

From source to tap and back to nature – Danish water management and learnings

By Jesper Goodley Dannisoe, Managing Director of Danish Water Forum and Hans-Martin Friis Moeller, Chairman of Danish Water Forum and CEO of Kalundborg Water Utility, Denmark

Contents

| | |
|--|---|
| Summary..... | 1 |
| Introduction..... | 2 |
| Water supply | 3 |
| Water resource protection and management | 4 |
| Water loss from the distribution system (Non-revenue water)..... | 4 |
| Waste water treatment and discharge | 5 |
| Water utilities as resource factories..... | 5 |
| Storm water and green infrastructure elements | 6 |
| Regulation as a driver for new innovation | 7 |
| Climate change adaptation | 8 |
| Conclusion | 8 |

Summary

The paper provides an overview of how water in Denmark has gone from something which was just there and to a commodity with a high value and with high protection needs. Denmark has developed its water supply and treatment systems through nearly 150 years and this story is the main topic of this paper.

Denmark is a groundwater-country, when it comes to water for consumption and being 100% reliant on groundwater has shaped the development of the Danish protection and management of the resources.

Water being one of the most precious sources we have and tied directly to the future of humans and nature, is too often being treated with no respect. The lack of respect towards water comes in many forms; pollution of water resources, waste of water, no treatment when delivering the water back to nature and finally over-exploitation of the resources, mainly due to not understanding the fragile nature of water and our dependency of water for survival.

Although water is not a scarce resource in Denmark, we have been able to raise water on the agenda and create the necessary understanding and respect for the resource and its capability of providing us with enough water with a high and safe quality. It did not come over-night and Denmark has also been in the stage, where water was not appreciated.

The Danish water sector is today one of the best developed sectors in the world and the expertise and innovation has through the last 30-40 years been driven by strict regulation and legislation, which has forced the sector to develop new technologies, develop new skills and ensure supply of skilled staff and management to run the processes in the Danish utilities. Another important trait in the development has been the very close corporation between all stakeholders in the Danish water sector like ministries, universities, supply companies and the consulting sector.

Introduction

Water being one of the most precious sources we have and tied directly to the future of humans and nature, is too often being treated with no respect. The lack of respect towards water comes in many forms; pollution of water resources, waste of water, no treatment when delivering the water back to nature and finally over-exploitation of the resources, mainly due to not understanding the fragile nature of water and our dependency of water for survival.

We are in a situation where many cities today are at risk of running out of water, with water availability now cited as one of the greatest risks to business continuity and growth. Latest cases that made the international headlines are Chennai (India), Cape Town (South Africa) and Rio de Janeiro (Brazil). A severe water shortage is stalking many cities, there are already about 1.2 billion people globally, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation (IWA)

How did we end there? It probably comes from the fact that we have taken access to (treated) water for granted and have forgotten to think about how we have used the resource. For urban water users, substantial reason for the limited respect is the fact that water is delivered un-metered at very low cost, often far below the actual price for abstraction, treatment, distribution, collection and final wastewater treatment and when a commodity is cheap, it does not call for respect. On top of this, water is very often managed by authorities, who do not have the full understanding of the importance of the value of water and where water management, financial issues and policy is often divided into several offices and units.

Although water is not a scarce resource in Denmark, we have been able to raise water on the agenda and create the necessary understanding and respect for the resource and its capability of providing us with enough water with a high and safe quality. The solutions did not come overnight and Denmark has also been there, where water was not appreciated.

In 1853, the capital of Denmark, Copenhagen, was hit by an outbreak of cholera, which killed more than 5000 citizens within a few months. The outbreak was an eye-opener for the authorities and it was recognized that the hygienic conditions in the streets with human and husbandry waste was the cause of the spreading of the disease. Water for human consumption was still picked up from wells with or without pumps in the streets and the liquid waste from the streets often entered the wells.



Figure 1: Replica of town water pumps in Denmark

The distribution of drinking water and removal of wastewater was put on the top of the agenda and within relatively few years, proper water supply systems were established. However, the wastewater treatment came many years later as top priority was given to the water supply.

Water supply is not a simple operation and it carries the costs related to abstraction, treatment, building the piping system and ensuring proper maintenance of all assets. The gradual development of the Danish water supply network took its start in 1860'ies in the larger cities and the basic infrastructure in the old parts of the cities are basically the same today. However, the piping systems have been replaced with larger pipes to cover the growing demand for water. The current systems have expected lifetimes of 30-50 years, depending on pipe material and soil stability. The asset value of the supply systems in Denmark is worth several billion Euros!

Nearly 100% of Danish water supply is based on groundwater and we therefore have legislation, which protects land to prevent pollution of the sources.

Water supply

From the establishment of the first public water utilities in Denmark, payment for the water has been part and parcel and it is still the fundament for the development of one of the most efficient water utility systems in the world. Pricing of water is based on the principle of full cost recovery, which means that the user pays a combined price for production, distribution, wastewater treatment and maintenance costs. Fair water pricing goes hand-in-hand with household meters, where Denmark produces state-of-the-art meters with remote access for the utility, which can read the daily consumption and also warn the user if there is a local leak in the household. Water has never been subsidized in Denmark!

Drinking water consumption per capita in Denmark has been on a constant decline since the 1970'ies from about 137l/day to 100l/day in 2018. The decline in water consumption has been driven by two main factors: Prices and awareness.

The water prices in Denmark are among the highest in the world with up to 10€/m³. However, the price for the water is as stated above a combined price for "Water in / Water Out", which means that it covers for both for drinking water and wastewater treatment and up to 50% of the price is in fact various taxes, used for e.g. green initiatives. The water companies and their owners (often the municipalities for the biggest) are not allowed to take out a surplus, it has to go back to the customers or invested in new installations. The companies has to rest in themselves.

The awareness in the Danish population of the important role of water has also been growing substantially during the last 30-40 years and it has become clear to the public that over-exploitation of the groundwater resources for drinking water purposes has created a negative side-effect from surface water and springs running dry in the summer period. The impacts have been described and the public has learned that they are both a part of the problem and also a part of the solution, where water savings provides less pressure on the resources and leave more water for nature. Water awareness campaigns have been launched with regular intervals and today every kid in school knows the basics of preserving water.

The water price has also been a driving force for the industry to develop new production methods to bring down the water consumption. First and foremost, reuse of water inside the industries have cut down the uses, following the principle of "the cleanest water for the cleanest part of the production" and the reusing the wasted water on other steps in the production, where drinking water quality is not necessary. One of the latest innovation projects in Denmark worked on having a "No-external-water Dairy", where water extracted from the dairy production could be utilized. The Danish beverage industry has also worked on

lowering their water consumption per produced unit, and for the international Danish brands, the water-saving technologies have been implemented on their factories abroad.

The aim to reduce the consumption of water contradicts what any other company would do, but the utilities are striving to reduce the consumption and this will require that the price for every cubic meter will gradually rise, since the costs for developing and running a utility will not decrease!

Water resource protection and management

Regardless if the water resources for human consumption comes from surface or ground water it is extremely important to protect and manage the resources prudently. As mentioned, Denmark is 100% reliant on groundwater for its water supply, and mapping and protection of the resources has been part and parcel of Danish resource polity.

The mapping of the Danish water resources has been done during the last 10-15 years. Focus has been on the quantity, quality and vulnerability of the resources. The last couple of years the mapping has been done with the Danish-developed SkyTem method, which makes use of a helicopter-borne TEM device which can detect subsurface structures and conditions down to several hundred meters of depth. The results were then processed and used to describe the ground water conditions and their individual vulnerability in terms of potential pollution through the soil matrix.

The mapping of how good the groundwater is protected from surface influence has been used to determine where to develop industrial sites. In general, most sites for industrial development in Denmark are placed along the coast, where the natural movement of the groundwater is towards the sea. This means that in the event of a soil pollution, the seepage of pollutants into groundwater used for human consumption is very unlikely.

Water loss from the distribution system (Non-revenue water)

One of the global challenges in water supply is water leaking from the supply systems, called non-revenue water (NRW) and besides wasting precious water, which cannot be sold, it also introduces risks of contamination of the drinking water in the pipes. There are examples of NRW of 60-70%, meaning that only 30-40 % of the water produced is delivered to the users and this is often seen especially in water scarce areas. In Denmark the average NRW in our systems is down to 5-7 %, which is considered financially and safety acceptable.

The water distribution system in Denmark has been developed since the 1890'ies and has gradually been extended and renovated with new pipes, new dimensions and gradually been equipped with more and more sensors, meters and other types of info systems. All networks in Denmark are divided into separate districts, which are monitored either constantly or at regular intervals. This enables the utilities to constantly monitor the distribution and use of water and it also helps them to identify unusual uses, which could indicate leaks or pipe bursts. This helps in detecting leakages and doing cost-effective rehabilitation of the pipeline network.

All water utilities have response-teams, who will take care of the repair of the supply lines within hours or days, depending on the size of the leakage. This also means that the users have safe water supply 24/7. All this has also come at a cost, where life-cycle assessment has been used to find the best solution, which may come at a higher initial cost, but where the longevity of the equipment used will provide a solid payback in terms of less maintenance, repair and changing units.

To test our NRW principle, Danish Water Forum brought this knowledge to India by way of a pilot project in Rajkot, Gujarat in 2013, where the Danish operators and managers showcased to the Municipality of Rajkot that they can bring down the NRW and leakage from around 48% to 25% very easily. Most of the water-loss

came from poor household connections made by unskilled people. India is most probably not the only country using unskilled people to work on the supply net!

In Denmark it is forbidden to work on any water connections without a license and this ensures that only educated and skilled staff are working on the system.

Waste water treatment and discharge

As said above, waste water treatment in Denmark came years after the supply, and a continued development of the sewage network has ensured that all urban areas are fully served with high-efficient wastewater treatment with nutrient-removal. The discharge from the plants is controlled by discharge permits and contrary to the normal global procedure to work with discharge standards, Denmark works with individual discharge permits, taking the robustness of the receiving waterbody into account. Accordingly, you will never find completely polluted rivers, lakes or coastal areas in Denmark, as is so often seen in many countries, where wastewater is treated superficially and discharged regardless of final quality.

Recycling of treated wastewater has not until now been an issue in Denmark, mainly because we have been able to constantly lower the consumption of drinking water and water for industrial purposes, both on a private and industrial scale, but that has changed and we are now looking into how and where to use treated wastewater or other water qualities for non-potable uses like watering gardens, creating wetlands and other uses.

Water utilities as resource factories

3-5 % of the global electricity is used to pump water and electricity is often the largest expense for a water utility. Denmark has innovative technologies, use of which can optimize the pumps to handle more water at lower energy consumption and just lowering the energy consumption by 10-30 % through use of variable speed drives eases the financial burden for the utilities. In addition, energy consumption to run a modern wastewater treatment plant is also among the largest expenses and besides the expenses it is also a heavy use of CO₂. Most of the Danish STP's have been energy-optimized and several of them are now net-energy producers, producing enough energy, biogas, electricity and heat for its own consumption and selling the surplus energy to the grid. The pay-back time for optimizing a plant is within a few years and afterwards it is a pure win-win, also because the plant is now part of the green energy and with no use of fossil energy.

Denmark has also taken a new approach when looking at wastewater, which is now considered a stream of energy, recoverable resources and possibilities. Our newest STP is called a bio-refinery, where energy, phosphate and bio-plast is harvested from the water, thus enabling more recycling and harvesting valuable resources. Treated wastewater has also been used for growing algae for harvesting proteins!

The agenda of the future calls for much more recycling, reuse and circular economy, when we work towards a greener future. In the circular economy there is no waste. All waste is in principle a resource, which we can utilise with our present technologies, but where more could be reused with new technologies. For more than 30 years this concept has been developed and tested in 'Kalundborg Symbiosis', where factories have clustered to form, what would traditionally be called an industrial estate. Here, one factory's "waste" is used as a resource for the other neighbouring factory. This could indeed be the model for all new industrial estates, and it would enhance innovation and research in finding new uses for "surplus resource streams". The main streams of resources between the industries in Kalundborg is recirculating water, reuse of energy and materials, and has resulted in big savings for the companies and a huge CO₂ reduction.

Storm water and green infrastructure elements

During the last 10-15 years, several heavy rain events in Denmark has increased the interest to secure houses and other important infrastructure. Traditionally, increase in rain has led to installing new sewage pipes with higher capacity to cope with the increase in storm water runoff. However, the traditional solutions are not always the cheapest way to handle the storm water. In Denmark the rain events has led to new ways of thinking and even in densely populated cities, initiatives to handle the rain water on the ground instead of forcing it down the sewage pipes have increased.

New suburban developments have been developed without storm water connections to the single houses. All houses have been established with their own individual or joint rain gardens to seep down the rainwater from roofs and sealed areas. The savings in developing sewage systems without the need for storm water capacity makes it cheaper and does also save the wastewater treatment plants the effort of cleaning the storm water. In addition, less storm water in the drainage systems gives less storm water releases into nature.

The storm water is now seen as an opportunity to re-shape the city and its infrastructure to be more robust and to increase space, where water can be stored, either temporarily until there is capacity in the sewage system or to increase areas where the rainwater can seep into the ground. Even new permeable paving of roads has been developed.

Cities like Copenhagen and Aarhus have seen substantial reshaping to cope with the effects from climate change and many parks have been redesigned to enable occasional storage of water, rain-gardens have been integrated in the streets and swales have been re-introduced in larger housing areas. Even play grounds have been reshaped to act as reservoirs during heavy rains!



Figure 2: Swales incorporated in the common green. Why not combine a playground with a reservoir? Rain gardens in the street

The obvious benefits are more green space in the cities and a cheaper and better spending of the public money. In addition, seeping rainwater into the ground can also help in increasing the groundwater table.

Finally, all the green solutions have a much better CO² footprint than traditional concrete-pipe solutions and in addition, they all act to prevent heat-islands in the city landscape.

Regulation as a driver for new innovation

Back in the days with the cholera epidemic, health was the primary regulatory mechanism for the development of the water supply systems in the Danish cities and towns and to a large extent, this is still the overall mechanism for ensuring safe 24/7 water supply to the public. The Danish water legislation has since entry in the EU in 1972 been subject to a coherence with the water-related EU directives:

- Urban waste water directive (1991)
- Nitrate directive (1991)
- Drinking water directive (1998)
- Water framework Directive (2000)
- Groundwater directive (2006)

However, before the above directives came into action, a strict Danish legislation, caused by water-related problems, had been a driver for e.g. the development of the Danish wastewater treatment systems. In the early 1980'ies, severe impacts from eutrophication in marine areas in Denmark caused the Danish ministry of environment to come up with a water-action plan for the marine environment and one of the

requirements was a very strict limitation to the discharge of nitrogen and phosphorus to all waters, far below common discharge standards. The Danish wastewater utilities came together with universities, consultants and product providers and within a few years new fancy wastewater treatment plants were developed, which could provide the required new discharge standards of 8 mg/l total nitrogen and 1,5 mg/l phosphorus. This is one of many examples from the Danish water sector, where the legislation has been a driving force for new innovation and development and in addition, the newly developed concepts were ready for being exported to other countries.

In contrast of what one would expect, today the Danish water sector is actually forcing the authorities to come up with new and high standards for future discharge requirements, minimum energy consumption and other elements in the water sector to ensure that Denmark and Danish technology will still be in the forefront, when it comes to the future and to the climate change adaptations. Any larger water utility in Denmark are participating in a wide range of research projects, which will enable them to move on and to be more efficient, better in cleaning, better in recycling water and better in saving or producing energy.

Climate change adaptation

Recognizing the fact that regardless of what we do today in terms of CO² reductions, greening and other actions, the impacts from climate change will continue to challenge us for the next 10-30 years. The last 10 years has pushed substantially to rethinking water and infrastructure. Many of the new initiatives, which have re-shaped Danish cities, have directly or indirectly helped towards a greener future, but there is still a long way. The Danish legislation is currently not completely fitted to support and help towards a greener future, but gradually, it has been changed, so it is not obstructing new initiatives.

New initiatives to utilize the available resources (waste!!!) look into harvesting energy from the heat in wastewater through use of heat-pumps. The harvested energy can be added to the vast district heating systems in Denmark and also to district cooling. This is an area, where the previous legislation did not allow such initiatives, and the legislation had to be changed.

The traditional walls between users, utilities, universities, manufacturers, ministries and consulting companies have been broken down through the last 10-15 year and the climate change adaptation has become a common field for research, development and innovation. All of the larger Danish utilities are involved in several research projects and not just by providing test facilities but also directly in the research. Our utilities are among the most innovative in the world and they have been able to offer jobs to highly specialized researchers. Research collaboration has been the key word driving Denmark to the front-end within water.

Conclusion

As we said in the start of this article, all the changes in Denmark did not appear overnight, but through innovative and well-planned processes over decades. Breaking down barriers between the traditional stakeholders and have them work together for a common future has been an important stepping stone towards being where we are today and will definitely also drive the development and innovation in the years to come.

However, as “water behavior” in Denmark is not unique, Denmark has for several decades been exporting our many innovative solutions to other countries with success and we therefore invite the reader to see the vast range of possibilities available in Denmark, which could benefit water utilities, municipalities and other stakeholders within water. Yes, there is a different way of doing things, but it is also a way to provide users with a much better water-experience and most importantly providing more precious water for an ever-growing population, requesting safe water for sustenance and welfare. The international Water

Association, IWA has asked Denmark to host the 2022 world water congress in Copenhagen¹, and this might be a good opportunity to visit Denmark and see for yourself, what we have done and where we are heading. We urge you to join us and to check the homepage for the event.

Mr. Jesper Dannoese is the Director of Danish Water Forum and is based in Copenhagen.

(dwf@danishwaterforum.dk)

Mr. Hans-Martin Friis Moeller is the Chairman of Danish Water Forum and the CEO of Kalundborg Water Utility, one of the only utilities, world-wide that provides three qualities of water to its users.

(hmm@kalfor.dk)