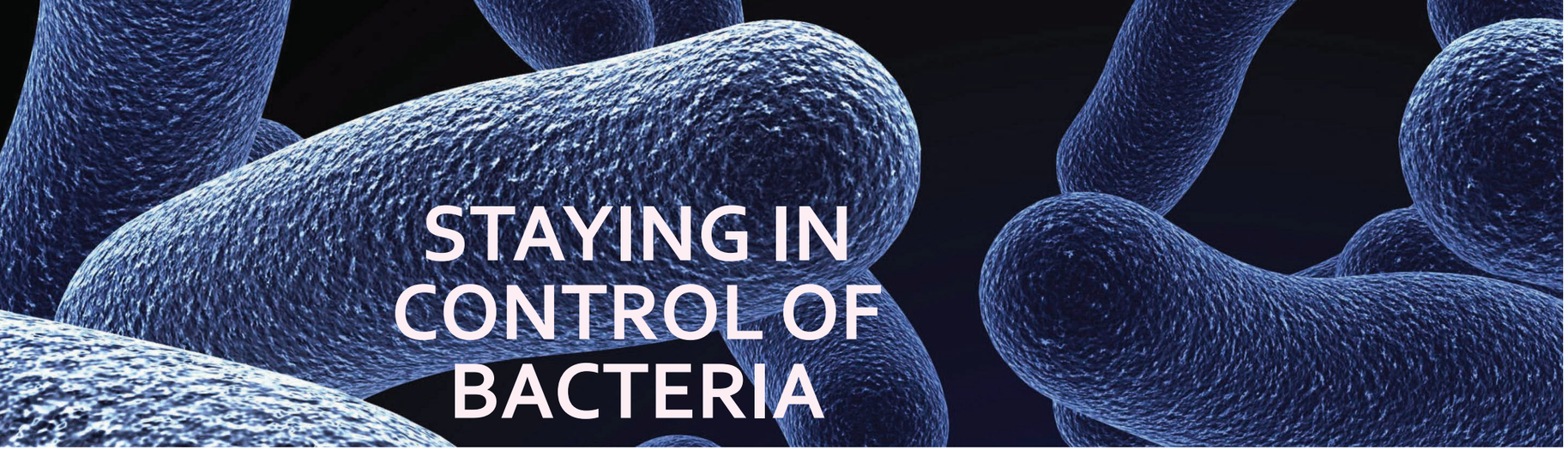
## Kuala Lumpur: ON TRACK TO HALVE WATER LOSSES

In Kuala Lumpur, water loss is a vast problem. The water company SYABAS supplies water to 6,000,000 consumers in the Malaysian capital and its surroundings. 3,800 million litres of water are produced each day, but a third of it is lost in distribution and never paid for (Non-Revenue Water).

Now, equipped with a real-time water network management system, SYABAS is on track to reduce the costly waste of water and energy. The goal is to curb Non-Revenue Water from currently 32 to 15 percent. Significant savings have been achieved already.

Much of the existing network's 24,000 km of water pipes are in a poor state. To find the leakages and repair them the traditional way would be extremely expensive. The system makes it possible to gain an overview of the entire network and to improve and optimize operation. Pressure losses due to leakages and unintended use are detected and the models help SYABAS to plan for future development and pipe replacements.

Malaysia experiences serious shortage of water. At the same time major extensions of the water supply systems are needed. Consequently, it makes good sense indeed to invest in better utilisation of the water already available.



# STAYING IN CONTROL OF BACTERIA

*A new on-site rapid method to detect bacterial contamination in water has reduced analysis time from days to minutes*

Early detection of bacteria in drinking water and industrial process water is of utmost importance. Bacterial contamination is a serious potential health hazard. In the industry early warning can reduce water system downtime and reduce costs.

With standard lab analysis, it can take up to 2 or even 7 days to grow bacteria cultures in order to determine if the water, e.g. in urban water supply, is contaminated.

The Bactiquant®-water test reduces the time required from days into minutes. The concentration of bacteria in a filtered sample of water can be determined in less than half an hour, and potential problems can be identified before they become critical.

### Comprehensive and quick results

The Bactiquant®-water test was developed by the Danish company Mycometer. The test has been extensively documented by customers worldwide and has recently been verified by the United States Environmental Protection Agency (US-EPA).

"The conventional methods used for detection of microbial contamination of water are labour-intensive, time-consuming, and sensitive to errors during the performance of the tests", says Morten Miller, co-founder of Mycometer. "Our method is quick. Even if the concentration of bacteria is low, the test can be completed in less than half an hour. It strengthens the ability to respond quickly and appropriately".

### Regaining control

Bactiquant®-water measures a specific enzyme-activity in bacteria. A water sample is passed through a filter and an enzyme substrate is added. When bacteria are present, the enzymes trigger the release of a fluorescent substance. The fluorescent light emitted by this chemical is proportional to the concentration of total bacteria.

"Our method is particularly suited to document and evaluate different water treatment methods. If, for example, a method for the removal of bacteria does not work as it should, you can quickly detect it, respond to it and regain control", says Morten Miller.

### Action on critical thresholds

The full advantage of the technology can be reaped by frequent and regular monitoring of the water quality. Mycometer provides data software to help customers establish baselines for normal operation and to define thresholds for response actions.

On this basis, statistical changes can be detected at an early stage. It is therefore possible to prevent problems from occurring, rather than using many more resources to correct them after they have occurred.

The method is easy to handle and the chemistry is simple and robust. Test results have a high reproducibility and repeatability as documented by the US-EPA. The detection limits are low and the sensitivity is easily adjusted Bactiquant®-water is available as a portable test kit ready for use on site. A stationary version is also available, allowing simultaneous filtration of five bottled samples.

In addition to the equipment and the data handling software, Mycometer also provides training and a Quality Assurance Package allowing for in-house proficiency testing of staff.

### Flexible use for many purposes

The versatility of the system is very high. Samples of potable water, process water, recreational water and liquid industrial products can be analyzed – along with suspended or dissolved surface samples. The method can also be used to detect microbial problems in water treated for reuse and in water humidification equipment.

Many water utilites and consultancy companies in Denmark, Scandinavia, other European countries and the Middle East use Bactiquant®-water.

"The method is relevant for producers and suppliers of water throughout the world", says Morten Miller. "Bottled water, tap water, process water, food & beverage industries, and many others".

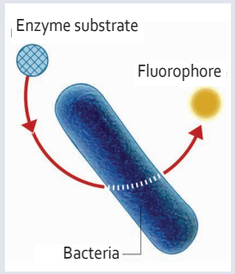
EARLY WARNING - The test can be performed on site and the result is available at short notice

mycometer
rapid microbiology – on-site technology

Based on micro-biological research, Mycometer has developed rapid tests for detection and quantification of mould and bacteria

*Company Profile page 105*

## *The Technology:* TRACES OF BACTERIA GLOWING IN THE DARK




Fluorescent objects emit light when exposed to light. If all bacteria were fluorescent, they would be easy to detect. You would just have to illuminate them and wait to see, if they emit light as a result.

Bacteria are not fluorescent. Nevertheless, Mycometer has developed a method to measure their concentration in water using highly sensitive fluorescence technology.

The method does not detect the bacteria themselves. Instead, it quantifies the amount of microbial enzymes. The concentration of these enzymes is equivalent to the concentration of the bacteria themselves. Bactiquant®-water targets a naturally occurring enzyme activity in bacteria. The enzyme activity is present in a broad spectrum of bacteria, representing all major taxonomic groups, including gram negative and gram positive bacteria as well as aerobic and anaerobic bacteria. The enzyme belongs to a class of enzymes called hydrolases. Bactiquant®-water is very sensitive to the presence of bacteria in water samples including suspended as well as bacteria immobilized on particles or in aggregates.

The method follows the following steps. First bacteria in the water sample is concentrated on a filter. Then an enzyme substrate is added directly to the filter. The substrate contains enzyme specific moieties combined with a fluorophore.

The enzyme specific moieties are molecules that are especially inclined to combine with certain microbial enzymes. When they do so, the bond to the fluorophore is broken.

The fluorophore is a fluorescent chemical compound. When illuminated with light at a wavelength of 365 nanometres (barely visible ultraviolet light) it emits light that can be measured at 445 nanometres (blue light). The intensity of the fluorescence is proportional to the concentration of bacteria.

The entire procedure takes 10 – 30 minutes, and it can be undertaken on-site.

# THE SOUND OF WATER

*Leaks in water pipes are not easy to find, but sensitive noise-loggers can reveal their hiding places*

Jørgen W. Koch

It is amazing how much they can hear at Leif Koch's. The company specialises in listening to the sound of water leaking from burried water pipes.

The skills they possess are urgently needed. Water leaks are increasingly a problem, especially in countries and regions where water is scarce. Acoustic leak detection can save the water utility companies a lot of trouble, digging, manpower, and money.

### A matter of experience

The principle is simple: If you hear water running in the pipes when all taps are turned off, there must be a leak somewhere.

The practice, however, is complicated. Babbling water is not exactly the only sound to be heard in the underground of London.

Precise instruments are needed to record the sounds. Complicated computer calculations are needed to analyse them. Comprehensive knowledge is needed to place the instruments in the right position, and to make sure that the computer interprets the information correctly.

"It is not rocket science, but it is built on craftsmanship, knowledge and experience gathered through many years", says Jørgen W. Koch, the owner and CEO of Leif Koch. "My parents founded the company in 1974. I joined the firm in 1980. At the time, Germany was a front runner in water leak detection. Today, Denmark is", he says.

### Underground leak detectives

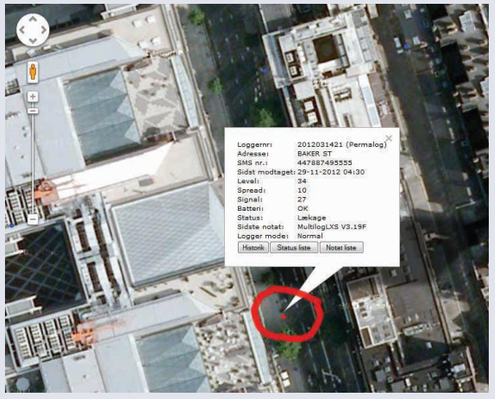
Microphones have been used to listen for leakages since the 1920's. Today's instruments are much more sensitive. They amplify the signal 200,000 times and some of the interference from extraneous noise sources is filtered out.

By the end of the 1990's, Leif Koch began using noise-loggers. They are small, robust units, which are fastened to pipe fittings with strong magnets, either temporarily or permanently. They are used to listen for the sound of water leaking from the pipes at night, as this is when consumption is minimal.

"In the beginning, one or two alerts from the loggers were genuine leaks, the rest were false alarms", Jørgen W. Kloch tells. "We had to adjust them to improve their reliability. Now, we have gained the experience required to exclude the noise of a compressor at the grocery store, a pump, a district heating pipe or a cab. Today there is almost certainly a leak each time we get a red alert from the loggers."

## *The Technology:* ALMOS LEAK

A leak is detected in Baker Street, London

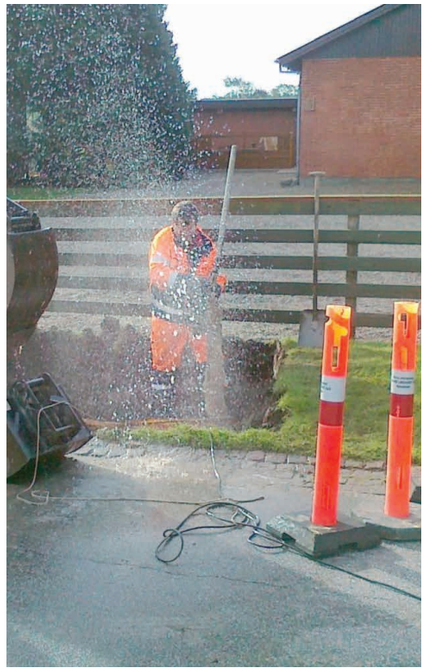



ALMOS LEAK is a truly global leak detection system. The letters stands for Acoustic Leak Monitoring Online System. Highly sensitive noise loggers record the sounds in pipes at night. They transmit the collected data to the internet via radio signals, typically using GPRS/SMS mobile network services. The next morning, users anywhere in the world can view their leak-situation at a glance via the internet. No special software is required. They only need to log in at the website www.almosleak.com.

The tuning of the loggers and the link to the internet are important, but the analysis of the noise-data is crucial. Based on significant experience, Leif Koch has adjusted the algorithms used by the software that constantly analyses the incoming data, compares them to historic data and evaluates the validity of leak alerts. As a result, the software is able to distinguish the steady sound of a leak with high probability.

The state of the loggers is listed on the webpage and shown on Goggle Maps. Blue dots indicate 'normal' state, red flashing dots indicate a leak. With a mouse-click on the dot or the list, the user gets detailed information, including historic data. The system can handle online flow- and pressure-data too. In this way, it is possible to evaluate the size of the leaks. The settings can be changed online.





### Log in to see your leaks

"In 2009, we got the idea to connect the loggers to the internet. In cooperation with the Copenhagen water utility company, we developed ALMOS LEAK. So now, users anywhere in the world can access their leak information by visiting our website almosleak.com", says Jørgen W. Koch.

ALMOS LEAK saves manpower and money. In the past, it would take several months to examine the networks of an area. With loggers permanently connected to ALMOS LEAK, an examination takes place every night. Leaks can be localised and repaired at once. Large water losses and the undermining of pavements can be avoided. The risk of contamination of drinking water during tre repair of water mains due to unknown holes is drastically reduced.

### Pinpointing the leaks

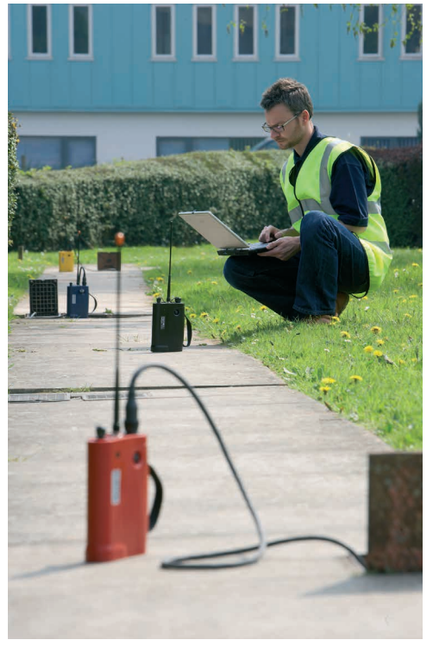
When a pipe is found to leak, the next step is to pinpoint the whereabouts of the hole precisely before digging. This can be done in several ways. One method is to put a microphone at each end of the pipe and measure how long it takes the sound to travel to reach each microphone.

Again the principle is simple, but the practice is demanding: The speed of sound depends very much on the dimensions of the pipes, the materials used to make them, and the density of the surroundings. Throughout the years, Leif Koch has refined this method, which is called correlation.

### Lower pressure reduces water loss

Another method to detect leakages is pressure measurement. Battery powered pressure meters and controllers can be connected to ALMOS LEAK and used to evaluate the amount of water loss in an area. They can also be used to control the pumps and lower the pressure to the minimum required. Lower pressure means less leakage.

Jørgen W. Koch remembers walking the streets of Cairo by night a couple of years ago. "I could see water leaking from water taps even though they were turned off. This is because the Egyptian water providers maintain a constant high pressure around the clock to be sure that they are supplying even the farthermost customer. In Cairo they produce 6 million cubic meters of water each day, and they are going to invest millions of Euro to increase their supply, but they could reduce their water losses by 1 million cubic meters simply by controlling and regulating the pressure."



Left: The position of the leak is calculated on site

Below: Noise loggers listen and transmit the sound

Leif Koch A/S is specialised in detection of leaks in water pipes. The company has helped many water companies in Denmark and abroad to reduce their water losses

*Company Profile page 102*

# MANAGING SCARCE WATER

*Integrated use of new technologies helps the Abu Dhabi Authorities manage water resources much more efficiently*

Water is definitely scarce in Abu Dhabi. Precious drinking water is made from seawater, and the demand is rapidly growing. However, until recently, a third of the water was lost in distribution.

The sewer system has its problems too. The capacity is insufficient. Street- and basement flooding is quite frequent. The flooding events are costly, unhealthy, and very unpleasant. Hydrogen sulphide, which smells like rotten eggs, is formed in the hot climate.

### Front runners from Denmark

The Danish consulting engineering company NIRAS is assisting the Abu Dhabi Water and Sewerage Authorities in solving these problems and improving their performance.

"We may have been chosen because Danish water management has a good reputation. Most of the world's water companies produce much more water than is actually paid for. People lift their eyebrows when they hear that the best performing utilities in Denmark have water leakages measuring only 2-6 percent", says Project Director Klavs Høgh.

### Modelling: A powerful tool

The purpose of the Abu Dhabi project is to reduce water leakages to below 10 percent, to prevent sewerage flooding, and to implement an online system for improved management of the activities. The water distribution system was analysed and a computer model of the daily flow of water in the entire network was installed. Such a real-time hydraulic model is a powerful tool for leak detection, network maintenance, operations and strategic rehabilitation planning, explains Klavs Høgh. The computer model builds on comprehensive databases of the location and state of the pipes, the pumps and valves and their operations, the meters and metering, the input of water and the billed consumption, the records of leaks and repair, the local impacts from road traffic, combined with online information of flow and pressure.

The model is able to calculate the water balance. The loss of water in the mains, service pipes and storage tanks in each district can thereby be identified.

"It is important to evaluate and consolidate the data", says Klavs Høgh. "Thorough work at the desktop can reduce hard work in the field".

No need to search for leaks and dig in vain if the problem is actually unregistered service connections, unauthorised consumption, or defect meters.

### Proof of the pudding

Leaks are detected with noise loggers. These are small electronic devices that measure the sound of water escaping the pipes.

"To our satisfaction, we were able to convince our customer by discovering a major leak only a couple of days after the first loggers were installed. 200,000 cubic meters of water a year was leaking at a location with loosely compacted sand, and nobody had noticed it", says Klavs Høgh.

The model is also useful for saving energy by optimising the pump operations and for calculating which parts of the system are most in need of maintenance, repair, and replacement.

### Prediction and avoidance of flooding

The sewerage is improved in much the same way. Well positioned online sensors measure the flow, the level, and the composition of the sewage, and the formation of bad smelling hydrogen sulphide. The information is processed by a computer model that simulates the flow in the system.

"When we have ascertained that the data are valid, complete and reliable, we are able to predict the state of the system and to determine if flooding is likely to occur six hours or a day ahead", says Task Manager Thomas Dueholm Blicher.

With this tool, capacity can be enlarged by system management and control instead of costly construction works. For example the sewage can be temporarily retained in an area until sufficient capacity is restored downstream.

### Management decisions based on facts

Most importantly, NIRAS has developed a new management tool during the project.

"New technologies are not a silver bullet. To take full advantage of computer models and expert systems, the company's organisation must also be altered. The knowledge of even highly skilled employees cannot be utilised efficiently if the company's management lacks overview and information", notes Task Manager Christian Balder.

The management information system HOMIS automatically generates 20-30 key performance indicators. With this tool, the management decisions on what to do, when to do it, and who to do it can be based on facts and figures rather than simply targets and expectations.

The system compares the performance in each field with the targets set and keeps track on the trends, as well as the results of the initiatives taken by the management.

Water management solutions is a key competency of the consulting engineering company NIRAS

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Green growth in the desert, close to the pipes and the wells, is evidence that water has been leaking for years

## *Technology:* HOMIS SOFTWARE

HOMIS is NIRAS' Business Intelligence and Management System. The letters stand for holistic management information system.

Modern utility companies constantly produce computerised data. The operations are simulated, measured, monitored and controlled by computers. Technical, geographical and financial data are stored in databases. Daily performance, critical events and maintenance activities are registered.

With HOMIS the managers do not have to wait for section leaders to collect the relevant data and present their reports. The system automatically gathers the relevant operational and financial data, and presents key performance indicators. HOMIS provides almost instant overviews. The results created by the company in a specific period are just a few clicks away. They can immediately be compared with the targets and benchmarks set. The system can also generate management reports.


NIRAS has worked for decades on integrating companies' technical systems into the management toolbox. To get the most out of HOMIS, NIRAS provides set-up and assistance to convert the corporate strategy into operational targets, elaborate the key performance indicators, extract the data and adapt the user interface. Hosting of software and training of managers and staff is also offered.

# THE EYE IN THE SKY

*Detection and mapping of water resources is a prerequisite for sustainable water management*

In the old days, water dowsers used sticks and branches to detect underground water. Today, helicopter-borne equipment can detect groundwater aquifers and map them from the sky.

EnviDan deploys this technology worldwide, together with the Danish company SkyTEM.

### Large scale mapping in Thailand

The eye in the sky is a hexagonal scanning equipment. The helicopter flies it back and forth above the ground.

"In Thailand we have already flown 5,000 kilometres with the chopper to measure the underground, and we have detected some fine aquifers", says Jens Baadsgaard Pedersen, "but this was only a pilot project".

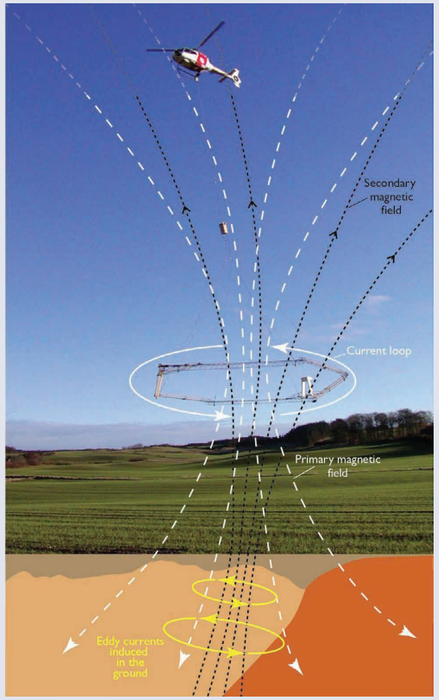
"The Thai authorities want a comprehensive mapping of their territories because extraction of groundwater plays a very important role in Thailand's water supply. The money has been allocated, and the authorities are in the process of investigating the pros and cons of different methods. Through our local partner, Thai Danwater, we offer a mapping of the entire watershed of the Chao Phraya River System", he says.

Jens Baadsgaard Pedersen is the chair of EnviDan International.

### Integrated management is needed

The Chao Phraya River is notorious for the flooding it frequently causes in Bangkok. The area drained by the river, however, is also prone to frequent droughts. Water from underground aquifers is needed to irrigate the fields, even in locations that at other times are flooded.

The water detection and mapping is essential to improve living conditions. "An integrated management of the water resources, including surface water as well as groundwater, is needed in the entire watershed. To this end, reliable data and tools to analyse them are necessary.




## *The technology:*

## EARTH SCAN

Hospitals use scanners to examine the inner parts of the body. Cross section images of the brain, the bones, the heart or womb can be seen on the screen. In much the same way SkyTEM's airborne geophysical survey technology creates images of the underground.

The equipment at the hexagonal frame within the helicopter transmits an electromagnetic field. This field creates whirls of electricity (eddy currents) in the ground. These currents in turn create a secondary magnetic field that is measured by the receiver at the frame.

The underground consists of materials with different electrical conductivity. These differences are reflected in the measurements of the electromagnetic 'echo'.

As a result, a 3D visualisation of the underground can be produced from the dataset. The system can, for example, differentiate sands and clays, and determine if they are saturated with water or not.

The system is internationally recognized to be one of the most accurate systems for mapping groundwater resources.

Initially the technology was developed by the Danish Ministry of Environment and the University of Aarhus, Denmark. The technology has been further developed and marketed by SkyTEM Surveys Aps and Aarhus Geophysics Aps. The system is in use for underground mapping worldwide.



What you don't know about cannot be managed" says Jens Baadsgaard Pedersen.

### Choppers to fly 320,000 kilometres

The Thailand tender is a large, four year project, intended to map an area of 64,000 square kilometres.

SkyTEM will collect the data. The helicopters will have to fly an astonishing distance of 320,000 kilometres back and forth along lines with a distance of 200 meters.

EnviDan, through the local company Thai Danwater, will manage the project, analyse the collected data, and present the knowledge in a usable form.

In addition to water resources, the geophysical survey will also detect deposits of minerals in the ground.

Similar surveys have been made in many other countries, including neighbouring Malaysia.

### Huge loss of water can be avoided

EnviDan is also involved in reducing water losses, especially in the Philippines and Malaysia.

"We help optimise the water distribution, especially in megacities such as Manila and Kuala Lumpur, where water losses are very high", says Jens Baadsgaard Pedersen.

EnviDan takes a holistic approach to water distribution management, meaning that all aspects of water distribution are treated as parts of an integrated whole.

"Huge water losses persist in many cities in spite of efforts made and money spent to reduce them. The reason is that the problems are complex. To achieve good results, you have to consider many aspects at a time and analyse them to figure out which actions are the most important", he explains.

### Smart work reduce the hard work

"We divide the distribution system into small controllable units, monitor them and collect a lot of data about them. Then we use an intelligent management decision support IT tool to store, interpret, and analyse the data. In this way we build up knowledge of the state of the system and how to optimise it", says Jens Baadsgaard Pedersen.

He calls it the smart work. Leakages can be detected and localised by computing the expected flow and pressure, and compare it to the data measured. In this way it is possible to figure out if new leakages have occurred during the night.

The next morning, those people who do the hard work – maintenance and repair in the field – will know where to go and what to do.

"Reliable data and tools to analyse the data correctly are incredibly important. A strong setup of the smart work enables effective targeting of the hard work", says Jens Baadsgaard Pedersen.

EnviDan provides innovative and professional solutions to all aspects of water and wastewater management

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# DEMAND DRIVEN DISTRIBUTION

*Substantial savings of water and energy are obtained with Grundfos' innovative management of water distribution pipe pressure*

Each day, 90 billion litres of drinking water are lost in distribution networks worldwide. Much of this water can be saved through better management of the pressure in the water pipes. According to a World Bank study, 17 percent, almost a fifth, of the potable water produced by all the world's water utilities combined is lost in distribution.

The figure corresponds to the needs of 360 million people using 250 litres per day. Many people would be happy with less.

### Great potential for savings

The authors of the World Bank paper wrote: "Half of the losses are in developing countries, where public utilities are starving for additional revenues to finance expansion of services and where most connected customers suffer from intermittent supply and poor water quality." An expense of approximately US $ 1.6 billion for water production and pumping could be avoided, if water leakages in the developing countries were halved, they conclude.

### High pressure – high leakage

Most of the losses are caused by small, invisible leaks. Repair of pipes of course prevent leaking, but network pressure is equally or even more important. In fact, if the pressure is not adjusted, pipe repairs can increase the leakages in other parts of the network. "10 percent more pressure translates in about 10 percent more leakage in volume", the World Bank specialists point out.

### High pressure at low demand

Demand Driven Distribution is about keeping the pressure constant at the end of the pipes where the consumers open their taps, rather than keeping it constant at the pumping station.

When many people use water at the same time, the pressure in the network drops. In order to keep the water flowing from all taps, the pumps have to compensate this pressure drop durning peak periods, typically in the morning and in the evening.

Most of the time, however (at night and midday), the flow of water to the consumers is much lower. If the pumping is not adjusted accordingly, the pressure rises. The excessive pressure causes more water to leak. Money is wasted on lost water, maintenance, and unnecessary use of electricity. With Grundfos Demand Driven Distribution, the pump pressure is automatically and gradually adapted to the actual flow. The risk of sudden changes that causes water pipes to crack (so called water hammer) is also reduced. To design systems based on this principle, Grundfos uses load profiles based on 24-hour consumption patterns.

Due to the savings on water, energy and maintenance combined, the return on investment can be less than a year, Grundfos says. Further savings come for free.

Unnoticed, leaking water pipes can undermine the roads and the buildings

GRUNDFOS

Grundfos is a world-leading manufacturer of pumps and pumping systems with a view to "create sustainable solutions from cradle to grave"

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## *The Technology:* DEMAND DRIVEN DISTRIBUTION

Grundfos Demand Driven Distribution (DDD) uses intelligent pressure control to ensure constant tap pressure at the consumer as opposed to a constant pump discharge pressure. The DDD Controller automatically adjusts the operation and speed of the pumps to the actual flow. When water consumption is low, the DDD controller lowers the discharge pressure accordingly. Typically, pumping stations are equipped with one duty and one standby pump, each of them able to meet 100 percent demand. As part of the solution, Grundfos suggests instead three or more smaller pumps in parallel, where the controller likewise will optimise to secure optimal system energy efficiency.

The DDD system results in a triple benefit; firstly by optimizing the water pressure in the distribution network to secure lower water leakage losses by up to 20 percent, and secondly by addressing energy efficiency and save up to 20 percent energy. And thirdly by supplying a stable pressure in the distribution network, that means less "wear and tear" and thus help reducing the pipe bursts.

A small illustrative film by the pump manufacturer Grundfos explains the concept of demand driven distribution on youtube.com — search for "Grundfos Demand Driven Distribution" (Courtesy Grundfos).

## SURPRISINGLY LARGE SAVINGS

Proportional pressure management saves energy and reduces leakages in the Municipality of Ploesti, Romania. The Nord Gageni zone supplies water to 60,000 consumers. The weekly pumped volume is approximately 100,000 m³ per week, or 5 million m³ per year. Pump pressure was 2.9 Bar during the day and 2.6 Bar at night. Non-Revenue Water (NRW) losses were at 30 percent, meaning 1.5 million m³ water is lost per year.

Following a period of investment with various flow reduction and energy saving measures, the owners of the Ploesti Nord Gageni pumping station agreed to implement a Grundfos Demand Driven Distribution proportional pressure management solution, in an attempt to gain even greater reductions in energy consumptions and Non-Revenue Water.

"Following our efforts over the years to reduce leakage and energy consumption, we didn't really expect we could achieve substantial further savings," says the utility's director, Alina Mihalache. "We were therefore surprised and delighted by the results achieved". A further reduction of water loss of almost 7 percent is realised by using Demand Driven Distribution, and the substantial energy savings accrued when the pumps run flexibly according to consumer demand proved to be over 7 percent.


Savings of water and energy were doubled in Ploesti, Romania

Filters clean the rinse water.
It is used again and again

# WATER SAVED IS MONEY EARNED

*Water saving and resource efficiency is becoming more and more necessary. Even at waterworks, saving can be made by water recycling*

Few people have clean and clear spring water outside their door. On the contrary, many people lack sustainable access to safe drinking water. As a whole, we sometimes tend to forget the efforts, energy and other resources required to make our tap water potable.

In fact, one of the resources used to make clean water *is* clean water.

### Rinse water reused again and again

At waterworks, the raw water is filtered to remove elements such as iron, manganese, and ammonium. These filters are composed of different layers depending on the quality of the raw water, but they all must be cleaned at regular intervals. Many water utilities use significant amounts of water to backwash the filters.

Flushing rinse water directly into the drain is not a sustainable use of water resources. Nor is it sustainable from an economic point of view. Instead, it is possible to recycle the rinse water by using pressure filters from EUROWATER.

### Costly discharge avoided

A Danish waterworks was using large amounts of water for backwash and as a result, flushed rinse water into the drain. The waterworks produces 60 cubic metres of potable water per hour. The filters are the traditional fine sand open bed type. Anticipating increased drainage fees, the waterworks decided to investigate a better solution.

The rinse water is now collected in a sedimentation tank and cleaned in a separate plant with two EUROWATER pressure filters. As a precaution against microbial contamination the water is also disinfected by way of ultraviolet light (UV treatment).

As all the rinse water is now reused, the waterworks does not pay any drainage fees at all. Within the new system, it is only necessary to have the sedimentation tank emptied once or twice a year. Furthermore the consumption of raw water has dropped.

Consequently the investment was proven to be profitable within just a few years.

### Pressure filters for many purposes

EUROWATER's pressure filters are widely used by many waterworks for the filtration of raw water. Many industries also use these filters to obtain the special water quality needed for boilers, district heating, cooling, washing, processing of food and beverage, and many other industrial processes.

Pressure filters can remove particles and suspended solids, iron, manganese, ammonium and nitrite, pesticide residues, arsenic, and aggressive $CO_2$. They are also used to adjust the hardness of water.

### Modules adapted to any task

Based on 76 years of experience, EUROWATER develops, manufactures, and markets complete water treatment plants, individually designed for almost any task within any industry and field of application.

The required water quality compared to the content of the water to be filtered determines the choice of filter media, materials, coatings and configuration of the plants.

EUROWATER offers to analyse the water free of charge. Subsequently the plants are designed and manufactured to meet the demands without using more energy and water than necessary. The compact modular design and the fact that most of the components are manufactured in-house make it possible to offer long-term effectiveness and service.

### Precarious water resources

Efficient filter technologies are of growing importance. Traditional sand filter beds are sufficient for filtration when aquifers with plenty of high quality water are at hand. In many places, however, more thorough filtration is needed.

The quality and the quantity of raw water depend on climate, geology, and human activities. Growing urban populations, growing consumption and more industrial activity led to increased demand. Climatic changes, water depletion, pollution, and contamination correspondingly limit the supply.

As a result, water utilities are increasingly forced to use raw water of inferior quality.

EUROWATER provides technologies for almost any kind and grade of water treatment. The company has more than 75 years of experience in the field

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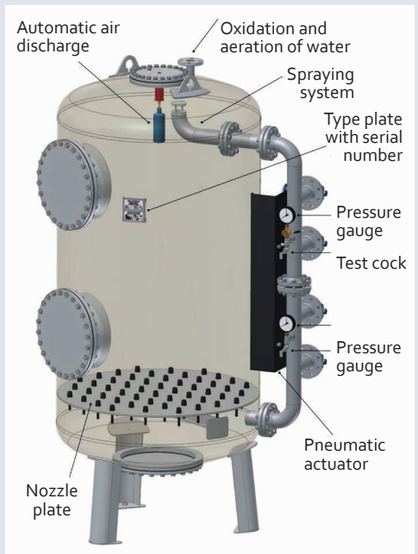
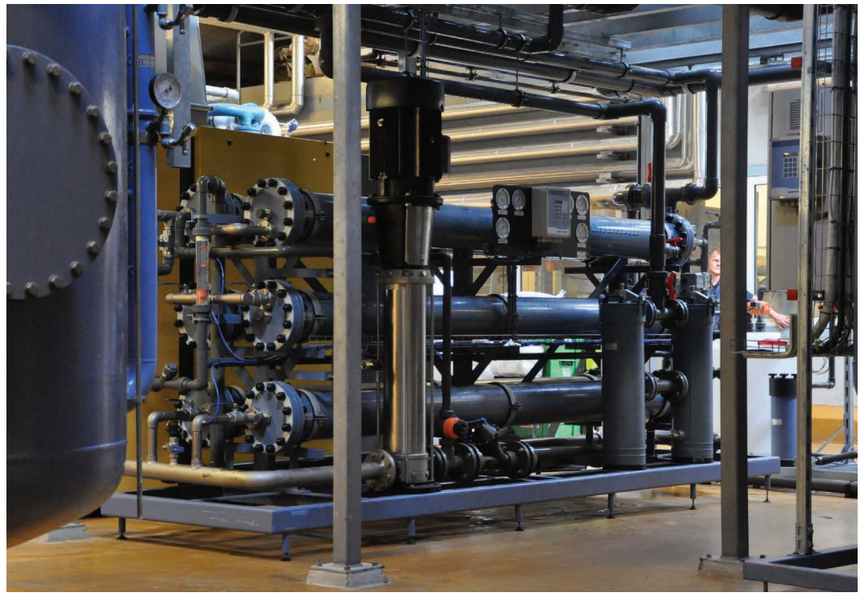
## *The Technology:* PRESSURE FILTERS




EUROWATER's pressure filters are designed for high durability – preferably with an expected durability period of 25 years. In the bottom, the steel tank is equipped with a steel plate with nozzles to secure an even distribution of load for the optimum utilisation of the filter medium and to avoid stagnant water, which is important to limit bacterial growth.

In the top of the filter tank, an integrated aeration and spraying system ensures optimum oxidation prior to the filtration. The nozzle system generates an efficient and even backwashing. A strong air flow is blown upward through the filter to loosen embedded particles that are afterwards removed through backwashing with clean water. The rinse water can often be reused as raw water after filtration and UV disinfection. The filter vessels are made in many different shapes and sizes. They can be filled with many different filter media and combined filter layers, all depending on the problem to be solved. For instance neutralisation of aggressive $CO_2$, removal of iron and manganese, suspended solids, ammonium, pesticide residues (BAM), arsenic and so on. The pipe system can be made of black steel, galvanized steel, stainless steel or polyethylene according to the corrosion risk determined from the analysis of the water. The inner and outer surfaces of the filter vessels are coated according to the application of the filter, as well as the legal requirements for hygiene and drinking water.



Breweries have large consumption of high quality water. EUROWATER installed this newly developed reverse osmosis plant at Harboe's Brewery in Denmark. The plant is highly energy efficient and up to 90 percent of the raw water is recovered. The upgrade resulted in considerable saving and lower environmental impact. Return on investment was about one year

# KEEPING TRACK

*Monitoring the water cycle and the water runoff is a basic need for any nation who wants to secure its citizens and manage its water resources in a sustainable fashion*

How much water is flowing in the stream? Will people and animals have enough water to drink? Is there water enough to irrigate the fields or to float the timber? Are water levels unusual? Is flooding to be expected?

Timely and reliable answers to such questions are essential for water resource management. Many people's livelihoods may depend on these answers, especially when water is scarce or abundant. Knowledge about water runoff can prevent many mistakes, accidents, and even disasters.

### Hundred years of experience

Regular hydrological monitoring of the streams and lakes in Denmark was established in 1917. The task was entrusted to Orbicon, at that time called Hedeselskabet.

Today, the monitoring stations with climate, hydrological and water quality data are connected online to Orbicon's database. The data is processed immediately. Reports and forecasts are delivered to municipalities, farmers, insurance companies and the like. Orbicon has condensed its 100 years of experience in this field into a software tool, HYMER. This is now a national hydrometric system used not only in Denmark, but also in Lithuania and Latvia.

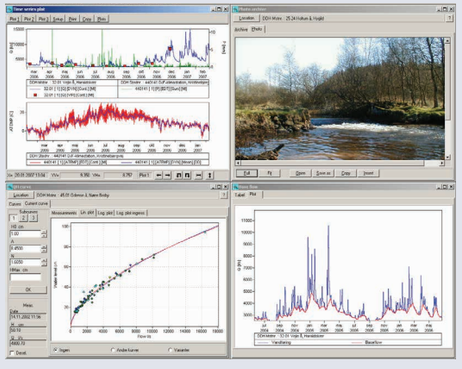
### Large volume of data

"At present, HYMER captures data from 1,200 gauging stations, 200,000 current meter measurements, 4,000 rating curves, 10,000 time series and 255 million records in Denmark alone", says Per Møller-Jensen, Orbicon.

"Our international customers, such as mining companies with remotely situated monitoring stations, are directly connected to our system via satellites and internet connections".

For mining companies, it is essential to know if there is enough water in the streams for their operations and the environment. "Further, we monitor the climate data for them such as temperature, wind speed and direction, precipitation, etc." Per Møller-Jensen says.

## *The Technology:* A tool for sustainable water resource management



Hymer is a powerful giant in Norse mythology. The software named after him is a powerful tool for handling hydrological data. HYMER has been developed by Obicon through many decades. The software condenses the company's almost 100 years of experience in gathering and processing water flow data.

More than 30 different data types are handled by the software, such as the level, current, velocity, discharge, temperature, conductivity, and oxygen content measured – along with meteorological parameters such as precipitation, evaporation, temperature, wind, moisture, pressure.

Raw data can easily be imported. All observations and original time series are stored in the database and kept intact.

With HYMER, the data can be analysed, compared and combined. Reports can be generated on each location, for current measurements, daily and annual time series etc. HYMER also calculates time series of discharge. Results are presented on screen, combined with photos and maps.



plans, management infrastructure and community level awareness and training. The consultancy also involves data acquisition and handling, monitoring schemes, and modelling of water quality and water resources.

Many countries have poor knowledge about the flow of water in their rivers. In some regions, the waste of lives, crops and resources could be avoided with better monitoring, reporting, and forecasting systems.

Orbicon's knowledge and know how in the field encompasses the design and operation of hydrometric recording networks, collection and processing of data, training, maintenance of nation-wide databases, and a wide range of consultancy services.

These competencies have been brought into play in various projects such as in West Africa (Ghana), Southern Africa (Botswana) and the Baltic countries (Latvia and Lithuania).

ORBICON

Hydrological monitoring is a core activity of Orbicon, an experienced consultancy company in the fields of the natural and built environment

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# OF THE WATER

Municipalities have the responsibility for enhsuring 'good ecological status' in streams and lakes. This knowledge is a useful tool in landscaping and watershed management as well as damage control in case of flood risk.

### Much money at stake

Knowledge about normal and exceptional water flow is also increasingly important for insurance companies. Because of climate change, some insured property holders are entitled to compensation in case of flooding caused by abnormally heavy rains.

Historical records of water flow are essential to determine whether flooding is caused by high but 'normal' water levels or by extreme weather events. Considerable amounts of money are at stake here, and Orbicon's almost 100-year data records play a financially important role.

### Integrated water management

Orbicon has experience introducing integrated water resource management at all appropriate levels: Capacity building and training of staff, development of water management

# A LITTLE CELL OF GREAT CAPABILITIES

*Easy and flexible in use, the SorbiCell can measure the concentration of chemical substances in water almost anywhere*

Monitoring water quality is an important task, particularly in densely populated countries like Denmark and the Netherlands, but also in many fast growing urban areas and emerging economies the world over. To this end, the Danish company, Sorbisense, has developed a simple and smart device based on many years of research: The SorbiCell.

### Traditional methods are costly

In order to prevent the pollution of drinking water, protect the aquatic environment, and trace sources of pollution, it is necessary to monitor many aspects of the water cycle.

With traditional methods, a large number of water samples have to be collected and sent to laboratories for analysis. Representative water samples can be difficult to collect. Sometimes it is even impossible, for example in cases where polluting substances are discharged only periodically. In any case, this sampling process is a costly and time-consuming activity.

### Simple-to-use sampler

The alternative presented by Sorbisense is the SorbiCell. Once mounted in a well, a stream, a pipe, a lake, a drain, or a sewer, it automatically collect chemical substances in the water and measure the volume of water running through the cell. It is deployed during a distinct time frame – anything from 24 hours to 3 months.

"We spare our customers a lot of time. Our technology is very simple to use. You place the SorbiCell in the water at the spot you want to monitor. After a certain time you bring it up again and send it to the laboratory. With a minimum of investments and manpower, you get representative data on your water quality", says Hubert de Jonge, CEO and founder of Sorbisense.

The SorbiCell can be used to detect many different chemicals, such as excess nutrients, pesticides, heavy metals, and many sorts of organic compounds.

### Increasing demand

The traditional method for monitoring is deeply rooted in legislation, and the way of thinking amongst authorities, water companies, utilities and industries. It has occasionally been hard work to convince them of the advantages of the new method.

"But due to our current focus on selling the high value proposition applications, our business is currently rapidly growing", Hubert de Jonge says. "Some of the largest laboratories have now accredited an important part of the methods. The confidence of the authorities rises accordingly. And many private customers have realised that the use of the SorbiCell is highly beneficial to their operations".

### Tracing sources of pollution

For example, waterworks save money monitoring the groundwater in their catchment area. It can be very troublesome and costly if residues of pesticides pollute the drinking water. SorbiCells installed in the area can warn them of pollutions approaching their wells.

Tracing the sources of wastewater pollution also saves money. For example the wastewater plant in a mid-size provincial town in Denmark had persistent problems for many years: Their sludge was not allowed to be used as a fertiliser, because it contained high levels of mercury, and the operators did not know where the mercury came from. They finally found the source, by using SorbiCells to trace it.

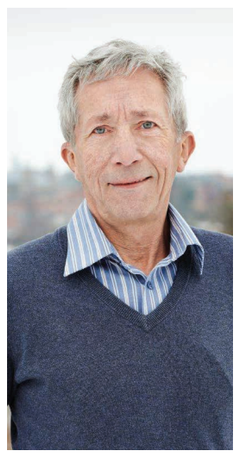
Now, Sorbisense has launched a special kit for source tracking and monitoring in sewage wells. "Currently the demand for this solution is rapidly growing", says Carsten Frederiksen, Head of Sales at Sorbisense. There is a growing demand for intensified monitoring of water quality in streams, lakes and rivers. This includes the drains and discharges from agriculture, horticulture, rural households and waste dumps of the past.

Clean rivers, lakes, groundwater and coastal areas are high on the agenda for many countries. In the European Union all countries have common legal obligations to implement River Basin Management plans in order to protect the aquatic ecology. Many doubts occur on who is responsible for the pollution. High quality monitoring is an important precondition for just decisions and settlement of controversies in this field.

### Worldwide demand expected

Until now, Sorbisense's primary market has been Denmark and the Benelux countries, says Hubert de Jonge. However, the demand for monitoring is increasing in many countries around the globe.

"You shouldn't underestimate how fast countries like China and South Korea are moving. The problems are huge, especially in China. The authorities have realised that environmental protection is urgently needed, and they are hurrying to implement monitoring systems and discharge control. Our technology has important benefits that can help end-customers to manage these problems more efficiently", he says.



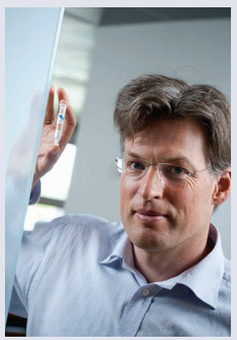
Finn Køhler, Water Manager at Viborg Waste Water Company, uses the Sorbisense method to track and find the sources of periodic discharges of toxic metals that cause serious problems at the wastewater plant

SORBISENSE

Sorbisense is a science based company that develops, manufactures and markets a multi-purpose sampler for monitoring of water quality

*Company Profile page 110*

## *The Technology:* SORBICELLS



Hubert de Jonge, CEO of Sorbisense, proudly presents a new SorbiCell . Photo: Torben Klint

A SorbiCell is a tiny plastic tube. It contains a resin, a highly porous material, which is able to capture chemical substances at its surface. It also contains a harmless salt.

The cell is a passive sampler. The water runs through the cell for a specified period, anything from 24 hours up to 3 months.

The chemical substances to be measured are captured (adsorbed) at the surface of the resin, also known as the adsorbent. At the bottom of the cell, the water passing through the cell gradually dissolves the salt and leeches it with the water flow. After the determined monitoring period, the cell is collected and sent to a laboratory for analysis. Based on the amount of substances adsorbed and the remaining amount of trace salt in the device, it is possible to calculate the average concentration of the substances looked for during the monitoring period.

The SorbiCell's unique feature is the combination of adsorbent and trace salt. Years of research and development have been used to validate this concept for a wide range of compounds and relevant environments, including waste-water and groundwater wells. Different types of SorbiCells and mountings are provided, dependent on which substances the user wants to detect, and where to deploy the cells.

The Krüger Relay – Open water swimming events take place in the harbour canals, right in the centre of Copenhagen

# BATHING IN THE CLEAN HARBOUR

Water quality is very high in the Copenhagen Harbour The water is safe for bathing, and three harbour baths have been established right in the heart of the capital. Two popular beach parks are also located in this central area. People who work in the city can now enjoy a swim in their lunch break. The former disgusting waters have now become a hot summer attraction. In the past, the port of Copenhagen was heavily polluted, just like the most other metropolitan harbours. Swimming in this water was a health hazard and had been prohibited by health inspectors since the 1950s.

This remarkable change was initiated by farsighted decisions in the Parliament and the City Council, and is the result of enduring efforts through several decades.

To effect this change, the municipal wastewater treatment plants were substantially enlarged and upgraded in the 1980s and 1990s. They are now equipped with state-of-the-art Krüger control systems.

The sewers have been modernised and re-routed. 55 overflow channels have been closed. Large storage tanks were built to prevent overflow of untreated water. Some of these tanks are the size of cathedrals.

### The investments have paid off

The benefits from this enhancement for the citizens of Copenhagen are not only recreational, but also economic. The harbour area is now an attractive neighbourhood where families want to live and settle in rather than moving to a house & garden in the suburb. The cafés are blooming and local property prices have increased by 57 percent. Additionally, the attraction of the harbour swimming areas has provided additional incentives and advantages in terms of tourism.

An online service, available on smartphones and mobiles, has been set up to alert people in case of closure at the swimming areas. In spite of all efforts, overflow of untreated water to the harbour can still occur during and after storm water occasions.

### Growing number of closure days

When a new storage tank, designed by Krüger, was set into use in 2006, it had an immediate effect: In three years, the number of closure days per season fell from thirteen to one.

Unfortunately, a new problem has emerged since then. Extreme rains have caused flooding and sewer overflows in the city's basements, as well as into the harbour. The harbour swimming areas have therefore had to be closed for 15 days in 2010 and a record 28 days in 2011.

### Climate adaptation

The pattern of climate change is clear: When it rains, the rains will be heavier and more intense than before.

Open channels and the separation of storm water from sewage water will be necessary to deal with the most extreme rain falls.

An advanced warning and control system will help solve the problems during 'mid-size' intense rains of 10 to 30 millimetres a day.

## *New Technology:* GLOBAL CONTROL OF THE SEWERS

Overflow of untreated water is of growing concern because of intense rainfalls related to climate change. The new control system minimizes the risk at low costs

A unique system for online control of the entire metropolitaqn sewer system is being developed by Krüger in collaboration with developers from the metropolitan water and wastewater utility companies.The new system will be able to predict high flows in the sewers several hours before they actually happens.

The operators, using STAR Control® Sewer View, will be able to follow the present and future state of the entire sewer system, and prepare for storm water in due time. Fewer overflows will occur, and the first, most polluted part of the storm water will be biologically treated.

»It is very complex and it has never been done before. Integrating rain forecasts, run-off modelling and steering functions in the sewer system and the wastewater treatment plants is very difficult.«, says Theis Gadegaard, Krüger. The local rains and their intensity is detected with local radars. The surface runoff into the sewers is modelled by computers, based on detailed database information.

Then the flow of water in the sewer system is measured and modelled. The model is callibrated, using online sensor measurements of the flow and the level in the sewer system. The model is also adjusted to reflect previous experiences.

This combination makes real time control of the pumps and weirs possible and feasible. The software will calculate the least costly way to deal with storm or sewer owerflow. If, for instance, intense rains are predicted, particularly in the southern part of the metropolitan area, the water from the northern part is temporarily retained in existing storage tanks. As a result, the wastewater plant at the end of the pipes is made ready to treat more storm water, or the overflow can be directed to areas where it does less harm.




KRÜGER

*The municipality of Copenhagen and the metropolitan water utility, has made a huge investment in restoring the harbour for bathing. Kruger has taken part in this effort as a consultant, contractor and supplier*

*Company Profile page 101*

## Beaches, beeches and grey waters

"Old Denmark shall endure as long as the green beech trees reflect their top in the blue waves" says the national anthem I Know a Lovely Land. The view below inspired the lyrics

Clean bathing water is a poetic part of Denmark's identity. By the end of the 1970s, however, something was obviously rotten in the waters of Denmark. The blue waves had become grey-green and greasy. Fish and shellfish were dying. The bottoms of streams and lakes were no longer visible. Oxygen-depletion and algae blossom occurred frequently along the 7,314 kilometres of Danish coastline.

In the 1980s it was decided to finally do something about it. Denmark became a forerunner in terms of strict requirements for wastewater treatment. The high environmental standards spurred the technological development, and Danish engineers developed cutting-edge competencies in the field.

# CLEANING OF STORM WATER

*Open water is an attractive part of city life. If the water is filthy, the attraction quickly turns to repulsion*

Suddenly out of nowhere, rain pours down, and the sewers soon swell with storm water. In seven locations close to the Copenhagen harbour, however, the storm water runs into HydroSeparators.

In Middelfart, 212 kilometres away, the engineers at Bonnerup Consult glance at the screen: They want to be sure that the automatic, remotely monitored and controlled storm water treatment system is working as intended.

### Filthy overflow

Regrettably, the opposite scenario is more common in most cities. Filth, dirt, and waste including residues of petrol, rubber and hazardous substances are washed off the pavements, particularly by the first flush of storm water. Some of it is flushed directly into the canals and harbours. The rest is a challenge to the capacity of the sewerage system.

If the rain is heavy, as is increasingly the case in many countries, the pipes and basins of the sewerage system may become overfilled. Overflow of storm water mixed with sewage may be discharged untreated into nearby rivers, lakes, or seas.

### Traditional solutions are expensive

Lakes and canals, rivers and waterfronts are attractive parts of city life, just like parks and alleys. Many mayors and city councils want to enrich their fellow citizens with such 'blue' qualities of daily life. To do so, the first priority is to keep the water clean. Otherwise the attraction of having rivers and canals inside city limits will quickly turn into repulsion.

Technically it is possible to drain the storm water away by extending the sewer system with large retention tanks. And of course the wastewater treatment plant can be enlarged to treat all water thoroughly even on the day of the heaviest rains. These solutions, however, are expensive.

### Seven HydroSeparators installed

The engineering company Bonnerup Consult and HydroSystems, have developed a much more affordable, yet effective solution: The sub-terrain HydroSeparator.

Seven HydroSeparators have been established in Copenhagen. They are installed in the vicinity of cultural, residential and commercial buildings in the areas of the former industrial harbour and navy port, close to the Opera and several schools and academies.

The areas are characterised by evolving leisure activities, which include bathing, swimming, and sailing.

### Simple and effective

"We were approached by the water and sewer utility company of Copenhagen in 2003, shortly after the city council adopted the 'Blue Plan'", says Thomas Gammelgaard, Bonnerup Consult. "They wanted a facility to clean the runoff surface water efficiently with a minimal need of control, service, and maintenance".

A HydroSeparator installed close to the Opera House

"It was a challenge for systems engineers, because the space for construction is very limited along the quays", he adds. "It would be very expensive to build large underground rainwater retention tanks there".

"We managed to create a system that effectively retains the first and dirtiest part of the storm water – the first flush – and subsequently purifies the water with an efficiency of 90 percent for suspended solids and a number of hazardous substances," Thomas Gammelgaard continues.

So, what about the maintenance?

"It is a fact of life that all filter works well –until they are clogged. We solved that problem by getting the flow right and flushing the filters automatically", says Thomas Gammelgaard.

When the rain is over, the HydroSeparator empties itself, pumps the remaining dirty water into the sewer, and automatically flushes its filters. Now, it is clean and ready for the next rain.

### Complete, standardized solutions

The HydroSeparator is delivered as a complete solution, which includes filters, pumps, sensors, connection to remote supervisory control system, and installation. Agreements on service, maintenance, and operation are offered.

The system can be delivered in a variety of standardised solutions for use in any location where improved stormwater treatment is wanted, such as industrial areas, roads, streets, squares, and other urban areas.

The HydroSeparator from Bonnerup Consult is used to handle storm water at the Copenhagen waterfront

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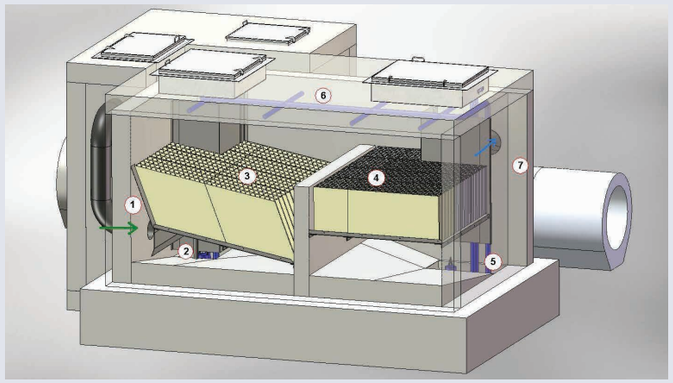
## *The Technology:* EFFECTIVE CLEANING OF STORM WATER




The HydroSeparator® is a system for cleaning storm water in places where space is limited.

The first and most dirty part of the storm water is retained (2). The next part of the storm water passes the lamellas (3) for removal and settlement of big particles. The next step removes small particles using a mesh filter (4).

After rainfall, the retention tank is emptied (5) and the dirty water is pumped in to the sewer system. The tank, lamellas, and filters are automatically sprayed and flushed with filtered water (6) to ensure that the system is clean and ready for the next rainfall. After a long rainfall, the storm water is relatively clean. In these situations, an optional bypass function (7) can be used. The system is remotely controlled.

## *Copenhagen:* BLUE PLAN

In July 2003, the city council of Copenhagen decided to go blue. The vision of the Blue Plan is to attract vibrant city life to the former harbour areas. The crucial prerequisite is to keep the harbour water clean.

Copenhagen means 'Merchant's Harbour'. The former commercial, industrial and military areas extend like a blue ribbon through the inner part of the city. Amidst new residential and commercial areas as well as public buildings and cultural institutions, the plan envisaged a multitude of daily activities unfolding along the waterfront.

Much of the plan has come into life, including sailing, bathing, swimming, fishing, bicycling, outdoor cafés, performances, theatre, music, houseboat living, and water busses.

Copenhagen Jazz Festival

# MAKING WATER HESITATE

*A Danish invention makes it possible to hold back water and prevent flooding at low costs*

Urban flooding is a growing problem for two reasons: First, extreme rain events have become more frequent because of climate change. Second, people around the world are moving into the cities. According to UN-reports, the number of urban dwellers grows by 70 million each year. Many of them are in need of sanitation, sewerage and flooding prevention. Better sewerage and improved handling of storm water is expensive. A Danish invention, the so-called water brake, is a less expensive alternative to costly enlargement of drains and sewers.

### Apparent magic

Generally intense rains are short and local. If flooding of a sewer pipe system and its surroundings shall be avoided, even at the height of the heaviest rains, the dimensions of the sewer pipes have to be very large.

Such large pipe dimensions are not necessary, if Mosbaek's water brakes are installed. The water brakes diminish the flow of water in the pipes when it is most needed. In case of sudden and heavy rain, they hold back some of the water and release it slowly downstream.

Surprisingly, this is achieved with no moving parts. There are no pumps, no valves, and no throttles. The only source of power used, is gravitation.

### No narrow holes

The secret is in the shape of the device: When the drains run full, the pressure build up would normally make the water run faster through the pipes, heading downstream. Instead, the shape of the controller makes the water rotate. The swirling movement restricts the normal flow. The maximum flow per second through the controller does not exceed the volume it is designed for.

When the rain ends, the water level in front of the controller falls. The water stops swirling. It runs freely again. The pipes and manholes and reservoirs upstream are emptied, ready for the next rainfall. The brake prevents flooding from happening downstream. If flooding should occur, it will take place upstream, where it does less damage.

### Smaller dimensions means money saved

An early project in the Norwegian capital Oslo, 1975, clearly demonstrated the advantages of this system. With Mosbaek's water brakes installed in run-off wells and manholes, the peak flow of water was reduced by 95 percent! The dimension of the sewer main could be safely reduced from 80 to 30 centimetres (12 inches). Total costs were cut by 30 percent.

Since then, Mosbaek has further improved the flow controllers. Today, they are able to restrict the flow to a fifth of that of an open pipe hole (orifice). Many shapes and sizes are available. Controllers can be designed to meet many different needs.

### More value for money

For Mosbaek, the fast growing urban areas are promising markets. "We try to make our case towards planners and utility managers of the developing world", says Technical Director Torben Krejberg. "They will get more value for money and serve their citizens better, if they integrate the use of water brakes in their planning and implementation".

Water brakes are widely used to control storm water in North America. Mosbaek's original water brakes were introduced in the US, Canada and the UK in the 1970s. When other companies copied the idea, Mosbaek decided to concentrate on the European market.

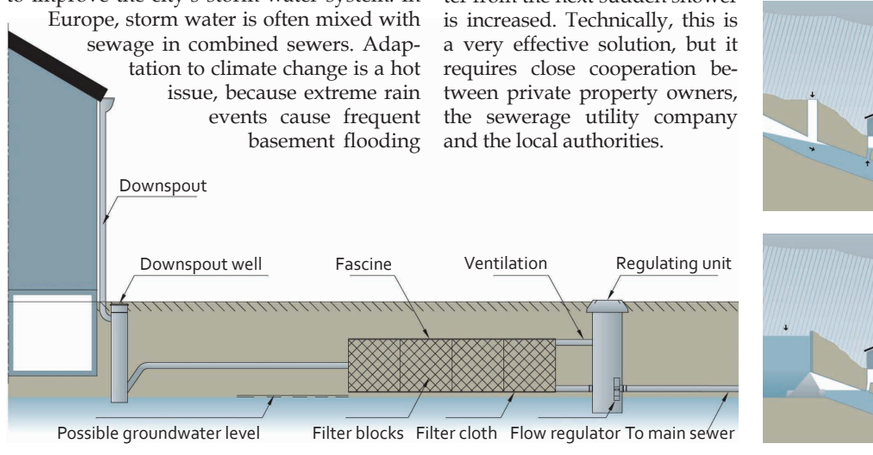
### Climate change adaptation

Today, the original Mosbaek water brakes are again being marketed in the United States and Canada, through Mosbaek North America Inc. For example, the city of Ottawa has ordered a four digit number of water brakes to improve the city's storm water system. In Europe, storm water is often mixed with sewage in combined sewers. Adaptation to climate change is a hot issue, because extreme rain events cause frequent basement flooding and high insurance costs. A suitable solution is to infiltrate the storm water locally before it reaches the sewers. Mosbaek has demonstrated the advantage of water brakes for this purpose.

In a low lying urban area south of Copenhagen, the water from roofs and pavement are conducted to *fascines*. The fascines are porous. Only 0.6 litres of water per second is directed to the sewer main through the centrifugal flow regulator.

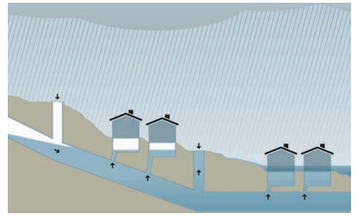
Rain water collected in the fascine infiltrates into the surrounding soil. In dry weather, the fascine is gradually emptied. It would thereby function as drainage.

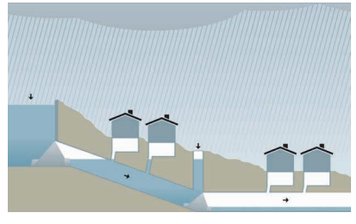
Water from the surrounding area seeps into it and is conducted to the sewer main. The groundwater level is kept low and the capacity of the soil and the fascine to absorb storm water from the next sudden shower is increased. Technically, this is a very effective solution, but it requires close cooperation between private property owners, the sewerage utility company and the local authorities.




Left: Local inflation of rainwater combined with Mosbaek flow regulators

Below: Basement flooding from overloaded sewers is prevented by Mosbaek cyclone flow controllers





Mosbaek A/S

Mosbaek A/S produces flow regulators for better management of storm water and better utilisation of sewer capacity

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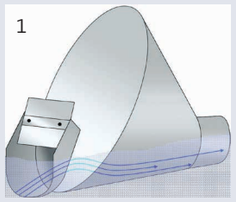
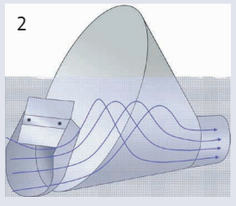
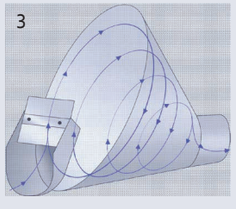
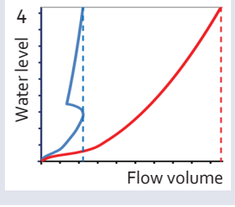
## *The Technology:* CONTROLING WATER WITH GRAVITY AND GEOMETRY




The core idea of Mosbaek's flow controllers is to make swirling water restrict itself.

At normal low level flow, the water runs through the cyclone flow controller with virtually no resistance (1).

At normal rain, when the water level rises, air is trapped inside the controller, and it begins to restrict the flow (2).

At extreme rain, when the water level rises further above the top of the controller, the increased pressure causes the water to rotate. A vortex is formed. The cross section available for water flow is reduced (3). Excess water can be stored in a detention basin. In case of overflow, a by-pass weir can conduct the water to a nearby stream or lake or another locality.

The combined result are shown as curves in the graph (4). The normal flow through an orifice is shown in red:The higher the water level rises, the more water is pressed through the pipe. The blue curve shows the flow through a Mosbaek cyclone controller. At highest water level, the flow of litres per second never exceeds 20 percent of the flow through an uncontrolled orifice the same size.

# INTELLIGENT WASTEWATER TREATMENT

*The best solution is not always the most expensive one. The STAR Control® system from Krüger avoids malfunctions and improves water quality while saving money and energy*

Urban areas all over the world often need to improve their wastewater management. Their capacity to treat water and protect health and the environment may be insufficient due to rapid urbanisation, population growth, obsolete systems, or frequent discharge of untreated water related to climate change.

However, the construction of new and additional sewers and wastewater treatment plants is a costly option.

## Saving money and resources

With Krüger's STAR Control®, it is possible to improve the utilization of existing facilities. More water can be better treated, using less energy and chemicals.

Discharge of untreated water can be minimised. Operation costs are diminished and costly construction works can be postponed or avoided.

STAR is a real time, online control system. It measures and monitors what is going on in wastewater plants and sewer systems. It fine-tunes the complex hydraulic and biochemical processes.

Since 1992, STAR has been successfully installed in many biological nutrient removal plants around the world. Novel STAR modules are constantly being developed.

## Making bacteria work harder

In biological wastewater treatment a broad variety of bacteria and other microorganisms break down, consume and bind the organic nutrients in the wastewater. The water must be aerated to keep the bacteria alive and busy, because they consume oxygen and organic matter in this process.

"This is the most important step in the water treatment, and the aeration is by far the most energy-demanding part of it", says Marketing Director Theis Gadegaard, Krüger. Much energy can be saved by adjusting the aeration to the specific load situation.

## Fine-tuning the process

The efficiency of the treatment depends on many other factors, which the STAR system can continuously adjust.

"Carefully positioned sensors measure a lot of things, which can tell us about the chemical composition and the biological processes taking place out there. The data is collected and reported, and the software calculates how to improve the situation. If the conditions are not properly controlled, you will not obtain the desired treatment", says Theis Gadegaard.

## Enhanced performance

"Since 1992, new features and algorithms to control specific processes have continuously been added to the STAR system", Theis Gadegaard continues. "The plants have become more complex. Their performance and flexibility has been improved, and more STAR modules are required to control the conditions".

STAR can optimise the quality of the water leaving the plant (the effluent), even at challenging loads and wastewater compositions, i.e. the precise amount of chemicals needed to precipitate phosphorous. Excessive use of chemicals is avoided. Additionally it is possible to enhance phosphorous removal, by improving the living conditions of certain bacteria which are able to accumulate large quantities of polyphosphate.

## Adaptation to the climate challenge

Climate change often means an increase in sudden, heavy and intense rains. With optional modules, STAR can be extended to include wet weather forecast from rain gauges and local weather radars. A storm water module will change the operation mode at the plant ahead of the high flow to increase the capacity during the rainfall.

With the SewerView-module, the operator can easily monitor the flow, the levels and the storage capacity in the entire sewer system. The weirs and pumps that regulate the flow can be remotely controlled to withhold water and avoid overflow of untreated water.

A cost function module calculates the optimal way of handling excess storm water, considering the economic and ecological impacts in different areas and the capacity of the basins.

The cost function can also be used to decrease the activity at the treatment plant when power prices are high, and instead use more energy when power is cheap.

## Proven results

Depending on the circumstances and the choice of STAR modules, the cleaning of wastewater can be improved by 20 to 50 percent, treatment capacity can be increased by 35 to 65 percent, use of chemicals and carbon dosage can be halved and overflows can be reduced by 20 to 30 percent. Energy consumption is reduced by up to 40 - 60 percent.

The return on investment is high. Typically, the payback period is less than 4 years.

KRÜGER

Krügers STAR family of online control system modules are based on many years of experience and vast knowledge of wastewater treatment

*Company Profile page 101*

WHAT'S GOING ON? At the huge Czajka Wastewater Treatment Works in Warsaw, the operator surveys the processes with STAR Control®. He can leave them on automated control or change the settings

## *The technology:* ONLINE MEASUREMENT AND CONTROL

STAR stands for Superior Tuning and Reporting. The system is a state of the art online tool for optimal control of wastewater treatment plants. It can be extended to control the entire storm drain and sewer system, including rain monitoring and wet weather forecasts.

Online sensors continuously measure the flow, the loads and levels, the temperature, the circulation and the concentrations of oxygen, ammonia, nitrate, phosphorous, suspended solids and so forth in the plant.

The advanced software calculates what is going on, and keeps track of changes. The results are displayed in a user-friendly interface, and STAR immediately reacts to implement the optimum operation on the basis of settings made by the operator. Adjustments such as the regulation of pumps, aeration and valves, can be carried out automatically.

Krüger has a vast and comprehensive knowledge based on many decades of experience in the field. This knowledge is incorporated in the complex algorithms governing the software calculations, as well as the positioning of the online sensors, which are crucial to obtaining rapid and reliable control.

The system has been continuously improved, updated and extended since 1992. It consists of many compatible modules, which can be seamlessly combined.

Therefore the system can be gradually updated and tailored to fit many different requirements.

# HOW TO BOOST WASTEWATER TREATMENT

*Some ideas sound simple once you have them. EnviDan found a way to treat much more wastewater in a better way with no need for extra process volumes*

A Columbus Egg for treating more water at biological wastewater treatment plants was invented by the engineering company EnviDan. Instead of undertaking costly construction works to increase the volume of the basins for wastewater treatment, EnviDan has simply organised the process in a smarter way.

### The return of bacteria

EnviDan's new idea is to use the normal biological treatment process in a more efficient way. In all biological wastewater treatment plants, bacteria degrade, bind and consume the organic pollutants during the time in the wastewater treatment plant.

When the bacteria have done their work, the sludge is withdrawn from the plant. It may be disposed on farmland, used to generate biogas or incinerated.

However, a part of the sludge mass must be returned to the aerated basins in order to ensure sufficient bacteria mass for the biological processes.

### Double treatment

EnviDan make these bacteria work overtime. Existing basins at the plant are used to activate them at a higher sludge concentration level, using the flow of the return activated sludge from the final sedimentation tanks because the concentration of bacteria in the return sludge is very high. In this tank, the hydrolysis process takes place, producing organic substrate, and nitrogen removal is also performed.

The process in the tank depends on the actual demand at the actual wastewater treatment plant. The consumption of organic substrate and removal of nitrogen is 3-4 times higher per volume than in the ordinary treatment process. Using the new concept, the plant as a whole can easily treat more wastewater in existing process volumes.

No additional basin volume is needed.

**COLUMBUS' EGG**: Christopher Columbus once dined with Spanish nobles. They suggested that some other great man would have discovered the New World, if Columbus had not done so. Instead of answering directly, he challenged his critics to make an egg stand on its tip.

"They all tried without success and when the egg returned to Columbus, he tapped it gently on the table breaking it slightly and, with this, the egg stood on its end. All those present were confounded and understood what he meant: that once the feat has been done, anyone knows how to do it"

Girolamo Benzoni, Italian writer and traveller, History of the New World, 1565.

## *The Technology:* THE ACTIVE RETURN SLUDGE PROCESS

The activated sludge process is the method commonly used to treat urban wastewater. The water is purified by bacteria that feed on the waste. The bacteria thrive when the incoming wastewater is stirred and aerated. They adsorb organic particles, break down organic compounds and consume the nutrients.

Subsequently the sludge is settled at the bottom of non-aerated basins and the clarified water is discharged. Some of the sludge, containing living bacteria along with dead bacteria and other organic matter, is returned to the first basins to make the process continue. EnviDan's Active Return Sludge Process takes advantage of activating the return sludge one more time before it is returned to the starting point.

Here a vivid decomposition of organic matter takes place, because the concentration of sludge is very high. The bacteria are stimulated to perform biological decomposition (hydrolysis) by varying the conditions in the tank. Oxygen-rich (aerobic) and oxygen-poor (anoxic) conditions alternate.

The effect per volume of the return sludge treatment is 4-5 times higher than in the ordinary part of the plant. To increase the amount of water treated or the amount of organic matter removed by 30 percent, an extra basin volume of only 6 percent is needed.

This Active Return Sludge basin increased the capacity of the wastewater plant by 50 percent

Active Return Sludge treatment at a wastewater plant in Roskilde, Denmark

EnviDan

EnviDan provides innovative and professional solutions to all aspects of water and wastewater management

*Company Profile page 93*

Additional hydraulic capacity is needed for two reasons. First, the amount of wastewater to be treated is increasing due to more intense rains caused by climate change. Second, many urban areas lack sufficient wastewater treatment capacity, particularly in the emerging economies of the developing world.

In China, EnviDan collaborates with the engineering/consulting company Aihua, which owns and operates many large wastewater treatment plants. The partnership includes utilisation of the Active Return Sludge Process as well as supporting online control of the plants. The first plant using the EnviDan technologies in China was opened in April 2012.

### The idea has been demonstrated to work.

"We built the first plant to test the idea ten years ago. Today the design has been demonstrated to work, and we now have 15 reference plants running in Denmark, Sweden, the Baltic Countries and China," says Søren Bruun Hansen, Managing Director at EnviDan International A/S.

At the municipal wastewater plant in Nykøbing Falster, Denmark, one of four existing treatment basins is now used to apply the new return sludge process. The concentration of sludge in the three other basins was lowered accordingly.

As a result, 50 percent more wastewater can now be treated to the same degree as before. The already planned construction of an extra final settlement tank is no longer necessary.

### The hard way and the smart way

"In Denmark, the precipitation has steadily increased since regular measurements began in 1874. According to meteorologists, it will continue to do so," says Gert Petersen, Engineer at EnviDan.

Millions of Danish Kroner have already been spent in some municipalities on construction of additional storm water basins in order to limit the discharge of untreated water during heavy rains.

"The capacity has been increased in an expensive way. They could have done so in a much more clever way", says Gert Petersen.

"The rest of the world has a choice. They can repeat what we have been doing for the past 30 years. Or they can choose to do something much cleverer."

# LOCAL WASTEWATER TREATMENT – AN ATTRACTIVE ALTERNATIVE

BIOKUBE

*Local treatment of wastewater is an inexpensive alternative to costly sewerage and wastewater treatment plants. The treated water can be safely reused for many purposes*

Local treatment of wastewater is BioKube's core business. The company itself is located in a village south of Copenhagen.

The reach of the company, however, is global. One day, for instance, BioKube surprisingly received an order from Papua New Guinea.

"That country was not exactly what crossed our minds when we considered new export opportunities", CEO, Morten Brix, readily admits.

It turned out that one of the contractors at a large liquefied gas venture on-going in Papua New Guinea urgently needed wastewater treatment at one of their camps.

BioKube expediently shipped a system to the costumer, and the company got what it needed: A stable, robust, and reliant tailor-made system for cleaning of wastewater right in the middle of the rainforest.

### Corporate responsibility pays off

"Actually we sell quite many of our systems for use in the oil & gas, mining and construction industries, which operate around the world", Morten Brix says.

Such companies often obtain their licences and contracts on the condition that they protect the environment. Frequently, the companies themselves also regard sustainable treatment of their wastewater as part of their corporate responsibilities. The same goes for many hotels and resorts.

An even more impressive case is the supply of large BioKube systems for construction sites and camps in the Middle East, such as Muscat Airport in Oman.

"In such places the local wastewater treatment is not an extra cost. It is a profitable investment. Water is scarce and the treated water can be reused for making concrete and for binding dust", Morten Brix explains.

### "Local treatment is common sense"

At first, the small BioKube systems were developed for use in rural areas to protect the the streams and lakes from discharge of untreated wastewater.

The systems are able to treat the so-called 'grey' wastewater from washing and cooking as well as the so-called 'black' water from toilets.

In a relatively densely populated country such as Denmark, it is possible to extend the sewer system to reach remote households and villages and connect them to existing wastewater treatment facilities. This option, however, is expensive and consumes much energy.

Instead BioKubes founder, Peter Taarnhøj, wanted to provide an opportunity for reliable biological cleaning at the local level. In his view, local treatment is common sense: Less energy and construction work is required, and the water is returned to the natural habitat from where it was taken.

### Strict requirements were enforced

However, the Danish authorities were very demanding. "High standards are required and the performance of our systems is strictly controlled", says Morten Brix. "We were obliged to offer a 40 year service contract. Consequently, we were forced to make our systems very reliable."

"We have obtained a high level of reliability by keeping the technology simple and effective", he says. "We had our system certified many years ago. Since then, we have constantly learned from our experiences and adjusted the technology accordingly. As a result, our systems perform better than required. Operation costs are low and the need for technical assistance is minimised."

Most importantly, special features invented and patented by BioKube keep the bacteria alive and well functioning even when the flow of wastewater stops for an extended period. The performance of the systems installed is regularly measured. The results are published on the BioKubes webpage.

### Strong case for local solutions

Many countries are in the process of expanding their wastewater treatment capacities. The case for local solutions is particularly strong in areas with no sewerage, and where population is relatively dense and water is scarce.

It is possible to protect the public health, local environment, and freshwater resources at low costs. The treated water can safely be reused for irrigation, crop watering, cooling, and other purposes; for some usages after UV-radiation.

"Local treatment is far less capital-demanding than sewerage and centralised treatment", Morten Brix points out.

BioKube provides robust and reliable systems for local biological treatment of wastewater

*Company Profile page 89*

Left: A BioKube system is delivered at an oilfield in Yemen.

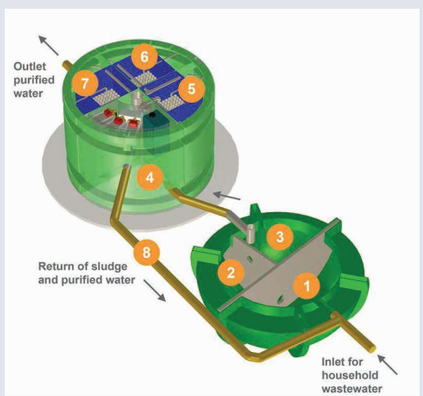
Below: Installaton of a BioKube for a single household in Denmark

## *The Technology:* CLOSE TO NATURES OWN METHOD

Running water in a creek is aerated. The bacteria living in the creek have plenty of oxygen and optimal conditions to decompose organic matter. In some parts of the creek however, where the water comes to a standstill, the bacteria sucks out the oxygen from the water. The water consequently appears greenish. The natural conditions are imitated in a BioKubes, and the BioKube-technology ensures constant flow of oxygen to the bacteria. First, the wastewater is led to one or more pre-settling tanks (1-3). Here sludge and solids are retained. The water is pumped into the first chamber of the BioKube at precisely timed intervals (4). Bacteria living at the surface of submerged aerated filters are fed with the wastewater. The aeration provides them with oxygen. The patented measurement and control system makes sure that they are evenly fed with wastewater round the clock.

The decomposition of organic material begins in the first chamber (5). In the second chamber (6) the biological breakdown of nutrient nitrogen begins. In the third chamber (7) the nitrification process reaches its full potential. In a quiet zone of each chamber, dead bacteria and particles sinks to the bottom as sludge, while the water continues to the next chamber.

The sludge is regularly pumped back to the settlement tank, together with some of the purified water (8). The patented recirculation system secures continued removal of nitrogen and elimination of odorous nitrogen sulphide. It also secures that the units' ability to treat water is preserved. The bacteria will survive at least 12 months even if not fed with additional wastewater (e.g. holiday cottages). Additionally, the BioKube can be equipped to remove phosphorous nutrients.



# BRINGING WASTEWATER BACK TO LIFE

*BioBooster is a new concept for wastewater treatment: The water is treated in high tech modular systems adapted to local needs*

Local treatment of wastewater is a fact of the future. Bent Gadgaard, the Managing Director of Grundfos BioBooster is convinced of this.

"Freshwater resources are increasingly scarce. If we want to use more and more water, we will have to make it clean again, reuse much of it and in the end bring back the water to where it came from – as clean as we got it", he says.

Instead of costly investments in large sewerage systems and centralised wastewater treatment plants, he expect many regions with scarce and vulnerable water resources to prefer local treatment in the future.

### The challenge: Competitive local treatment

BioBooster is a corporate venture of the world-leading pump manufacturer Grundfos.

The mission is to "bring water back to life", which means to clean the water to such a level that it can be safely reused for crop watering and other purposes and recycled back into the local environment from where it was taken.

The challenge is to make such systems cost-efficient and to make them work just as well as the conventional central wastewater treatment plants – preferably even better.

### A compact, modular system

To this end, Grundfos BioBooster has developed a compact modular system based on membrane technology.

A system for treatment of wastewater from the equivalent of up to 6,000 people takes up very little space. It can be manufactured and tested in the workshop. It comes with a truck, and it is adapted to local needs. Once installed and connected to the internet, the system can be remotely controlled and operated for instance by BioBooster's staff.

## *The Technology:* HIGH TECH BIOREACTOR MODULES

The Membrane Biological Reactor, MBR, is the core technology of BioBooster's packaged wastewater treatment plants.

The module combines advanced ultra filtration with biological treatment. Each filtration unit consists of 180 ceramic discs. The pores of the ceramic filtration discs are so small that most bacteria are unable to penetrate them. The biological treatment takes place in the closed tank under pressure. The reactor operates at high concentrations of suspended solids. The design is compact, the performance is high and the energy consumption is low, compared to conventional MBR technologies.




A BioBooster solution in opreation in Hemsedal, Norway

GRUNDFOS

Grundfos BioBooster has developed compact wastewater treatment units based on membrane technology

*Company Profile page 99*

### High water quality

The biological treatment takes place in closed reactor modules. Membranes with ultrafine pores are used to separate sludge from treated water.

The pores are so fine, that bacteria can't pass them. The resulting water quality is safe for bathing, crop watering and technical use in industries and households. No odours are released. No large concrete basins or other extensive construction works are needed.

### Fit for industrial batch production

The modular and compact design has the advantages of flexibility, reliability, and competitiveness.

"Our aim is an industrial product", says Bent Gadgaard. "The modules can be produced in a standardised way and stored continuously. In the future we will be able to meet customer's needs by combining modules taken from our store and shipping the entire system within three months."

The industrial approach means that rising sales will entail lower prices. "Here at Grundfos we know from experience that the more pumps we can make, the cheaper we are able to make them", Bent Gadgaard laughs.

Today, the total costs of purchasing and operating a BioBooster system are in the order of less than € 2 per cubic meter of water treated.

In Denmark, houseowners often pay more than € 4 per cubic meter of water discharged. These charges are mostly used for maintaining the vast sewerage systems.

The BioBooster system is attractive to food & beverage industries with high organic loads as well as to remotely located communities. A full-scale test plant is in operation in Bjerringbro Wastewater Works, Denmark.

An integrated retrofit solution is in operation at the Norwegian ski resort Hemsedal.

BioBooster test plant in Bjerringbro, Denmark


June 2011: ET Carwash world premier. The mayor of Nyborg, Denmark, shuts the sewer

# CAR WASH WITH NO DISCHARGE

*No filthy water is discharged. No sewer is needed with ET Carwash*

An ordinary car wash consumes approximately 100 – 250 litres of clean water. The wastewater contains oil, dirt, heavy metals, harmful substances and wash chemical residues.

ET Carwash is a radical solution to this environmental problem. It is a closed loop system. The water is cleaned and reused, over and over again. Nothing is discharged into sewers.

### Full stop

Traditional wastewater treatment and water savings help to diminish the problems caused by carwashes. ET Carwash, however, does not only diminish the problems. It eliminates them.

The ground-breaking concept is based on the Danish company Envotherm's patented water evaporation technology. The equipment has been developed by Envotherm, in collaboration with Statoil Fuel & Retail, which operates 2,300 fuel and retail stations across Scandinavia, Poland, the Baltic countries, and Russia.

The new environmentally friendly technology has the potential to become standard equipment for car wash facilities.

"On average, our system is able to reduce the consumption of water per car wash from 250 litres down to 10 litres. The discharge of waste water can be totally avoided. In addition the return on investments is below 3 years", says Envotherm's CTO, Richard Dines Schmidt.

### Washing with distilled water

Extravagant as it may seem, the recycling is obtained by distillation of the water. Normally it would be far too expensive to wash cars with distilled water. Significant energy is required to evaporate water and condense water vapour again.

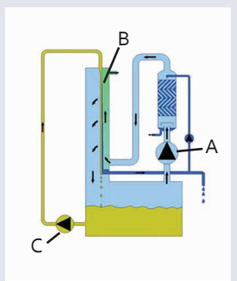
Envotherm, however, has developed a system that recovers the heat used for the evaporation of water. The heat, just like the water, is used over and over again.

The only source of energy used in Envotherm's system is a blower to boosts the pressure of water vapour.

### Eighty times less energy used

Pressure cookers are used for quick cooking of food because the boiling point of water increase as the pressure rises. The water is superheated and the steam contains more energy.

## *The Technology:* MECHANICAL VAPOUR RECOMPRESSION




The method used by Envotherm to distil water uses no permanent heat source. Instead a blower (A) is used to compress water vapour.

The energy content of pressurised vapour is higher than for non-pressurised vapour. The boiling point is elevated.

Therefore, at the right, green side of the thin metal plate (B) the vapour condenses and forms water drops at a temperature slightly higher than the normal boiling point of water.

When water evaporates, it uses heat. Everybody know this from experience: When you sweat, your skin is cooled because the sweat evaporates. When water condenses, the opposite thing happens: heat is released.

So, the metal plate is heated to a temperature slightly higher than the boiling point of water at normal pressure. As a consequence, more water evaporates at the left, blue side of the metal plate, which is constantly kept wet with waste water by the pump (C). This vapour is drawn to the compressor (A), and the process continues.

Because the heat is constantly recovered, Envotherm is able to distil water using only an eightieth of the energy normally required. The distilled water collected and used to pre-heat wastewater before it is used for car wash.

Suspended and dissolved solids along with nitrogen, organic matter, fatty acids, heavy metals, and other minerals are concentrated in the yellow condensate at the bottom.

The entire equipment is integrated in a one-unit compact design. Internal monitoring allows for remote control and service via the internet.




Envotherm uses the same principle in the opposite way: The pressurised water vapour condenses at a temperature above the normal boiling point of water. The heat released by the condensation is recovered and used to evaporate more water, at normal pressure.

This system has been optimised by Envotherm to lower the energy consumption.

"We use eighty times less energy than would normally be required to evaporate water", says Richard Dines Schmidt. The power consumption is practically lower or the same as my wife's hair dryer".

To distil 50 litres of water, the evaporator uses only 1 kWh of power.

### Only a few grams of waste per car

The use of soap and chemicals is also reduced, because distilled water is soft.

Newly distilled water is used particularly for the final rinsing of the cars, leaving them with no lime traces. The risk of corrosion is reduced, because the water is free of salts. The washing and flushing of more dirty parts of the cars is made with less clean, 'grey' water. The dirty water is filtered and conducted to the evaporator, where the waste is concentrated and taken away.

At a facility with more than 10,000 car washes per year, the total amount of waste is in the order of only 100 - 250 kilos of dry matter per year. It is removed for incineration.

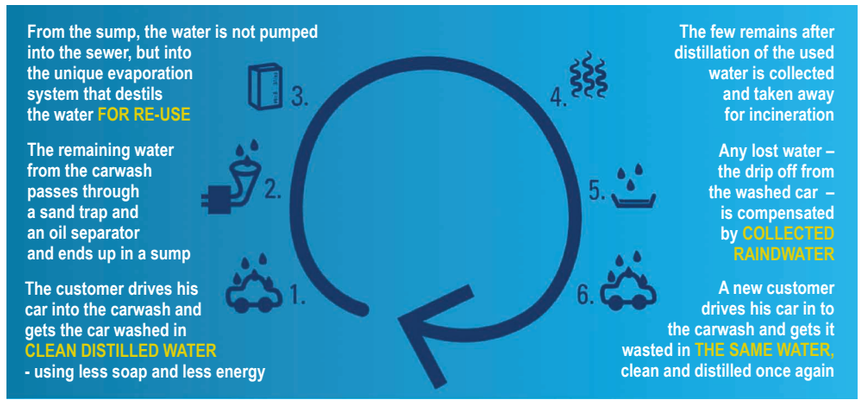
### Zero water consumption is possible

The only water consumed is the moisture in the air and on the cars leaving the facility. It can be compensated by collecting rain water from the roof.

The system can be integrated at an existing car wash facility, and the installation does not require much space.

Depending on local water price and waste water charges, the money saved is likely to outweigh the investment in a few years.

Since no wastewater is discharged, the time consuming applications and documentation to have the car wash approved by the authorities is no longer an issue.




Envotherm supplies evaporators for energy efficient treatment of heavy loaded waste water

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ET Carwash

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# *Turning* WASTEWATER *into* POWER

*The sludge from wastewater treatment is a valuable source of energy. Krüger's EXELYS™ technology makes the energy more available*

Costly wastewater treatment can be turned into a profitable operation. Actually, the organic compounds contained in wastewater are useful resources. For the sake of the environment, they have to be removed from the water before it is discharged into open waters. But the remaining sludge is not only rich on nutrients, it is also a valuable source of energy.

### More biogas – less sludge

EXELYS is a technology developed by Krüger to extract energy from the sludge in a highly efficient manner.

"Our full scale demonstration plant has been in operation for more than one year in Hillerød, Denmark. In 2011, we started commercialising the technology, and it has attracted guests from many countries. The proven results are significant. With EXELYS, you can make more biogas from the same amount of sludge, the quantity of final sludge to dispose of is reduced, and the costs of operating the entire treatment plant are reduced", says Ole Fritz Adeler, Krüger.

### Making biogas

Anaerobic digesters are commonly used to extract energy from organic waste such as sludge, manure and other organic residues by production of biogas.

The main component in biogas is methane ($CH_4$). Methane is formed by certain bacteria as the final step in the anaerobic degradation of biomass, under conditions where no oxygen is present and at a temperature of 35-37 or 55-57° Celsius. In nature we see this happen e.g. in swamps, rice fields, landfills, and in the stomachs of cattle. The digestion is significantly enhanced if the sludge is kept at high temperature and high pressure for at least 30 minutes before they are fed into the biogas digester. This pre-treatment degrades the biological cells, and large organic molecules are split into smaller ones. This makes the organic matter more available to the bacteria.

Due to this pre-treatment, called thermal hydrolyses, the digestion will produce much more biogas and less final sludge.

### Attractive solution

Until recently the thermal hydrolysis has only been used at very large wastewater treatment facilities. The thermal hydrolysis process in itself is very energy-demanding, and additional reactor volume since it has been performed in batch-mode, e.g. treating one portion of sludge at a time.

EXELYS overcomes these constraints and therefore makes thermal hydrolysis attractive for a wide range of treatment facilities.

Instead of a stop-go process, the hydrolysis functions continuously. It can be sized for the actual quantity of sludge produced by the plant over time, and the energy-use is optimised.

### Heat and power production

In the Exelys process the biogas can be used to fuel an engine which drives an electricity generator. The power produced by such a combined heat and power unit can be used internally or sold to the grid.

Heat is required to produce the hot steam needed for hydrolysis. As soon as the hydrolysis is finished, EXELYS recovers the heat contained in the sludge. Most of it is recycled to the steam generator. The rest of the heat is useful for other purposes at the plant – or it can be sold to the local district heating network.

With further optimisation of EXELYS, and the possible use of fuel cells as CHP-unit, it will be possible to not only be self-sufficient, but to also sell power and/or heat from the wastewater treatment plants of the future.

### Fits well with renewables

Another great advantage of EXELYS is that it fits very well with renewable energy sources, such as wind and solar power.

When the wind is not blowing or when it is dark, renewable energy sources need backup from other sources. When the wind and sunlight is plentiful, the renewable produce more power than needed. The power-prices at the spot market fluctuate accordingly.

With a STAR® Control system (see page 68), the processes at the wastewater plant, including EXELYS, can be slowed down or accelerated. As a result, the plant can use power from the grid whenever the price is low, and sell power to the grid when the price is high.

EXELYS™ is developed by Krüger to make production and use of biogas more efficient and attractive to all sizes of wastewater treatment plants

*Company Profile page 101*

## *The technology:* CONTINUOUS THERMAL HYDROLYSES

With EXELYS, the production of biogas in wastewater plants can be enlarged by up to 50 percent, and the remaining sludge for disposal can be significantly reduced.

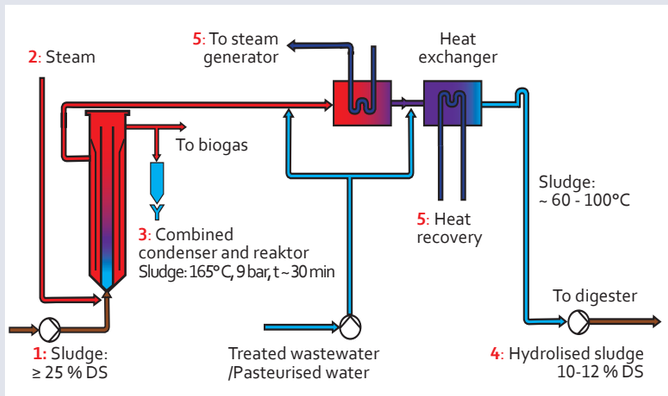
The sludge(1) is mixed with hot steam (2) under pressure. It is retained in this condition for at least half an hour (3). This hydrolysis breaks down the organic compounds in the sludge. Hydrolysis enhances the production of biogas because the organic matter becomes much more available for digestion by anaerobic bacteria.

The hydrolysed sludge is fed into the biogas digester at a decreased temperature (4). It has been demonstrated, that EXELYS can improve biogas production by 30 percent.

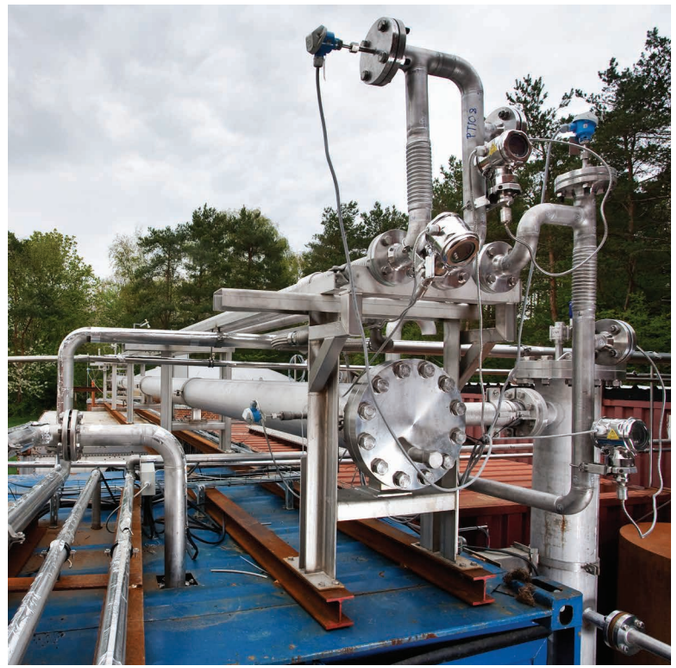
The heat from hydrolysis is recovered (5). Compared to traditional batch thermal hydrolysis, EXELYS consumes less energy for hot steam, mixing and pumping. Less capacity is needed for treatment and storage.

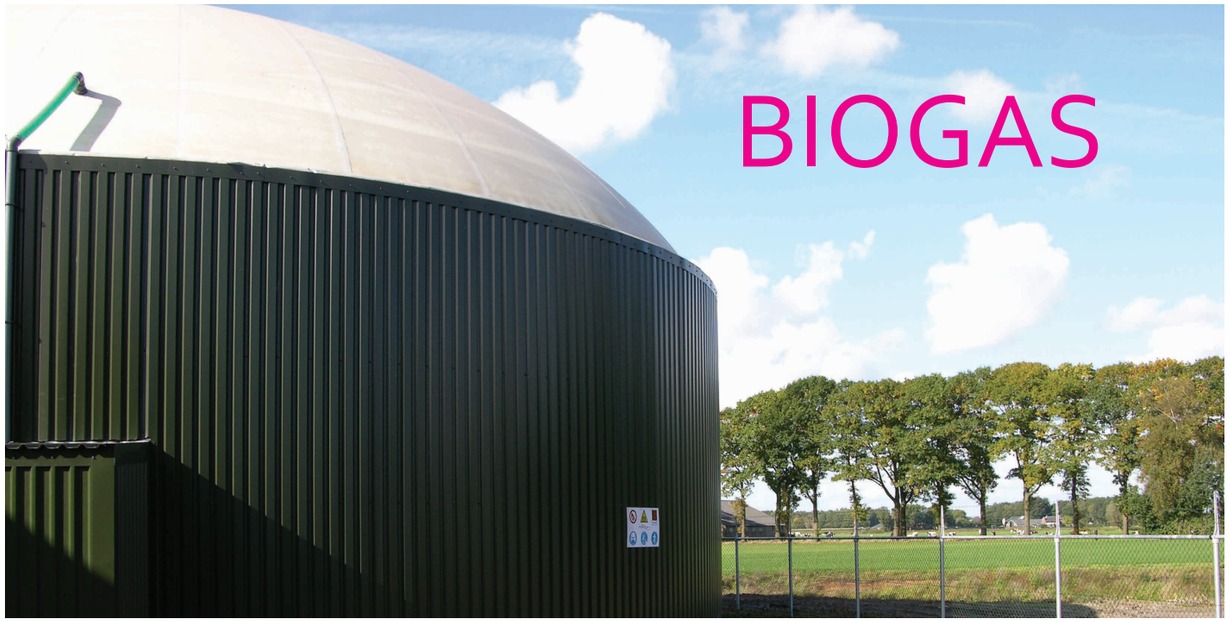
The water content and the volume of remaining final sludge after the production of biogas is significantly reduced. Expenses for final disposition are therefore lowered.

The biogas can be used for combined production of power and heat. Some of it can be used to reduce the need of external power sources at the plant - the rest can be sold to the grid and/or to local district heating networks.




At this plant, EXELYS® increased the production of biogas by nearly 30 percent. The disposal of sludge was diminished by 20 percent





# BIOGAS

*AgroTech made it possible to detect and measure invisible leaks of biogas*

Biogas is a promising source of renewable energy. The manure from one cow, if digested in a biogas reactor, can provide enough energy to generate the amount of electricity consumed by an average Dane.

With 560,000 diary cows, not to mention the rest of the cattle and 13 million pigs in a country of 5.6 million inhabitants, the potentials are significant. Plant residues and food wastes can also be used to make biogas.

### Detrimental effect

Biogas, however, mainly consists of methane, and methane is a powerful greenhouse gas.

So, if biogas leaks from the plant where it is made, it is detrimental to climate stability. Much methane can escape, even from small leakages. The agri-technological institute AgroTech has developed a new method to detect these leaks and measure the quantity of methane leaking.

### A special camera makes it easy

"It is quite difficult to detect biogas leaks, because the gas is invisible", notes Kasper Stefanek, AgroTech. "Previously we used complicated and not very precise methods. Today, we use a specially designed video camera that makes this detection much easier".

The camera operates at a wavelength where the escaping stream of methane is visible. AgroTech needs only to film the entire plant, and zoom in on the leaks. "Typically, we find ten or more leaks when we inspect a biogas plant. Some of them are very small, but combined, they can seriously affect the overall performance and the economy of the plant", Kasper Stefanek says.

## *Technology:* MEASURING BIOGAS LEAKAGES

The first step is to locate the leaks. Biogas consists primarily of methane, and methane is invisible to the human eye. However, escaping methane can be viewed and filmed with a special video camera, operating in a part of the infrared spectre.

The AgroTech-team locates leaks with just such a camera, much like the cameras widely used to detect heat escaping from buildings.

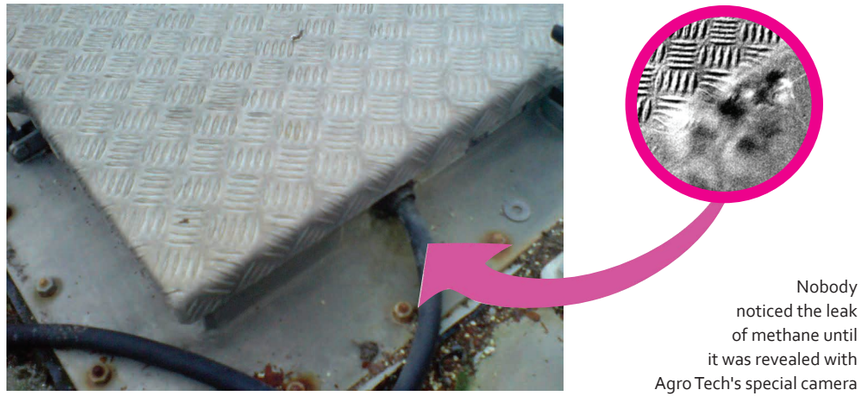
The next step is to measure the amount of methane leaking. This is done with a device called a 'dynamic chamber'. The leaking methane is drawn into the chamber by suction – like with a vacuum cleaner. Observing the fan of methane with the video camera, the team makes sure that all leaking methane is captured and sucked into the dynamic chamber.

Inevitably some ambient air is drawn in too, but that is not a problem, because the equipment measures the total airflow as well as the concentration of methane.

From these figures, the total amount of methane escaping from the leak per hour is calculated.



# MADE VISIBLE



Nobody noticed the leak of methane until it was revealed with Agro Tech's special camera

### Inspiration across disciplines

The novel concept for measuring the amount of methane leaking is inspired by the methods used by his colleagues to monitor emissions from livestock.

"At AgroTech, the experts work closely together across disciplines. Otherwise, I suspect we would not have had the idea to combine the two methods", Kasper Stefanek admits.

### Fast pay-back

Christian Beck, the owner of a farm biogas plant, estimates that AgroTech has saved him the expense of a couple of hundred thousand Danish Kroner (€ 27,000). AgroTech found a leak in the membrane covering the storage tank at his ten year old plant.

"I expect to call them again", he says. "It is very difficult to find the leaks. It just seeps, slowly and quietly".

"It is a smart technology", says another customer, Jens Peter Lunden, owner of a biogas plant called Greengas, "AgroTech found more leaks than we expected".

Biogas digesters are fed with plant residues, livestock manure and fatty waste from the food industry. According to Kasper Stefanek, one of the customers reduced his purchase of fatty waste with DKK 135,000 a year (€18,000) subsequent to the detection and repair of a major leak.

### Killing two birds with one stone

Biogas production reduces waste and produces energy. The residues from digestion are useful as fertilisers, and the biogas fits well into an energy system based on renewable sources. Contrary to wind power and solar energy, the biogas is stored in tanks. Consequently, it can be used when the wind does not blow and the sun does not shine.

Manure and livestock wastes, harvest surplus and plant residues, waste from food industries and households, wastewater sludge and municipal solid waste can be used to feed biogas digesters.

Biogas production is expanding in many countries. In Denmark, the government has launched a plan to increase biogas production in the coming years.

### Improving biogas technologies

AgroTech assists the agricultural sector in assessing the biogas potentials and developing, testing and improving the biogas technologies.

Among these activities are assessments of plant biomass for biogas production, pretreatment of liquid manure and other feedstock, optimisation of plant operations, posttreatment and utilisation of degassed slurry and residues, purification and utilisation of the biogas produced, an so forth.

AgroTech
Institute for AgroTechnology and Food Innovation

AgroTech A/S provides advice and technological services to the agricultural sector, horticultural nurseries, and food producers

*Company Profile page 86*

# ASSESSING THE IMPACTS

*The Arctic is rich on minerals, and many companies are preparing for mining in the area*

Greenland, the world's largest island, is an autonomous country within the Kingdom of Denmark. Some of the indigenous traditions are quite strong, but the original fishing and hunting culture is far from able to finance the modern way of living.

The current production is dominated by the fishing industry, while more than half of Greenland's overall public spending is funded by Denmark.

### Many exploration licenses

The Self-Government hopes that economic independency and prosperity for the 56,800 inhabitants will emerge from mining and oil exploitation. "Greenland has all the minerals you can imagine", says Per Møller-Jensen, Head of Department at the consultancy company Orbicon. "There is gold, diamonds, rubies, tin, lead, iron, uranium, rare earth elements, you name it".

The mapping of minerals has gone on for many years. The Self-Government has issued more than 100 exploration licences to mining corporations. However, in order to be granted permission to mine the minerals, the mining companies must demonstrate in detail how the environment will be affected by their work and how they intend to protect it.

### Close to the North Pole

Orbicon is engaged in assessing the environmental impacts of mining projects in many parts of Greenland.

"We conducted studies as far north as Citronen Fjord, where the Australian company Ironbark Zink Ltd. plans to establish the world's northernmost mine to exploit zinc and lead deposits", says Per Møller-Jensen.

Greenland's wilderness is vast, and the conditions for mining are harsh. In some aspects, the environment is vulnerable because the biological turnover is very slow in the Arctic. The locals are particularly concerned about future conditions for hunting and fishing.

"Greenland is known for its pure nature and mining is a controversial subject", says Per Møller-Jensen. "The mining companies are focused on meeting the international requirements for environmental assessments in order to have their projects approved and financed. We satisfy these requirements, based on knowledge of the Self-Government legislation and on our extensive experience".

## Environmental Impact Assessments

The purpose of Environmental Impact Assessments is to identify, evaluate, and minimize the environmental effects of a project. Such assessments are mandatory prior to large scale mining and construction operations.

To assess the impacts and evaluate the precautions to be taken, it is important to examine the environment in an undisturbed state. Baseline studies have to be carried out 2-3 years before the activities begin in the area. Usually Environmental Impact Assessments are very extensive and detailed. A broad basis of professional experience is required to complete the multi-disciplinary task.

Orbicon is experienced in assessing environmental impacts. In addition to mine projects in Greenland, it includes extensive studies at Femarn Belt, the water between Germany and Denmark, prior to the construction of a tunnel, planned to connect the two countries.



### Huge iron ore

Orbicon has established a local branch office in Nuuk, the capital of Greenland, and works closely with the Bureau of Minerals and Petroleum as well as their advisor DCE.

In Nuuk Fjord in Western Greenland, not far from Nuuk, Orbicon has assessed the impacts of the huge iron ore project. London Mining plans to produce 15 million tonnes of high-grade 70 percent iron concentrate from an open pit mine operation close to the edge of the glacier. The environmental impact assessment is a 1,500-page document.

### Rare Earth Elements

Greenland also has the potential to meet the world's rising demand for rare earth elements. These minerals are extensively used, especially in high tech and clean tech industries such as production of electrical car batteries, wind turbines, loud speakers, cell phones, and lap tops.

Kvanefjeld in South Greenland has long been known for its uranium deposits. Now the Australian company, Greenland Mining and Energy, has also detected the world's supposedly second-largest deposits of rare earth elements in the Kvanefjeld. Zinc is also abundant. Orbicon has conducted baseline studies of biota, dust and so forth at Kvanefjeld over the past four years. The environmental impacts assessment is expected to be finished this year.

Orbicon has also examined the environment and the impact of mining operations at Killavaat Alannguat, where other deposits of rare earth elements and other metals are found.

## Offshore wind farms are like artifical reefs

The construction of off-shore wind farms is rapidly expanding across Europe. Hitherto, Denmark has been a leader in the field, with 12 off-shore wind farms in operation.

Orbicon has investigated the impact of this type of wind farm on fish life, at one of the largest wind farms off the Danish coast. In collaboration with the Technical University of Denmark, they found that the wind farms have positive effects on local ecosystems. The 'artificial reefs' around the wind turbine foundations are beneficial for fish communities.

"Orbicon has been involved in all offshore wind projects in Denmark", says Head of Department Per Møller Jensen. "Among other things we have found that the intensively discussed impact on the birds seems to be less than earlier expected".

"Fortunately these impacts can be solved by choosing the right locations – based on thorough investigations and assessments".

ORBICON

Environmental Impact Assessments is a core activity of Orbicon, an experienced consultancy company in the fields of the natural and built environment

*Company Profile page 107*

# COMPANY PROFILES

# Improving Food Production Technologies

*Case Stories:*
CLEAN TECH CATTLE BARN
*Page 28*

BIOGAS MADE VISIBLE
*Page 80*

AgroTech is an Approved Technological Service Institute offering research-based consultancy and technological services for the agricultural sector, horticultural nurseries, and food producers.

AgroTech aims at creating green development, new business opportunities, and improved competitiveness through innovation in the entire value chain, from primary produce to final consumption.

Among its clients are the suppliers of technology and equipment to the food producing sector, the primary producers, and the food companies.

AgroTech's focus areas include crop and livestock production, biogas, vegetables, horticulture, bioplastics and fibres, environmental protection and green energy, and novel food products.

### Clean Tech development

In the field of environmental technologies, AgroTech covers the entire development chain from the conception of ideas at innovation workshops through concept development, design, tests, and trials, to implementation, documentation, and certification of the final products.

To promote environmentally sound and innovative practices AgroTech offers a range of tests, measurements, evaluations, analyses, and technical advice. Among them:

- Development and documentation of new technologies, including measurements, life cycle analyses (LCA's), and verification
- Proof-of-concept tests
- Estimates and measurements of biogas potentials
- Optimisation of cultivation and storage of biomass intended for energy use
- Measurement of emissions

### Innovation across borders

AgroTech has a staff of approximately 90 employees. Most of them are experts in their field.

Their competencies cover most aspects of agritechnology and food innovation, including livestock production, sensor technology, clean-tech solutions, biomass technologies, environmental and climatic impact, data analyses, and so forth.

The variety of its projects can be illustrated with some examples:

- Feed efficiency of dairy cows
- Carbon neutral chicken production
- Zero emission pig production
- Reduction of food wastes
- Farmers as energy suppliers
- New types of lettuce in the salad bowls
- Development of innovative plants
- Microalgae as a new crop
- Urban greening

In consultancy and projects, AgroTech's experts work closely together, combine their knowledge across professional disciplines, and involve the client's knowledge as well as the knowledge of external experts in the final solutions. AgroTech collaborates with scientists at the Faculties of Agricultural Science at the University of Aarhus and the University of Copenhagen.

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# Nano-biotechnology in Water Filtration

*Case Story*
THE PERFECT WATER FILTER
*Pag2 42*

Aquaporin A/S is a Danish cleantech company engaged in the development of advanced membranes for filtering and purifying of water.

The goal is to create some of the world's most efficient membranes for water filtration.

Aquaporin recently launched its first prototype membrane, Aquaporin Inside™, based on seven years of research, development, and tests.

### Extremely pure water

Aquaporin A/S was founded in 2005 by the biochemist, Peter Holme Jensen, and the biophysicist, Morten Østergaard Jensen.

Their idea was to make the properties of natural aquaporin proteins useful for water filtration at an industrial scale.

Aquaporins, also known as 'water channels', are proteins present in most living cells. They have the ability to selectively transport water through the membrane of the cell. They only allow pure water to pass the cell membrane.

This property is vital to our kidneys as well as to the life and metabolism of most animals, plants and other living creatures.

The water passed by aquaporins is more pure than distilled water.

### Funding and finance

From 2005 through 2012, the company's activities have attracted financial funding in the order of € 30 million. Half of the finance has been provided by public/private funds, such as Danish and European Union supported research and development programs, and technological business-development programs. The other half of the finance is venture capital, mainly investments from M. Goldschmidt Capital A/S, which is now majority shareholder in Aquaporin A/S.

### High tech teamwork

The creation of the first prototype membrane has been achieved by a team of specialised scientists. Experts in many fields have worked together, to solve complex problems and make the new technology work in practice.

Since 2009, Aquaporin A/S has also worked with Singaporean scientists. The Singaporean government has supported the project with a financial grant of Singaporean dollars 3.5 million.

Today, Aquaporin A/S and its subsidiary Aquaporin Asia have 28 employees.

Further development and commercialisation of the first membranes is now being carried out in collaboration with the German-based Membrana GmbH, the world's largest supplier of microporous membranes for medical applications, as well as the Singapore Membrane Technology Centre under Nanyang Technological University's Environment & Water Research Institute (NEWRI).

### Far reaching perspectives

The technology has the potential to deliver extremely pure water for various purposes and to purify contaminated water that needs special treatment, for example in the medical sector and the pharmaceutical industry.

At present, Aquaporin A/S focuses on filter solutions for industries in which high grade purification of water is especially valuable – such as the aerospace industry, medicine, pharmaceutics, and hospitals.

In the future, however, aquaporin membranes may be applied at a much larger scale for many purposes, including desalination of seawater.

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# Biological Odour Removal

*Case Story:*
BACTERIA AND FUNGI CONSUME THE ODOUR
*Page 32*

BBK bio airclean A/S supplies biological filters for the removal of odours from air ventilated from organic industries. The filters are built to treat airflows from levels of 500 to several hundred thousands of cubic metres per hour. The odorants are efficiently digested by microorganisms when the air passes through the filter. After this treatment, the bad smell can barely be detected.

### Many years of experience

The company was founded in 1992, with the objective of improving the existing biological air cleaning methods.

Today, the company has twenty years of experience and more than ten years of proven results. A total of 80 BBK filter plants are in operation in Denmark, Norway, Spain, the UK, Ireland, Sweden, and other countries.

BBK's main fields of activity are facilities for the composting of organic waste, biogas plants, sewage treatment plants, and animal rendering plants. However, other types of organic industries, such as the processing of food and animal by-products, can also benefit from BBK filters.

Improvement of traditional technology

The development of the filter technology was undertaken in cooperation with the Biotechnological Institute in Kolding, Denmark, which is now part of Eurofins Denmark.

The principle is to make the stream of malodorous air pass through a humid filter medium, which is covered with specific, naturally occurring micro-organisms, preferably bacteria and fungi. The organisms feed on the odorous compounds in the air – and decompose them, leaving only carbon dioxide, water and energy.

### A high quality solution

BBK has improved all aspects of this process: The filter medium, the selection of microorganisms, the choice of materials, the design, as well as the control of humidity, temperature and acidity (pH).

Much of the development has been achieved through trial and error. A large number of tests with various combinations of micro-organisms and filter materials have been carried out. The key to high performance has been "hard work, studies, and persistence", as CEO and founder of BBK, Arne Poulsen puts it.

As a result, the BBK filter media are very homogenous, stable and durable. More than ten years of constant high performance has been proven.

Instead of using a broad and uncontrolled variety of microorganisms, BBK achieves a high efficiency (typically more than 95 percent of the odorants are removed) by inoculating specific micro-organisms into the filter medium. The flora of micro-organisms are selected to fit the needs of each individual type of industry.

### Durability lowers the costs

BBK insists on using high quality materials and equipment for construction, piping, ventilation and so forth. Warranties and after sales service is a part of the contract.

"Our plants are expensive compared to other biofilters, and we do not offer any discount solutions," says Arne Poulsen. However, if the durability, the efficiency and the stability are taken into consideration, he is confident that BKK remains a competitive option.

BBK biofilter at a composting plant in Spain

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# Robust Local Wastewater Treatment

*Case Story*
AN ATTRACTIVE ALTERNATIVE
*Page 72*

BioKube makes local wastewater treatment systems. More than 2,500 BioKube systems have been supplied to Danish costumers, and approximately 2,000 have been supplied globally.

Initially, the BioKube systems were intended for biological treatment of wastewater stemming from single households or small villages in remote areas where no sewerage exists.

Yet larger systems are also available. Wastewater derived from several hundred people in villages, resorts and camps, can be treated with BioKube systems.

Several BioKube units can be combined to treat up to 1,000 cubic meters per day.

### Global common sense

According to BioKube, the local treatment of wastewater, recycling of water and reuse of valuable nutrients in wastewater is "simply common sense".

"Water resources should be preserved locally. All over the world, freshwater resources are becoming increasingly scarce. It is therefore essential that they are not contaminated. BioKube is dedicated to supplying world class wastewater treatment for safe reuse by man and nature all over the world", says BioKube's CEO, Morten Brix.

### No surveillance required

The BioKube technology is not high-tech and computerised. Rather, it is basic and natural. It is constantly developed for the purpose of improving the reliance and stability of the systems.

"Most of our solutions are implemented in areas where infrastructure is insufficient and specialists in wastewater treatment are not at hand. Consequently, our systems must function steadily with a minimum of service and no surveillance required", says Morten Brix.


### Durable and reliable

The performance and reliability of the BioKube systems is amply documented. The polymers and other materials utilised within the system are selected with a view to ensuring a 40 year durability at minimum.

The systems are designed to keep functioning, regardless of varying temperatures, inlet volumes, organic loads and pollutants such as household chemicals.

The outlet water from the system is clean enough to be discharged into local waters without further treatment. When reuse is desired, e.g. for crop watering, BioKube recommends after-treatment with UV-light in order to eliminate germs and avoid the risk of infections.

### Low energy consumption

The designs are made to minimise energy consumption in the manufacturing, installation and operation of the BioKube systems. For phosphorus removal, a precipitation chemical is needed. However, the consumption of this chemical has been significantly reduced by adapting the doses to the actual volume and concentration and through a specially designed filter.

A positive side-effect of this filter is that the nutrients become more accessible to plants when the sludge is used for fertilisation.

### Shipped all over the world

BioKube has 14 employees and an annual turnover of approximately € 3 million. The systems are shipped ready to use or tailor made for special purposes all over the world.

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# Handling of Sewage and Storm Water

*Case Story:*
CLEANING THE STORM WATER
*Page 64*

Bonnerup Consult, founded in 2002, is an engineering consultancy firm which specialises in drainage and sewerage systems, storm water, basins and waste water treatment. HydroSystems was founded two years later. It supplies products for drainage and storm water systems, including the patented HydroSeparator. Both firms are owned by Bonnerup Invest.

### Many years of experience

Arne Bonnerup is an experienced engineer. He has worked with drainage and sewerage systems since 1981, holding several positions in municipalities and private companies, before starting his own firm. Since then, the consultancy firm has experienced sustained and rapid growth.

The primary customers are utility companies. Many of them are in need of improving their handling of sewage and storm water.

### Growing challenges

Discharge of untreated water into the aquatic environment is a growing problem for several reasons. Climate change means that heavy rains are becoming more frequent and more intense. In many areas, the sewerage systems are obsolete and the capacity to handle storm water is insufficient. Flooding of basements and low-lying areas is occurring more and more often. At the same time, the legal obligations to protect the environment are growing. Policy makers are tightening regulations. A clean aquatic environment and the prevention of flooding has now become a public demand.

### Stormwater management

Local infiltration of rain water, local treatment of storm water and better control of overflow are all parts of the solution. Bonnerup Consult has demonstrated that storm water can be retained and treated separately from sewage water at a relatively low cost. In close cooperation with utility companies, Bonnerup Consult offers a comprehensive approach to storm water management and a strategy to meet expected future challenges.

### Better use of existing capacity

The modernisation and expansion of existing sewerage systems are costly investments. The opportunities to reduce costs by making better use of existing capacities are, however, often neglected.

Bonnerup Consult offers assistance through the analysis of the existing system, which includes modeling of sewer systems, flow measurements forcalibration, automation of cleaning operations, dynamic flow regulation, and other methods to optimize the utilisation of existing pipes and volumes. The consultancy assistance also includes flood calculations in urban areas as a consequence of climate changes, project management, planning, and design of new facilities such as pipes, pumping stations, and basins.

A HydroSeparator being established close to the Opera House in Copenhagen


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# Treatment of Ballast Water

*Case Story*
ALIEN SPECIES NO ENTRY
*Page 36*

Three Danish companies have joined forces to develop an efficient, reliable, flexible and cost-effective system for the treatment of ballast water, the DESMI Ocean Guard OxyClean system.

The system is fully tested and certified according to the requirements and guidelines of the International Marine Organization, IMO.

The performance of this system has been proven to exceed the requirements of the International Maritime Organization, IMO. The requirements of the US Coast Guard are also surpassed.

### High demand expected

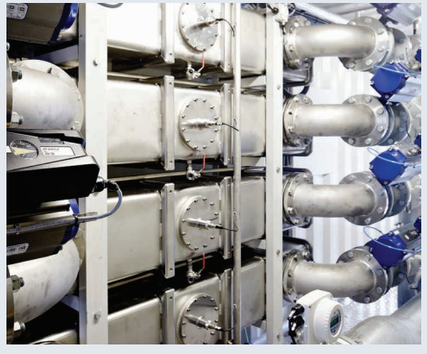
The introduction of alien species into local waters is a serious threat to the marine ecology, fisheries, and health of people around the world.

Millions of tonnes of water are carried from coast to coast in the ballast tanks of the world's ships. At any given time it is estimated that this water contains 7,000 species, including microorganisms, small invertebrates as well as eggs, cysts and larvae of various marine species. Some of them are able to invade local ecosystems and disturb their balances, with devastating consequences.

From now until 2020, approximately 50,000 – 70,000 vessels will be required to install ballast water treatment systems to comply with IMO's Ballast Water Management Convention.

### Joined competencies

Desmi Ocean Guard was established in 2009 by A. P. Moller – Maersk A/S, DESMI A/S and Skjølstrup & Grønborg Aps.



Maersk operates the world's largest fleet of container ships, along with approximately 200 tankers and many other vessels.

Desmi is a leading provider of pumps for the marine industry, with supply and service organisation worldwide.

Skjølstrup & Grønborg is specialised in sophisticated water treatment. Under the brand name UltraAqua, the company supplies water treatment systems for aquaculture, zoo's and swimming pools.

Combined, these three companies possessed the competencies to consider any potential implication from the very beginning of designing the system.

### A flexible system

The result is a modular system, which can be scaled for treatment of any volume of ballast water between 100 and 3,000 cubic metres per hour.

The system is available in containerised and skid-mounted versions ready for plug-in, as well as configurations adapted to the available space and design of each vessel. In any case, the system does not require much space.

The water is treated at intake and discharge by filtration, UV-radiation and ozone.

No chemicals are added and the energy consumption is kept low.

An important feature is that the DESMI Ocean Guard OxyClean system is efficient even in turbid freshwater. This is important because the loading of ballast water often takes place in ports situated in the estuaries of major rivers.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going the extra mile

# High Emission Standards

*Case Story:*
LIFEGUARD AT THE TAILPIPE
*Page 24*

Dinex supplies exhaust systems and low emission technologies for commercial diesel vehicles and industrial machinery. Among Dinex's customers are some of the world's largest manufacturers of trucks, vans, buses, and off-road vehicles.

### Complete exhaust systems

The Dinex business concept is to develop, manufacture and distribute the entire system, from turbo to tailpipe, for all heavy-duty vehicles.

Dinex has the facilities and the competences to make all the parts needed for complete exhaust systems that meet the highest emission standards of the near future: EURO VI/Stage IV for on-road/off-road heavy-duty diesel vehicles in Europe. In the USA, these emission standards would be the EPA 10/Tier 4f.

Dinex manufactures practically all components in-house. The production encompasses the ceramics used for diesel particulate filters (DPF) and SCR catalysts as well as the coating hereof, the silencers, bended pipes, insulation of pipes, flex pipes, fittings, clamps and insulation.

Dinex works with automotive partners worldwide to design and develop, test and validate, manufacture and distribute the complete exhaust and emissions control system appropriate for each make and model.

### High tech development centre

The modern Technology Centre is equipped to facilitate the development of new technologies and constructions. It is in through this centre that Dinex works with customers to meet the challenges of tomorrow. Silencers, filters, catalysts, and prototype systems are tested in a fast and flexible, accurate way and in great detail. Their ability to meet required standards for noise, vibrations, and air pollution are verified and documented.

### Access to low emission zones

Approximately half of Dinex' activity concerns the manufacturing and supplying of original equipment. The other half is the supplying of spare parts, including the retrofitting of filters and catalysts to elder vehicles.

All major makes of trucks and busses can be retrofitted with the complete solutions developed by Dinex to meet varying demands.

Vehicles with a DiSiC® Dinex diesel particulate filter are allowed to drive anywhere, because the filter is certified in all countries that have established low emission zones.

### Global presence

Dinex is a family-owned company which was founded in 1982. In Europe, Dinex is among the leaders of its field. Their vision is to become the main supplier of exhaust systems for heavy duty vehicles worldwide.

The head office and the Technology Centre are located in Denmark. The production takes place in Denmark, Germany, Latvia, UK, Turkey, Russia, China and the USA.

### Certificates

Dinex' quality management is certified according to the most recent version of ISO 9001. Dinex is also certificated in accordance with the 14001 standard, ensuring that the environmental impacts of the manufacturing and the products are continuously evaluated and managed according to clear objectives.

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EnviDan

# Holistic Approach to Water Management

*Case Stories*
THE EYE IN THE SKY
*Page 52*

HOW TO BOOST WASTEWATER TREATMENT
*Page 70*

EnviDan is an engineering company dedicated to preserving a healthy water environment. The company is a preferred partner for many municipalities and utility companies in Denmark. EnviDan's mission is to provide innovative, professional solutions to all aspects of water and wastewater management. Its ambition is "to create as much healthy and safe environment and value for money as humanly possible for the clients".

### Activities are rapidly growing

EnviDan was founded in 1995 by three pioneers within the Danish wastewater industry. During the last 5-6 years, the company has experienced a rapid growth; the size of the company has almost tripled. Today the EnviDan Group has approximately 160 employees spread across 4 offices in Denmark.

EnviDan International conducts projects in countries all over the world. This includes their permanent office in Sweden and well-established business relations in Malaysia and China.

### Combined knowledge

EnviDan has developed a range of technologies and concepts to improve operations in the entire water cycle, spanning from detection of groundwater, to water treatment, water distribution, sewer systems, wastewater treatment and control systems.

"We are confident that our team of process engineers are among the strongest in northern Europe," says EnviDan Internationals Managing Director Søren Bruun Hansen. "Combined, EnviDan has a profound knowledge of hydraulics, design, construction, and machinery, combined with an understanding of the climate changes which greatly influence modern urban planning".

### Increased capacity, reduced footprint

Climate change challenges utilities to improve their capacity and reduce energy consumption. EnviDan works intensively to adapt the methods and systems used to handle sewer systems and wastewater treatment, and to identify possible energy savings.

In a further quest to reduce the carbon footprint of the wastewater industry, EnviDan also offers expert consultancy on biogas plants and landfill gas solutions.

EnviDan Water provides services on sustainable water management including geophysical surveys, water extraction, protection of water resources, minimisation of non-revenue water, and integrated water resource management.

### Hosted maintenance solution

EnviDan has a software toolbox to facilitate the control and management of all tasks related to the handling of water and wastewater treatment.

EnviDan has developed a hosted solution to operate and maintain sewer systems and wastewater treatment plants. The solutions are popular with the Danish municipalities and utilities: Citizens are invited to report problems such as basement flooding, rats or bad smell to the homepage of the municipal utility which is linked to EnviDan's database. Afterwards, the utility can examine it, and send a description of the problem and the action requested to the person or department responsible.

Details on location, such as links to Google Maps or other GIS-mapping are included.

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ENVOTHERM
A CLEAN SOLUTION

# Pure Business

*Case Story:*
CAR WASH WITH NO DISCHARGE
*Page 78*

Envotherm has developed a compact low energy evaporator system for the recycling of industrial wastewater at low costs. The system is able to separate waste water into a distillate of cleaned water and a waste concentrate of only 3-15 percent of the original quantity. Heavy loaded waste water, which otherwise would have to be treated as chemical waste at high cost, can be recycled with no further treatment.

### Entrepreneurship

Envotherm was founded in 2006 by three engineers. The company is supported by Danfoss, a major Danish producer of components for heating, cooling, energy savings and renewables. Envotherm is located at the premises of the Danfoss-owned Mads Clausen Entrepreneur Park in Nordborg.

The company is owned by two private partners and Vækstfonden, a public innovation- and investment fund.

### Low energy consumption

The technology used is Mechanical Vapour Recompression. No boiler is needed. Instead a compressor boosts the vapour pressure to make it condense at a higher temperature. The heat released by condensation is recovered and used for further evaporation. In addition, a patented absorber reduces the amount of organic matter and nitrogen.

Particles, oils, heavy metals, minerals, fatty acids, soap, organic matter, nitrogen, and ammonia are efficiently separated from the distillate at low energy consumption.

### Wide range of applications

Envotherm systems are manufactured in standard sizes, ranging from small scale compact and pilot units to 2500 litres per hour. Custom-made evaporators with higher capacity are offered, and turn key projects can be carried out on demand.

Waste water from many origins can be treated. Among the applications are:

- Cutting fluids
- Waste water from alkaline cleaning
- Rinsing water from surface treatment
- Process water from glass production, galvanisation, polishing etc.
- Wastewater from washing of cars, aircrafts etc.

The ET Carwash system was introduced in 2011.

### Fast return on investment

Thanks to water savings and lower waste disposal costs, the return on investment is often very short. As an example, the Mineralölhandel Hans Schmidt GmbH had to pay € 625,000 a year for external processing of wastewater containing cutting oil and emulsions until 2008. The waste is collected from industries throughout Germany.

Envotherm's system was installed in 2008, and the savings surpassed the initial investment in less than one year.

The oils and emulsions are concentrated 10-15 times and sold to the cement industry or recycled. The remaining distillate is so clean that the water can be discharged directly into the public sewage system free of charge.

Envotherm was granted the European Business Award for the Environment in 2012.

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EUROWATER
PURE WATER TREATMENT

# Water Treatment Plants

EUROWATER has more than 75 years of experience in developing and manufacturing water treatment plants.

The company, named SILHORKO in Denmark, was founded in 1936 to provide pressure filter plants for the treatment of water at co-operative diaries in Denmark. Today, EUROWATER supplies water treatment to customers worldwide, within any line of business.

### Broad scope

EUROWATER offers consultancy, free analysis of water samples, sketch proposals, design, installation and start-up, training, and after sales services. In short: Everything from consultancy to complete solutions.

The wide range of standard products includes a comprehensive array of technologies for the treatment of all sorts of water for any purpose.

In most cases the demand can be met through the use of standard modules, often configured, assembled and frame-mounted at the factory in Denmark. The plants are ready to use, including computerised control.

The company also undertakes special projects and custom-made solutions.

### Wide range of technologies

The treatment technologies include a variety of pressure filtration methods, spanning from sand filters to membrane filtration and nanofiltration. Ion exchange and electro-deionisation is used for softening, demineralisation, and dealkalisation. Degassing and disinfection (UV-technology or dosing of chemicals) are also applied.

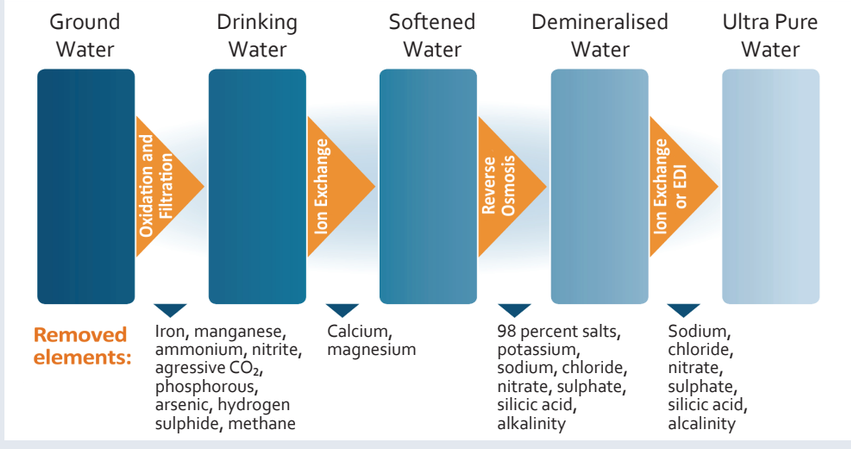
EUROWATER is experienced in applying the technologies for the production of drinking water, process water, boiler water, water for district heating, cooling, rinsing, and other applications. Typical customers are heat and power plants, waterworks, hospitals, the food and beverage industries, chemical plants, pharmaceutical companies, surface treatment, glass industries, etc.

### Made in Denmark

The equipment is manufactured at EUROWATER's own factory in Denmark. It has a reputation for reliability, durability and minimal maintenance requirements. This is due to careful selection of materials, broad experience, extensive technical know-how, and highly qualified employees.

SILHORKO-EUROWATER A/S is an independent Danish company with a turnover of € 42 million (2011) and more than 290 employees, half of which are based in Denmark.

EUROWATER has subsidiaries in 14 countries with 21 local offices. In total, including local distributors, the company is active in 35 countries.




*Case Stories*
WATER SAVED IS MONEY EARNED
*Page 56*

PURE WATER - PERFECT ICE
*Page 40*

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# Air Pollution Control

*Case Stories:*
PREVENTING AIR POLLUTION
*Page 14*

CLOSED LOOPS IN THE PAPER INDUSTRY
*Page 18*

FLSmidth has installed more than 8,000 air pollution control systems for industries around the world, over the course of more than 80 years.

Today's portfolio of products and solutions spans virtually everything required to control any sort of air pollution deriving from a wide range of industrial processes. This includes emissions of dust particles, sulfur dioxide and other acidic substances, nitrogen oxides, hydrocarbons, volatile organic compounds, heavy metals, mercury, and dioxins.

### Custom-made and integrated solutions

FLSmidth was founded in 1882. With more than 15,000 employees and a local presence in more than 50 countries, the company provides engineering, machinery, complete plants, maintenance, support and services to the cement and mineral industries.

The air pollution control business area is part of FLSmidth's 'one source'-concept: To provide each customer with all they need, no matter their requirements and location.

The business area has 650 employees with project offices in India and the USA and it has offices in Brazil, Spain, China and other countries. Based on extensive experience and knowledge of a broad range of industries, they provide custom-made solutions ranging from key part engineering to complete systems including planning, design, manufacturing, installation, testing, commissioning, and customer services.

Dust particles are removed with fabric filters, electrostatic precipitators and hybrid combinations of the two. Gases are absorbed with a variety of technologies, including gas suspension absorber technology.

The products also include various technologies to reduce nitrogen oxides, sulfur, mercury etc.

### Research and development

In terms of air pollution control FLSmidth's research and development is focused on the development of new technologies such as catalytic removal of hydrocarbons, and improvement of the performance of existing technologies in order to meet increasingly stringent environmental requirements.

### Guaranteed performance

FLSmidth guarantees the performance, and has never failed meeting an emissions guarantee. "We stay until the job is done", they say.

For new equipment, FLSmidth utilises the latest in predictive modelling software (Computional Fluid Dynamics) to calculate what levels will be achieved once the plant is operating at full capacity.

For existing equipment, FLSmidth provides recommendations on how to improve the performance, based on measurements of current processes and emissions. FLSmidth offers to rebuild, retrofit and upgrade existing air pollution control equipment.

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# Improving the Performance of Clean Technology

*Case Stories*
TAMING THE FLOW
*Page 12*

TAKING CLEAN TECH TO A HIGHER LEVEL
*PagE 20*

FORCE Technology is a leading provider of technological services and consultancy. Headquartered in Brøndby near Copenhagen, the company has offices in many countries, including Sweden, Norway, Russia, China, Singapore, and USA.

More than 1,100 employees strive to transform their understanding of science and technology into practical and cost-effective solutions for a broad range of business sectors and industries.

### Access to combined knowledge

FORCE Technology has expertise and exhaustive experience in areas such as materials and welding, inspection and testing, integrity management and risk assessment, sensor technologies, metrology, hydrodynamics, aerodynamics, simulation, education and training, quality and environmental management, energy, climate and environment and certification.

Across these areas, teams of experts are put together for each task. In this way, it is ensured that customers gain access to the diverse knowledge relevant to obtain the best solutions overall.

### One stop shopping

FORCE helps customers achieve their goals and create value through the application of new and advanced technologies and methods. The services are laid out to cover the entire process from idea through implementation to delivery and documentation.

FORCE Technology offers 'one stop shopping': Clients can focus on their core businesses while being provided with all services necessary for their project, including consultancy, advice and design, education and training, access to international networks of experts, measurable results, knowledge sharing and partnership.

### Serving the environment

Implementation of clean technologies is an integrated part of the activities. Specifically, FORCE Technology serves the environment in providing environmental assessments, labelling and certifications, emissions measurements and control, process and equipment design, and energy optimisation.

FORCE's integrity services help to maintain e.g. offshore and pipeline equipment, protect it against corrosion and reduce the risks connected with the operations as well as the final decommissioning of the equipment.

In the fields of energy and environment, FORCE provides expertise in energy optimisation, comprehensive environmental consulting, and measurements of air pollution and noise. The assistance is focused on ensuring optimum benefit from the environmental and energy investments.

FORCE Technology's services for the wind turbine industry cover the entire spectrum from design and constructional calculations to on-going service control of towers and wings.

FORCE is an independent non-profit company with an annual turnover of DKK 1,100 million (approximately € 150 million). A substantial part of the activities is research, development and innovation projects.

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# The Caretaking Pump Manufacturer

*Case Story:*
DEMAND DRIVEN DISTRIBUTION
*Page 54*

Grundfos is one of the world's largest manufacturer of pumps and pump systems, with an annual production of more than 16 million pump units. The main products are circulator pumps for heating and air-conditioning and other centrifugal pumps for the manufacturing industries, water supply, sewage and dosing.

In addition to pumps and pump motors, Grundfos produces state-of-the art electronics and software for monitoring and controlling pump systems.

### The bigger picture

Grundfos regards the manufacturing of pumps as part of a much wider enterprise. The purpose is not only to be a "global leader in advanced pump solutions and a trendsetter in water technology"; but is also to "contribute to global sustainability by pioneering technologies that improve quality of life for people and care for the planet".

10 percent of the world's electricity is used for pumping, so Grundfos is very much aware of the impact its solutions may have on global trends. The innovation efforts are focused on energy- and water-efficiency, as demonstrated by the case given in this book.

*"We do business in an environmentally sustainable way and create sustainable solutions from cradle to grave"*

*"We aim to create cleaner technologies and solutions which limit water consumption, improve efficiency, enable consumers to reduce their water and energy consumption and increase the reuse of resources"*

*"We want to enable people to look after themselves and to give more people a more comfortable life without it being at the expense of the environment and the planet's natural resources"*

*"We are always eager to find solutions for the world's most poverty-stricken communities and people with special needs"*

*www.grundfos.com*

### Truly global

Grundfos' first sales company and factory outside of Denmark was founded in Germany in 1960.

Today, the Grundfos Group is represented by over 80 companies in more than 55 countries..

The Group employs almost 18,000 people. Net turnover 2012: € 3,035 million.

### Technology leader

Grundfos was founded in 1945 by Poul Due Jensen. His son, Niels Due Jensen, took over management in 1978.

The first pump was marketed in 1946. The first centrifugal pump was launched in 1952, and the first circulator pump in 1959.

Grundfos was the first company to introduce pumps with infinitely variable speed (1962), stainless steel pumps (1965), inline pumps (1971), pump calculation computer programs (1984), composite pump housings (1989), build-in micro frequency converters (1991), remote control (1995), and digital dosing (2000); all of which have later become business standards.

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# BioBooster: Decentralised Wastewater Treatment

*Case Story*
BRINGING WASTEWATER BACK TO LIFE
*Page 74*

Grundfos BioBooster is a corporate venture of the pump manufacturer Grundfos, intended to challenge the traditional way of treating wastewater.

Grundfos BioBooster has developed a compact modular system for wastewater treatment, based on membrane technology. The core objective is to "bring wastewater back to life" by treating it efficiently close to the source where it was used, making the water fit for reuse and safe for recycling into the natural environment from where it was taken.

### Combination of standard modules

The modules are standardised, pre-engineered components that can be combined in many different ways. The size and the performance of each system can therefore be adapted precisely to the demand.

"With this system we can meet the individual customer's needs", says Managing Director Bent Gadgaard. "If the wastewater is heavily loaded we can add more modules. On the other hand, each system consists of only the modules necessary to treat the specific flow of wastewater at the site."

"Most experts agree that such local treatment close to the source is wiser than conventional treatment of heavily polluted water along with e.g. harmless rainwater. The use of money, energy and resources should be confined to where the real needs are."

Development, test, and demonstration of the BioBooster system have gone on for several years. Now several full scale plants are in operation, and the company is in the process of fine-tuning the technology.

### Promising markets

Many industries, especially food and beverage, have special needs in terms of of wastewater treatment. This is also the case for hospitals, where the elimination of environmental and human health risks due to pathogens, resistant bacteria, pharmaceuticals and other hazardous substances is utterly important.

Municipal wastewater utilities can save money for sewer infrastructure by local treatment in remote locations.

Safe reuse of treated water is a growing challenge in many parts of the world, especially where fresh water is scarce.

In a wider perspective, the ambition is to increase the sales to such a level that the price can be lowered du to large scale manufacturing of the components.


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# Air and Water Purification

*Case Story:*
A FAREWELL TO BAD SMELL
*Page 30*

JIMCO provides equipment for purifying air and water to a wide range of industries, utilities, and institutions worldwide.

Among JIMCO's customers are McDonalds, McCain Foods, Marriott Hotels, Scandic Hotels, Daloon, and Danish Crown, along with many other private companies and public institutions.

### Wide range of products

Based on the patented technology originally created in 1993, JIMCO undertakes all types of air- and water-cleaning projects. This ranges from solutions for large scale industrial plants to small devices intended for singular rooms.

When implementing the technology, JIMCO combines common sense with innovative thinking. The equipment is constantly developed, often in close cooperation with customers, to ensure that the final products meet all specific needs and requirements.

### Odour removal

The JIMCO technology is safe, energy efficient, and environmental friendly. Short wave ultraviolet radiation and ozone treatment is an efficient solution to odour problems caused by food industries, commercial kitchens and other utilities. The UV-C-radiation breaks down odour-binding proteins, and the ozone created by the radiation oxidises any organic compound such as fats and oils in the exhaust air. The process is known as photolytic oxidation or 'cold burning'. The remaining dust and wax is 100 percent biodegradable. Excess ozone is well below the threshold value of 0.1 ppm. In addition to cleaning of air and ducts, fire risks are reduced by up to 95 percent.

### Indoor climate

Inspired by the increasing focus on indoor air quality JIMCO has developed air cleaners of different sizes. They eliminate unpleasant odours and unhealthy micro-organisms such as bacteria, fungi and germs in any place where clean air and high indoor air quality is vital: offices and other workspaces, living rooms kindergartens, schools, hospitals, nurseries, automobiles, containers, hotels, cruise liners etc. The spread of odours and microorganisms through ventilation systems is prevented. A scientific survey, published in the medical journal The Lancet 2003, showed 99 percent reduction of micro-organisms in a Canadian office building. The well-being and work output of the employees were significantly enhanced. Absence due to illness was significantly reduced.

### Air sterilisation

The UV-C technology is also used to sterilise air in areas where high standards of hygiene are needed, such as bakeries, slaughterhouses, dairies, breweries, animal breeding stables, surgery rooms and many others. 99.9 percent sterilisation can be achieved. In facilities for fruit and vegetable storage a prolonged shelf life of up to two weeks is demonstrated.

### Waste water treatment

With JIMCO's ozone flotation organically loaded wastewater can be pre-cleaned without using any chemical additives. Compared to biological wastewater stations, the ozone flotation requires less space, less maintenance and less power consumption.

The treatment significantly reduces bacteria count and water-soluble colouring agents and breaks down stable organic compounds into less harmful products.

### Awards

JIMCO has received a number of environmental awards including the European Union award for Cleaner Technology 1999-2000.


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# Water Treatment with a Vision

Krüger has significant experience and expertise in water and wastewater treatment. The processes and technologies developed by Krüger are widely used in many countries.

Being a part of Veolia Water, a leading global provider of water services, Krüger also offers a wide range of cutting-edge technologies and solutions, implemented with local partners.

### Novel solutions to known problems

Krüger is dedicated to the development of new technologies to improve effectiveness and optimise operations. The innovative solutions are adapted to local needs. Value can be added e.g. by the recovery of energy, reuse of water, and extraction of raw materials.

"Waste must be regarded as a resource. The energy content should be utilised and the entire plant should function as a bio-refinery, in which valuable resources are recovered to be recycled", says Krüger's director, Leif Bentsen.

Krüger helps customers make the most of their installations, reducing carbon and water footprints, and adapting to climate change.

Occasionally the goals for water quality, environmental protection, energy consumption, carbon emissions and cost-efficiency may conflict. Krüger utilises transparent methods to calculate the effects and impacts, in order to facilitate sound decisions when different options are considered.

### Wide area of businesses

Krüger acts as a consultant, a contractor and a supplier of equipment, services, technologies and solutions. The core competencies include everything required to design, build, operate, maintain, control, regulate, supervise and upgrade municipal and industrial water- and wastewater treatment plants and sewerage systems.

Additionally, Krüger is active in the fields of drinking water, industrial process water, sludge treatment, design and control of entire sewerage systems, and remediation of soil and groundwater.

Krüger manages the activities of its parent company, Veolia Water Solutions & Technologies, in Scandinavia, Finland, Poland and the Baltic countries.


### Experience gained through many years

Krüger was founded in 1903. Water and wastewater treatment has been its primary focus ever since.

In the 1980s, highly demanding standards for wastewater treatment were set in Denmark. As a consequence, Krüger improved its processes for nutrient removal and soon became a dominant actor in the fast-paced construction and extension of the country's wastewater treatment facilities. Today Krüger also uses it's experience to set new standards for water treatment in eg. Norway and Greenland, where drinking water quality is improved significantly by using new and robust processes.

### High standards spurred innovation

"High environmental standards prodded us to develop state-of-the-art technologies and gave us a competitive edge when the European Union and other countries subsequently introduced similar standards", says Krüger's Director, Leif Bentsen.

Today, environmental awareness and the need for water and wastewater treatment is rapidly growing at a global scale. The solutions must be sustainable, while at the same time remaining smart and affordable.

Krüger employs 867 members of staff. The 2011 revenue was DKK 1.5 billion (€ 200 million)

The parent company, Veolia Water, has 80,000 employees based throughout its 120 business units around the world.

*Case Stories*
BATHING IN THE CLEAN HARBOUR
*Page 62*

INTELLIGENT WASTEWATER TREATMENT
*Page 68*

TURNING WASTEWATER INTO POWER
*Page 76*

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# Precise Detection of Water Leaks

*Case Story:*
THE SOUND OF WATER
*Page 48*

Leif Koch is a highly specialised company, which deals mainly with the detection and localisation of leaks in buried water pipes.

The company was founded in 1974. Through almost 40 years of activity, it has gathered broad experience and comprehensive knowledge within this field.

### Multiple solutions

Today, Leif Koch serves water works, utilities, and industries 24/7. Highly skilled teams are available, whether for the detection and localisation of a leak in a single pipe or for the examination of an entire distribution network.

The company also undertakes activities such as searching for hidden pipes and valves, controlling their functions and adjusting the map over the network.

Many methods are used: acoustic detection and monitoring, acoustic correlation analysis, measurement of pressure and flow, sectioning, trace gases, etc.

### State of the art technology

Leif Koch remains up to date on the latest development of instruments, meters, loggers, software, and other tools. The staff is continuosly trained and equipped with state of the art technology.

Customers are provided with all equipment necessary, from single instruments to total technology packages.

Leif Koch also acts as a consultant, helping utilities and other customers in finding the shortest route towards the reduction of their water losses. All waterworks are different and many solutions are possible. Leif Koch provides accurate solutions to urgent problems, as well as turnkey ready installations for continuous monitoring and control.

In any case, the users receive instruction and training. Each year, more than 100 field engineers attend the training courses offered by Leif Koch.

### Watch your leaks via the internet

Research, tests, and the development of new, precise and user-friendly methods, are of great importance for Leif Koch. A remarkable result is the 2009 invention of ALMOS LEAK, an online tool for the permanent monitoring of leaks.

The service is internet-based. Sensitive noise-loggers record the volume and frequency of sounds in the pipes, and advanced software algorithms interpret them. The next morning, the users simply log in to the almosleak.com website to check the state of their water distribution network. Blue dots on the Goggle Map indicate 'normal' state. Red flashing dots indicate leak alerts.

Besides acoustic detection, the system can also be used for pressure- and flow-monitoring, or a combination of the two.

### Value for money

Early and precise detection of leaks means money saved. The amount of savings depends on local water prices and the overall state of the existing network.

The costs of water losses and repair can be quite substantial if leaks are left undetected for an extended period, eventually undermining pavements.

With only six percent of its drinking water lost in distribution, Denmark is renowned as a front runner in prevention of water loss. Leif Koch has assisted many utilities in Denmark and abroad, including in the UK, Scandinavia, Eastern Europe and the Middle East, in reducing their water losses. The company often acts as a subcontractor for development projects conducted by larger engineering and water companies.

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# Extremely Durable Membranes

LiqTech's membranes are made from silicon carbide, one of the most durable manmade materials.

"The ability to manipulate Silicon Carbide is at the core of our company", says Lasse Andreassen, CEO and founder of LiqTech. "In essence LiqTech was created out of the need for new technologies to meet the ever increasing demand for cleaner air and cleaner water. It was born from a vision that technology companies with the right products and management could deliver sustainable profits and growth."

### Competitive edge

LiqTech is a US listed technology company with head-quartes in Denmark. The membranes are used worldwide, mainly for two purposes: To remove particulate matter and other pollutants from diesel engine exhaust, and to provide clean water, especially in cases where high-grade treatment is needed.

The high durability of the material permits LiqTech to design relatively small units with high flow rate and long lifetime. As a minor company focused on development, LiqTech is also able to quickly design membranes for special applications, even in relatively small quantities. The unique material utilised and the rapid response to customer's demands has allowed LiqTech to compete successfully in two distinct industries.

### Control of diesel exhaust

The emission of particles from diesel engines is a growing concern. LiqTech has grown to be a leading supplier of Diesel Particulate Filters, which remove up to 99 percent of the particulate matter emitted by the engines. LiqTech has also developed catalytic coatings of its own design to make it possible to meet emission standards for removal of nitrogen oxides as well.

The diesel filters have found their way into engines both new and old, and has been a major component in addressing the Low Emission Zones in Europe, the US and Korea. The demand is expected to grow rapidly as emission standards are tightened in heavily polluted cities of the emerging economies in Asia and South America.

> *"In 2006 I had the pleasure of being invited to invest in LiqTech International, with a vision to develop a ground breaking technology in liquid technology membranes. I had invested in a number of companies, but never in a company that was developing a new, but already profitable, technology"*
>
> *Aldo Petersen*
> *Chairman, LiqTech*


### Water treatment

The superior flow rate indicated, even at high levels of filtration, makes it feasible to use membrane technology for many purposes. The separation of oil and water in the offshore oil industry is amongst these purposes.

Among other applications of the membrane are the removal of microorganisms from ballast water, cleaning of pool- and spa water, filtration of drinking water, treatment of wastewater from households and industries such as food and beverage, the pharmaceutical, chemical, biotech and mining industries.

### Anti-virus membrane

The porosity of LiqTech's membranes is 45 percent and they are offered with pore sizes varying from 3 to 0.04 thousandths of a millimetre.

LiqTech has developed a ceramic membrane for removal of bacteria and viruses, with a pore size of only 20 nanometres. The new membrane is tested in collaboration with Chinese partners. It is expected to remove 99.9999 percent of bacteria and 99.99 percent of viruses. This was introduced to the market in 2013.

*Case Stories*
KEEPING THE SKY BLUE
*Page 22*

TINY HOLES WITH A GREAT EFFECT
*Page 38*

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# Water Brakes

*Case Story:*
MAKING WATER HESITATE
*Page 66*

Mosbaek A/S produces a range of unique flow regulators for storm water management. The flow regulators are made of steel plates. They have no moving parts, and no electrical components. The opening of the regulator is constantly large. Nonetheless it is able to hold water back until the capacity downstream is sufficient.

Regardless of the water level, the flow of water per second through the so called 'water brakes' is close to constant. Even in cases of sudden and heavy rain, the risk of flooding downstream is prevented. If the pipes, wells, and manholes upstream run full, the excess water can be temporarily stored in detention basins or diverted into local streams and lakes.

### Money saving devices

The 'water brakes' save money. The pipe dimensions needed to prevent flooding downstream is much smaller when the flow of storm water is delayed during sudden and heavy rain. Yet, if flooding occurs, the damage done upstream is less harmful, because here, the stormwater is relatively clean. It has not yet been mixed with water from sanitary sewers.

Mosbaek manufactures a range of flow regulators designed to fit different needs. The devices are produced at Mosbaek's factory in Denmark and sold worldwide. Approximately 20,000 have been sold. One fifth of these were sold in Denmark, and the rest internationally.

The company offers individual advisory services based on 50 years of experience. Each water break is designed through specially adapted Computer Aided Design software to suit the specific needs of the customers.

### A unique idea

Jørgen Mosbaek conceived the idea to develop a water brake in 1959. As a young engineering student, he prepared a complete run-off project for a single family house. He wondered if it would be possible to store the rainwater and retain it slowly to the mains in the public road. This way, the dimensions of the sewage pipes could be considerably reduced, he reasoned.

Such a device, however, had yet to be invented.

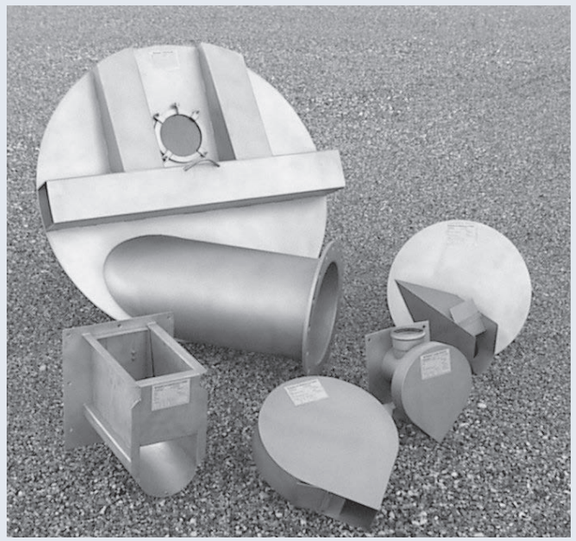
After a decade of experimentation, he was finally ready to apply for patent in 1971. The solution he found was a cylindrical design that causes the water to rotate during its passage.

The vortex thereby created acts as a brake when the water level upstream is high. When the pressure lowers again, the water runs freely through the orifice.

### Climate adaptation

The first water brake was sold in Norway in 1974, and subsequently the devices were marketed by licence holders, particularly in the USA, Canada and the UK. Since 1979, the water brakes have been marketed and manufactured by Jørgen Mosbaeks' own company in Denmark.

In many cases, the use of water brakes is a very cost-efficient solution to the ongoing climate adaptation, as well as the need for new or additional sewerage capacity in fast growing urban areas.

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# Rapid Detection of Microbial Contamination

*Case Stories*
STAYING IN CONTROL OF BACTERIA
*Page 46*

Mycometer has developed rapid tests for documenting and delineating microbial contamination in buildings and water systems. Rapid detection is often of great importance, for instance if drinking water, grain, or fruit are suspected to be contaminated.

### Applied science

The company was founded in 1998 and is based on research conducted by the microbiologists Morten Reeslev and Morten Miller at University of Copenhagen in the late 90's.

The first product, the Mycometer®-test, was presented to the market in 1999. It is a field test for detecting and quantifying mould in buildings.

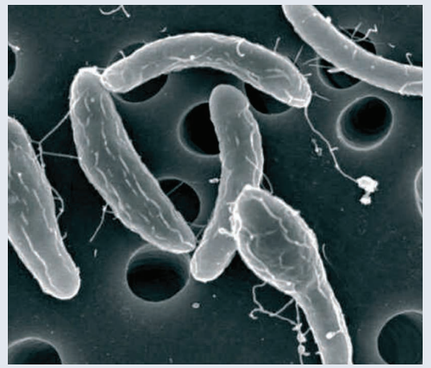
The BactiQuant®-water test, presented to the market for the first time in 2006, is a method to detect and quantify bacteria in water systems.

Since 2006, the company's activities have grown at a high rate, notably in the past six years at an average yearly rate of 25 percent. 5 full-time and 8 part-time staff are employed in Denmark. The team in the United States consists of 2 staff members.

### Fluorescent light is the indicator

"We concentrate on making our technology useful in real life," says Morten Miller. The tests' can be carried out on-site in less than half an hour, and the equipment can be transported in a small suitcase. The tests detect the enzyme activity of mould and bacteria, rather than the microorganisms themselves. The sample to be tested is mixed with a substrate supplied by Mycometer. When the substrate reacts with enzymes in the microorganisms, a fluorescent substance is released. The fluorescence measured is equivalent to the concentration of microorganisms.

"Our expertise lies in identifying the enzymes that are relevant to indicate the number of microorganisms present, and in preparing the substrates that make precisely these enzymes trigger the fluorescence", says Morten Miller.



### Moderate costs

In addition to the test kit, the customers are provided with training of personnel before they receive the user certificate. The overall costs of using the methods are comparable to the utilisation of standard lab analysis.

The equipment can be used for many different purposes, such as for tests of indoor air quality, detection of contamination due to moisture, construction errors, and flooding.

Early detection of bacteria in water is crucial in water works and water supply systems, as well as in the food & beverage industries and in industries in need of ultra-pure process water. It is also an excellent tool to control the quality of recycled water.

"We also make applications for customers with special needs, spanning from detection of moulds in antique books to monitoring bacterial contamination of the sediments from flue gas scrubbers at power plants", says Morten Miller.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# Knowledge Obligates

*Case Story*
MANAGING SCARCE WATER
*Page 50*

NIRAS is an international engineering consultancy company with more than 1,400 employees located in offices throughout Europe, Asia and Africa. The company provides impartial consultancy in fields such as construction and infrastructure, public utilities, environmental and natural resources, energy and climate change adaptation, planning, management, and development consulting.

NIRAS has completed projects in more than 180 countries. "As a consulting engineering company we believe that knowledge obligates and that the global challenges demand action now. We have a holistic perspective, and we focus on sustainable long-term solutions that do not merely solve a technical problem but are in harmony with their surroundings and benefit the climate and the environment", says CEO Carsten Toft Boesen.

### Fast growing business

Since its founding in 1956, the company has expanded through organic growth and acquisitions. The expansion at home and abroad has

been particularly significant since the late 1990s. New business areas have been added and the growth has been sustained even in recent years, despite tough market conditions.

Today NIRAS is Denmark's third largest consulting engineering company and a leading global player within a number of business areas.

### Water management

Denmark is widely renowned as a front-runner in the field of water management. NIRAS has 50 years of experience in water management solutions at home and abroad and is a leading global player in the water sector.

200 in-house professionals work in collaboration with more than 500 external specialists to implement water sector projects in Europe, Africa, Asia, the Caribbean and South America. Feasibility studies, design, implementation and commissioning of safe rural water supply are

core competencies of NIRAS. Community based management and local capacity building is an integrated part of the solutions offered.

In the urban water supply and wastewater treatment, NIRAS assists public and private water companies and utilities in optimising their operations. NIRAS is also engaged in many integrated water resources management projects, institutional development of the water sector, training programmes and climate adaptation projects around the world.

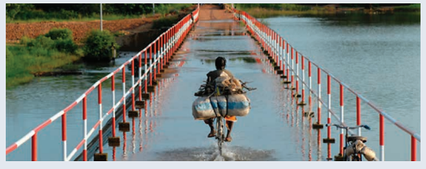
### Interdisciplinary approach

NIRAS favours a holistic and interdisciplinary approach and employs a team of highly skilled consultants and specialists within a number of professional areas.

The company has notet through their experience that integration of the necessary specialists across disciplines leads to the best and most cost efficient solutions for the clients. However, the approach is always based on the characteristics of the specific projects and the success criteria defined in co-operation with the clients.

### United Nation's RISK award

NIRAS was awarded the internationally recognised RISK Award in 2012 for the project proposal "Making the city of Beira resilient to floods and cyclones". The city of Beira in Mozambique is extremely vulnerable to floods. The proposal is a monitoring system to warn the inhabitants when water starts rising above a certain level.

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# Cooperation Opens the Door for Sustainable Solutions

Orbicon is a consultancy company providing services in the fields of the natural environment and the build environment. The company advises on technology, legislation, and economy. Environmental assessments and implementation of environmental technologies are core activities.

### More than hundred years of experience

Orbicon's history dates back to 1866, when Hedeselskabet was formed in Denmark with a vision to cultivate moorland, prevent sand drift, and reclaim new land. Through the years, the company has played a central role in Danish land and water management.

The branch dealing with environmental consulting evolved into Orbicon, which today is a 450-person firm with offices and partnerships in many countries.

The fundamental approach is holistic and multidisciplinary. Through recruitment, acquisitions and mergers, new competencies have been added. They include climate and energy, building and construction, working environment, informatics, evaluation and analyses, and social sciences.

### Natural environment

A large proportion of Orbicon's employees are specialised in working with nature and the environment. Environmental impact assessments, land management, water resource management, marine environment, protection of nature and natural resources, rural development, implementation of environmental technologies, and the handling of contaminated soil are among these core competencies.

Orbicon's long experience is a valuable asset in consultancy on hydrological and biological monitoring, baseline studies, coastal and offshore environment, protection of wetlands etc.

### Building and construction

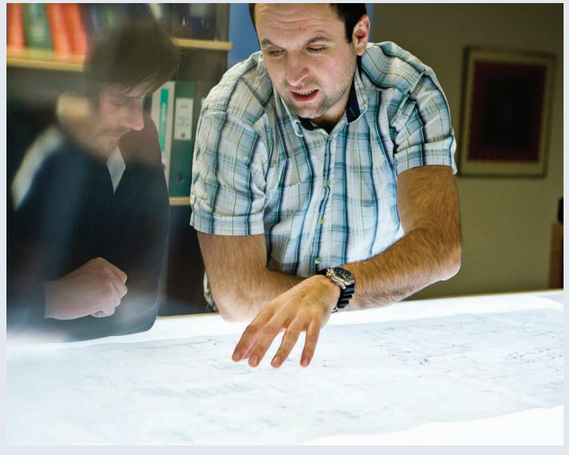
Within the construction area, Orbicon offers consultancy on all kinds of construction works, planning and building of houses, apartments, offices, institutions, and facilities for sports, culture, and education.

Consultancy is provided on large and small plant projects spanning from the UN Nordic head-quaters to the development of new artificial turf for the local sports club.

In collaboration with the US-based partner Thonton Thomasetti, Orbicon has worked on energy modelling and specialised structural design on several iconic projects.

### Climate change and the Water Challenge

Adaptation to the changing climate is a growing challenge. Orbicon works with municipalities and others customers to adjust society to the effects of global warming and reduce the consumption of energy.



Orbicon serves as a consultant for utility companies and organisations regarding water, wastewater, electricity, and heating. The experiences and competencies cover the entire water cycle and all activities for the utilities.

Orbicon has developed high-end software solutions for the water and sewerage sector. Planning, managing and registration of the information becomes more and more important in delivering clean and safe water, and handling the wastewater. The solutions are used in several European countries.

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KEEPING TRACK OF THE WATER
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MINING IN THE HIGH NORTH - ASSISSING THE IMPACT
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# Doing More with Less

*Case Story:*
CONTROL THE FLOW
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Water Network Management

District Heating Management

Industrial Automation

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The Danish software house 7-Technologies was founded in 1984. For almost 30 years it has been engaged in the development of hydraulic computer simulation and control systems for industrial plants and utilities.

The company is now part of Schneider Electric, a global specialist in energy management with operations in more than 100 countries..

The vision of the highly skilled team of software developers, engineers, and system specialists in Denmark is to improve the global environment through engineering knowledge. They are focused on innovative solutions for industrial plants and utilities companies.

The common denominator is 'to do more with less'. Optimizing the flow and performance in industrial processes and distribution networks is cost-effective. Less energy is used, less $CO_2$ emissions, less waste, and less negative impacts on the environment.

### Smart thinking spurred by regulation

The company owes its success partly to strict environmental regulations.

When the Danish Environmental Authorities in the 1990s demanded water leakages to be reduced to no more than ten percent, the water utilities realized it would be extremely costly to renovate their water pipe networks.

Instead they looked for smarter thinking. The innovative hydraulic modelling software tools currently marketed worldwide turned out to be an important part of the solution. Today, the water leakages in Denmark have been confined to a volume in the order of 5 percent only.

Since its establishment the Danish software house has experienced rapid growth. It has supplied systems for industrial automation and management of water and district heating networks to public utilities and industries all over the world. The company has 40 employees.

### Network management

The Water Network and District Heating Management software for online modelling is designed to optimize the operation of blue water and district energy networks.

Initially the hydraulic simulation programmes were developed as tools for dimensioning, planning and design of distribution networks. Today they are also powerful tools for management, control, and regulation of entire networks.

In their fields the systems are the leading applications on the world market. They have been sold to more than 2,000 cities with a total population of 200 million people.

### Industrial automation

The Industrial Automation software is designed to manage, control, and supervise industrial processes. Initially the program was created to collect data and supervise the process at a wastewater treatment plant in the 1980s.

At that time, it was a revolutionary achievement to operate the system at a standard PC using the mouse to navigate the system.

Today more than 27,000 industrial systems worldwide are run and operated by the system, among them airports and traffic control centres, food industries, power plants, and many others.



# Water Purification

*Case Stories*
SAFE AND PLEASANT SWIMMING
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BALLAST WATER TREATMENT
*Page 36*

Skjølstrup & Grønborg is an innovation and engineering company. It specializes in science-based solutions for all kinds of water treatment and water purification problems. Systems, technologies and equipments are developed based on scientific knowledge.

### Team of inventors

"If someone lacks the expertise and scientific competencies to develop their ideas for an exciting project to solve water treatment-related problems, we are there to assist them", says co-founder and partner Ole Grønborg.

A dedicated team of experts is at the core of the company. They specialise in hydraulics, water treatment, disinfection, purification, filtering, and so forth.

"We work with many business partners and research institutions to develop cutting edge solutions", says Ole Grønborg.

### Zoo's, aquaria and aquaculture

Among the first to benefit from Skjølstrup & Grønborgs expertise were the animals in zoos and the fish in aquariums.

Hippopotami, crocodiles, elephants, sea lions, penguins, seals, manatees, polar bears, piranhas and a lot of other fish species have had their lives in zoos and aquariums enhanced by water treatment, filtering and disinfection systems designed by Skjølstrup & Grønborg. The step from supporting zoos and aquariums to developing water treatment at aquaculture plants for salmon and other fish species was not very long. Skjølstrup & Grønborg has assisted many aquaculture companies in improving their water treatment.

Much equipment for ultra violet water purification, membrane filtering, reverse osmosis, and ozone treatment of water has been developed and marketed under the brand Ultraaqua.

### A range of special applications

Skjølstrup & Grønborg works with the world's leading container shipping company, Maersk, and the pump manufacturer, Desmi, on the treatment of ballast water from ships.

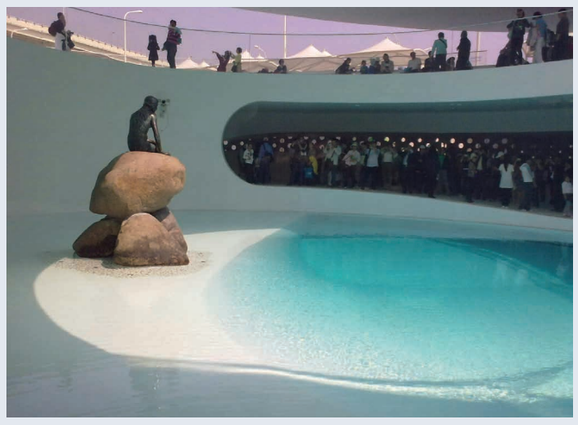
In cooperation with Grundos Biobooster, the pre-treatment of wastewater comprised of precarious medical contaminants from a new large hospital in Copenhagen is being developed.

In partnership with BioKube and DHI in China, the development of local systems for safe reuse of treated wastewater is being undertaken

Several other research & development projects are being undertaken with Danish and European Union funding.

### The inBlue swimming pool concept

Skjølstrup & Grønborg has developed an entirely new concept for swimming pools. The aim is to reduce the negative impact of chlorinated by-products.



When The Little Mermaid left Copenhagen to join the world exhibition EXPO 2010 in Shanghai, Skjølstrup & Grønborg designed a water treatment system to provide clean water surroundings for her in the exhibition pavilion.

Simulation of flow in the basin.

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# Smart Monitoring of Water Quality

*Case Story:*
A LITTLE CELL OF GREAT CAPABILITIES
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Sorbisense is a knowledge-based company that develops, manufactures and markets a novel technology for water quality monitoring. The new technology is the patented SorbiCell, a tiny cartridge containing a porous material (the resin) and a tracer salt. The cell can monitor water quality during a specific period of time – from 24 hours up to 3 months.

The chemical substances to be monitored are captured (adsorbed) at the surface of the resin. The volume of water flowing through the cell is indicated by the amount of trace salt dissolved and washed away.

After the monitoring period is complete, the SorbiCell is collected and sent to an approved

laboratory. Based on the analysis of substances adsorbed and the amount of trace salt missing, the average concentration during the monitoring period can be calculated.

### Easy to use

The method is simple to use, and it can be applied almost anywhere, even in places where it is difficult or impossible to collect traditional water samples. The SorbiCells come in different types, and are suitable for the sampling of different compounds in different environments.

The list of chemical compounds that can be detected is long: Heavy metals and other metals, volatile organic compounds, oil residues and fuels, polyaromatic hydrocarbons, nutrients, and pesticides.

Sorbisense provides a range of different mountings for single- or multi-level sampling in groundwater wells, pipes, lakes, ponds, streams, sewers, drains, and other wastewater streams. An installation kit for source tracking of periodic discharges into sewers is also available.

### Superior to the traditional methods

The traditional way of monitoring water quality is to analyse water samples, taken as single "grab samples", at a laboratory. This traditional method will only tell you what was in the water at the moment the sample was taken. The SorbiCell can tell you the average concentration of substances in an extended period of time, which is usually the information you want.

Additionally, the Sorbisense technology is an inexpensive alternative to permanent monitoring e.g with online sensors. No power supply, calibrations, or other resources are needed. The method is robust, sensitive and applicable for a wide range of chemical substances.

### Continuous research and development

The company was founded in 2004 by soil scientist Dr. Hubert de Jonge, now the CEO of Sorbisense, and his partner, chemist Dr. Gadi Rothenberg, professor at the University of Amsterdam.

The SorbiCell was invented and developed on the basis of research conducted by the Danish Institute of Agricultural Sciences, now known as the Faculty of Agricultural Sciences at Aarhus University. Sorbisense is located next to the university in the Agro Business Park, where the company has access to the university's research facilities and cooperates with other innovation companies and university scientists.

The technology is continuously tested, validated and further developed in close cooperation with universities, customers and partner laboratories.

In April 2011, Sorbisense opened a branch office in the Netherlands.


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# Catalysing the Businesses, Cleaning the Air

Topsøe has been dedicated to the development and application of catalysts for more than 70 years. Topsøe's catalysts and technologies are constantly under development. They are found in industries, refineries, power plants, ships, and vehicles all over the world.

The Topsøe product portfolio plays a key role in promoting an energy-efficient and eco-friendly use of the world's resources.

### Shortcut through the tunnel

Catalysts are the genies of chemistry. They promote a chemical reaction, without being consumed by the reaction themselves. Topsøe compares catalysis to a tunnel.

If your way forward is blocked by a mountain, you will have to use a tremendous amount of energy, efforts and resources to climb over it. Using a catalyst is like taking en energy saving shortcut through a tunnel.

According to Topsøe, 90 percent of all chemical processes use catalysts, and 60 percent of industrial products are made using catalysis.

### Science and engineering

42 percent of Topsøe's 2,100 employees are scientists and engineers. Their research ranges from

atomic level studies and nanotechnology via chemistry, material studies and process technologies to large scale engineering constructions.

The company was founded in 1940 by the chemist Dr. Haldor Topsøe. He firmly believed that a position second to none in catalysis could be reached through applied fundamental science.

Topsøe's ambition is to attract excellent scientists from all over the world.

### Research and business

The research is subject to long term planning. "We focus on where we must be in 5, 10 or 15 years and in which sectors of research and development, technologies, industries and markets we must be particularly active to achieve our goals", says Topsøe in one of their Annual Reports.

Science is the foundation of Topsøe's business, but another goal indicated by Dr. Topsøe has always been to combine the researcher's skills with those of the businessman. Topsøe strives to combine relevant competencies across its departments, to offer steadily improved solutions to the clients and to venture into new areas. In other words, the research is funded through business.

### Wide range of competencies

Researchers explore the possibilities. Sales engineers engage in detailed technical discussions with customers to uncover client's needs and find better catalytic solutions. Design engineers develop the plants and processes to provide efficient, customer-specific equipment.

The employees at Topsøe's production plants optimise catalyst production. And technical support is offered after sales. Topsøe's catalysts are produced at facilities in Frederikssund, Denmark and Houston, Texas.

### Linked to the worlds long-term challenges

Topsøe has experienced a steady growth in spite of the recent international financial crisis and economic recession. The company is confident that the growth will continue, because most of the activities are related to the world's long term challenges in relation to energy, resources and the environment. The 2011 revenue was DKK 4.4 billion (€ 0.6 billion).

*Case Stories*
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