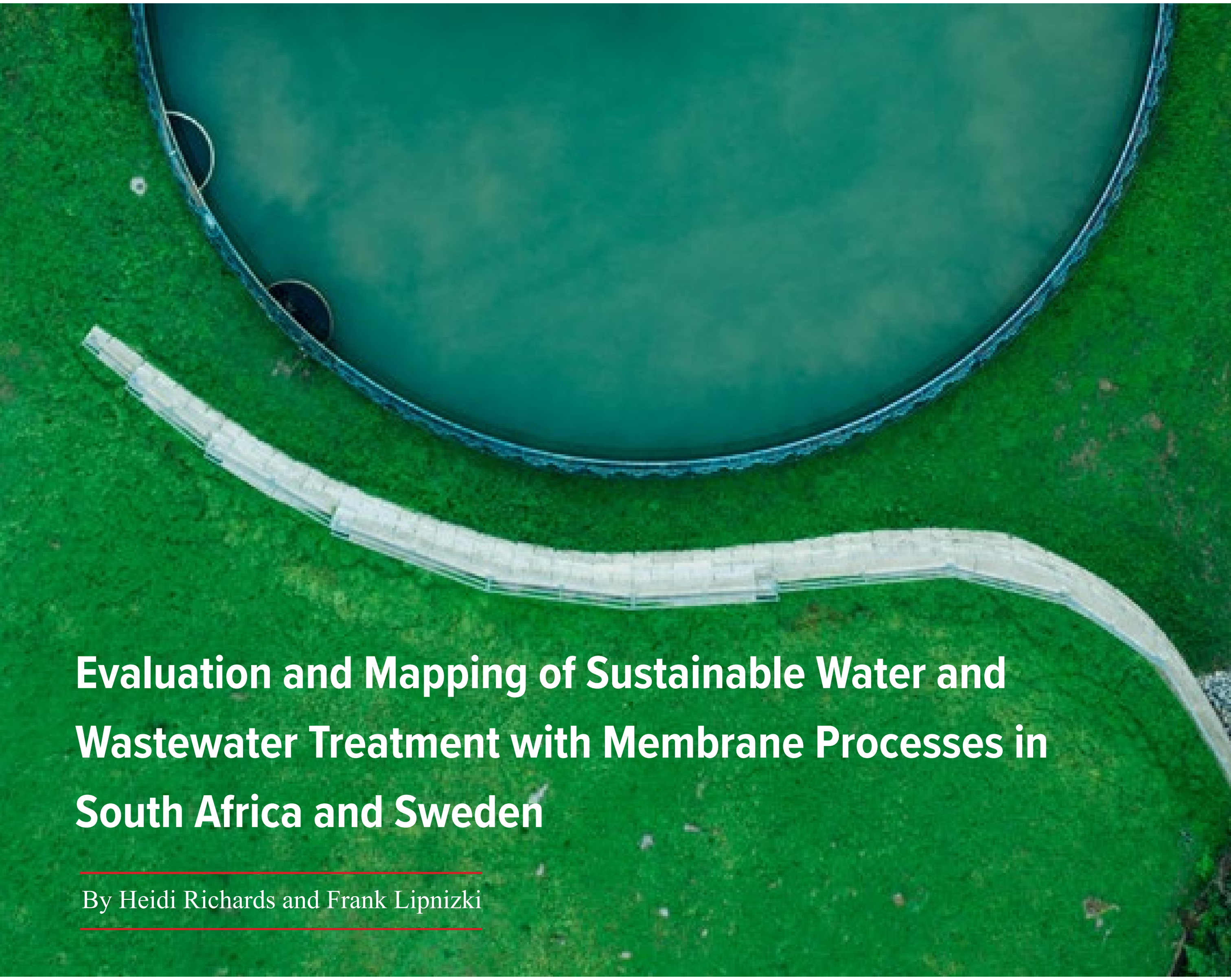


Evaluation and Mapping of Sustainable Water and Wastewater Treatment with Membrane Processes in South Africa and Sweden

By Heidi Richards and Frank Lipnizki

Abstract

Membrane technology is crucial to achieving Sustainable Development Goal No. 6 of clean water and sanitation for all. Despite its numerous benefits, high capital and operating costs pose major challenges. Recent research has focused on sustainable materials as membranes and more effective cleaning regimes to reduce costs and improve membrane lifespan. While South Africa and Sweden have both begun using membrane technology for water and wastewater treatment, it remains relatively rare. Collaborations through SASUF aim to evaluate and share best practices. Although MBRs have produced high-quality effluent in South Africa, cost, maintenance, and membrane replacement, as well as river pollution, remain major considerations. In contrast, Sweden has seen large-scale membrane installations in drinking water and wastewater treatment plants. Establishing working membrane references is crucial to the success of membrane technology, which is well-established globally but often requires local adaptations. Collaborations between the two countries are essential to support this approach by sharing knowledge and learning from each other.

Introduction

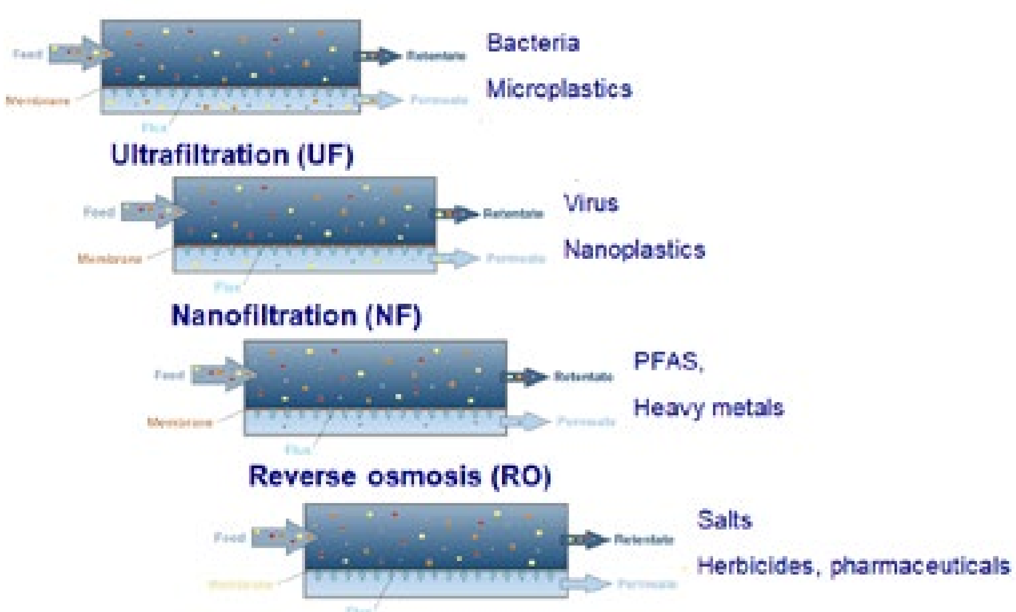
Water is a global future challenge as highlighted in Sustainable Development Goal 6: 'clean water and sanitation for all'. One of the key technologies which can significantly contribute to reach this important goal is membrane technology. Although there are numerous merits of this technology, some major challenges like high capital and operating costs still exist.

The heart of membrane technology is a semi-permeable (often polymeric) membrane which acts as a barrier retaining targeted components and allowing others to pass. In order to address the operating cost challenges, recent research has focused on the use of more novel, sustainable materials as membranes, as well as more effective cleaning regimes that can improve the membrane life span and reduce costs in the longer term.

Membrane technology is still often considered as an emerging technology but in fact it is already a widely established technology for both drinking water preparation and wastewater treatment. The success of membrane technology started in the 1960s with the invention of the phase inversion membranes. Since then, the membrane market grew rapidly and the total membrane market for industrial/municipal and medical applications is today approx. 20–25 billion Euro worldwide and the market is still growing with a stable average annual growth rate (AAGR) of 8–9%. The water and wastewater market including desalination is the largest membrane market after haemodialysis for treating patients with kidney failure. Other, key membrane markets are agro-food, biorefineries and biotech including pharmaceutical applications. The key membrane technologies are the pressure-driven processes microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). Figure 1, below, shows an overview of how these processes can retain different micro- and nano-pollutants from water and thus purify the water.

Despite the global success of membrane technology, membrane processes for water and wastewater treatment are still relatively rare in South Africa and Sweden. Thus, this collaboration between South Africa and Sweden tries to accelerate this development by mapping and evaluating the status on membrane technology for drinking water and wastewater treatment in the two countries and share experiences and best practices.

Figure 1: *Membrane processes for water and wastewater treatment and their retentions.*



(Source: The Authors)

South Africa

Globally, membrane technology is very common for the treatment of water and wastewater; in South Africa, however, this is not the case. The few drinking water treatment plants using membrane technology are based on RO as part of the treatment regime; however, the technology has been slow in uptake in the wastewater treatment area. This is due to several complex reasons that are not all easy to overcome. Currently there are only 4 membrane bioreactors (MBRs) operating on wastewater treatment plants (WWTPs) in South Africa, a shockingly low number considering that there is a total of 824 treatment plants. This fact led us to look critically at the existing plants and their successes and/or challenges.

South Africa has nine provinces, of which Gauteng is the smallest in land size, but the most densely populated. The province that is furthest south, and the most well-known by tourists, is the Western Cape. It is here where one currently finds the only MBRs in the country. Table 1 indicates the location of the MBRs that are currently in operation, as well as the type of effluent that they treat.

It must be noted that scientific publications focused on the applications of MBRs in the South African context are very limited; in fact, they are near non-existent. Therefore, information obtained for this article was sourced directly from municipal managers with the necessary expertise and background in the technical aspects of the MBRs currently in operation. We acknowledge and thank the City of Cape Town for their contribution in this regard.

Witsand Desalination Plant was the first desalination plant in South Africa that uses solar energy to power its processes. Its new technology applications allow for the elimination of storage batteries in the design. The plant's new Osmosun® technology involves the use of a specialised 'intelligent' membrane that is able to continue delivering reverse osmosis, even when the sun goes behind a cloud, thus reducing the amount of solar energy delivered (The Gremlin, 2019). The energy delivered would increase again when the clouds moved away. This ability to 'soften' the variability in the energy delivered preserves the reverse osmosis membranes. At night, when there is no sun, the design allows the plant to switch to conventional grid-electricity and continue working all through the darkness, until the sun rises the next morning.

The first municipal MBR module in South Africa was installed at Zandvliet WWTP. The MBR plant was sized for 18 Ml/d average dry weather flow and was commissioned in 2009. The membranes used were Zenon hollow fiber (now Suez). The plant is currently significantly overloaded, and a second capacity upgrade will have to occur immediately after the one currently under construction (Capacity will increase from 72 Ml/d – 90 Ml/d when complete (Mandela, 2019). The plant has a combined inlet works and consists of two treatment modules:

Table 1: *Summary of membrane treatment plants in South Africa in 2022.*

Plant type	Location	Application	Pilot vs. full scale
Drinking water			
RO	V&A Waterfront – Cape Town	Seawater desalination	Pilot
UF + RO	Beaufort West – Western Cape	Reclamation plant WW to drinking water	Full
RO	Witsand – Western Cape	Solar-driven seawater desalination	Full
Wastewater			
MBR	Malmesbury WWTP – Western Cape	Domestic effluent	Full
MBR	Bellvile WWTP – Western Cape	Domestic/industrial effluent	Full
MBR	Zandvliet WWTP – Western Cape	Domestic effluent	Full
MBR	Stellenbosch WWTP – Western Cape	Domestic effluent	Full

(Source: The Authors)

> Membrane processes for water and wastewater treatment only became established in the Swedish market at the beginning of the 21st century. The main reasons for the late entry of these technologies into the Swedish market were the generally good availability of high-quality water and the initially high costs of membrane processes compared to conventional treatment technologies.

- 54 Ml/d Conventional Activated Sludge (CAS) Module treating raw wastewater and using chlorine gas for disinfection (2 bioreactors, MLE process configuration);
- 18 Ml/d MBR treating raw wastewater with dedicated 2mm fine screen, 1 MBR (UCT process configuration) and site chlorination for disinfection (chlorine gas).

The entire WWTP is currently being upgraded with a new combined inlet works, new combined primary sedimentation, second 18 Ml/d MBR section, together with refurbishment of all existing modules and a new mechanical dewatering installation. The commissioning of the new plant is anticipated to be by December 2023.

It is clear that MBRs are producing high quality effluents at the 4 WWTPs where there are currently in use, which brings us to the question: why is it not being considered by the rest of the treatment works in South Africa?

There are a number of reasons for this, but some of the considerations are:

I. First and foremost is the cost of the technology. Not only is the budget for construction of a MBR plant huge, but maintenance of the plant and cleaning of the membranes is very expensive. The membranes have a limited life cycle and have to be replaced every number of years. South Africa is still a developing country, with many challenges such as poverty and poor infrastructure. Not all municipalities are therefore equipped to justify such a huge capital expenditure.

II. Secondly, our rivers in South Africa, especially in the North of the country in provinces like Gauteng, are extremely polluted. Discharging a final effluent obtained from a multi-million-rand treatment facility into a river that is polluted on a daily basis, is simply not economically feasible.

III. Thirdly, due to the two reasons just mentioned, it is very difficult to convince the decision makers in local government to invest in more MBR based WWTPs.

IV. As researchers in membrane technology, we remain hopeful that this will change in the not-too-distant future.

Sweden

Industrial applications for membrane processes in Sweden started in the 1970s. However, in contrast to many other countries, the focus was not on drinking water production but on process applications in the dairy and pulp and paper industry with the demineralisation of whey from the cheese production by ultrafiltration as one of success stories. Membrane processes for water and wastewater treatment only became established in the Swedish market at the beginning of the 21st century. The main reasons for the late entry of these technologies into the Swedish market were the generally good availability of high-quality water and the initially high costs of membrane processes compared to conventional treatment technologies. However, in recent years, a major change with regard to the amount of large-scale membrane installations has been noted in Sweden. Generally, three major trends have been observed:

1. Drinking water plants based on UF/NF using ground and surface-water, e.g. river or lake water.
2. Drinking water plants based on RO using brackish water aka water from the Baltic Sea.
3. Wastewater treatment plants using MBRs.

An overview of key membrane plants installed in Sweden is given in Table 2.

Table 2: *Selected membrane plants in Sweden status 2022.*

Plant type	Location	Application	Pilot vs. full scale	Ref
Drinking water				
UF	Gothenburg	River water	Full	[3]
UF	Kungälv	River water	Full	[4]
UF	Varberg	Lake water and ground water	Full	[5]
UF + RO	Ôland	Industrial waste and brackish water	Full	[6]
UF + RO	Gotland	Brackish water	2 x Full	[7, 8]
Wastewater				
MBR	Stockholm	Domestic effluent	Full	[9]

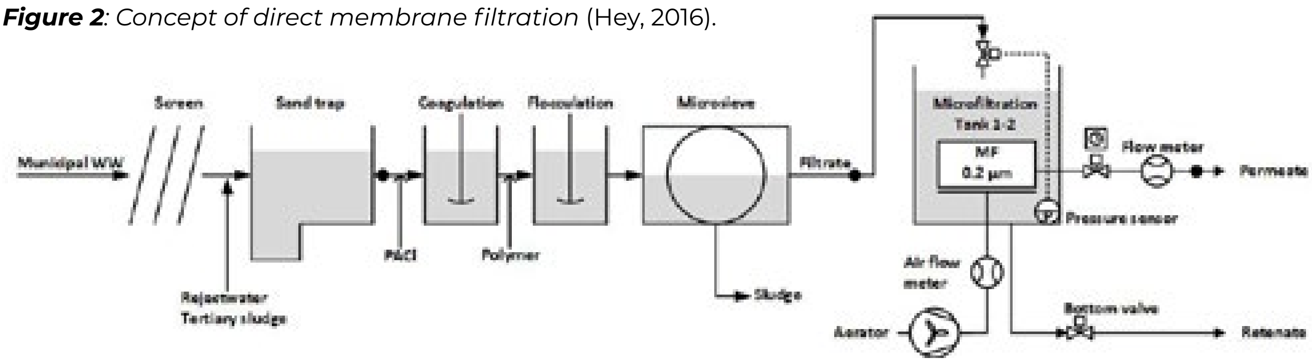
(Source: The Authors)

A milestone in the use of membrane technology in Sweden for drinking water preparation was the Lackarebäck plant in Gothenburg. The UF plant was not only the first major plant in Sweden, with a capacity of 186 Ml ~~m³~~/day, but also one of the largest UF plants in Europe (Pentair X-Flow(a), n.d.). The treatment plant converts river water from the Göta älv to drinking water for the second largest city in Sweden. The success of this plant led to the installation of similar plants using river, lake, and ground water in locations such as Kungälv (Pentair X-Flow(b), n.d.) and Varberg (Keucken, 2017).

Another important step was the installation of membrane plants on the Swedish Baltic Sea islands Gotland and Öland. The first installation was RO plant at Herrvik on Gotland with a capacity of 20 m^3/h in 2016 (Region Gotland, n.d.). The treatment plant directly takes water from the Baltic Sea, passes it through a strainer plus UF and then desalts it to produce drinking water. The second installation on Gotland is the Kvarnåkersham plant, which uses the same concept and was started in 2019. With a capacity of 7.5 Ml/day it is the largest brackish water desalination plant in Scandinavia (NCC, n.d.). An interesting concept for drinking water production was realised at Mörbylånga on Öland (Mörbylånga Kommun, n.d.). The plant uses brackish water from a well close to the Baltic Sea and industrial wastewater from a food processing plant. The industrial wastewater passes initially through an industrial WWTP and is then further polished by flocculation, UF and UV-light before being mixed with the brackish water. The combined stream is then further treated in a second line of UF, RO and UV-light as major steps before being used as drinking water.

Most recently the Henriksdal wastewater treatment plant in Stockholm opened the first of four MBR stages (Andersson, 2018). The total capacity of the plant once completed is two million persons equivalent and it will be ranked among the largest MBR plants in the world. An interesting feature is that the plant is completely installed inside a mountain close to the centre of Stockholm. The use of MBRs for municipal wastewater treatment is only a very recent trend. It is foreseen that other Swedish municipalities will follow that trend and update their wastewater treatment plant to MBRs.

***Figure 2**: Concept of direct membrane filtration* (Hey, 2016).



(Source: The Authors)

Furthermore, at Lund University the use of another concept described as direct membrane filtration (DMF) for municipal wastewater treatment is investigated (Hey, 2016). The DMF concept treats municipal wastewater by flocculation/coagulation followed by microsieving and thereafter by MF/UF, Figure 2. Key to the process is that negligible biological degradation is involved in the treatment process and thus the solid biodegradable organic load of the wastewater is available for biogas production. The supernatant containing soluble nutrients such as phosphorous, ammonia and nitrogen is available for surrounding agricultural activities.

Conclusions

The use of membrane technology in drinking water and wastewater treatment in South Africa and Sweden is growing despite the relative late start of both countries. Key for the success is the establishment of working membrane references for both drinking water preparation and wastewater treatment to serve as best practice examples. Membrane technology as such is very well established on the global market but often needs some local adaptions to work effectively. Reclamation of wastewater effluent would either be done indirectly as present scenarios and/or directly with the use of membranes. Thus, the collaborations between South Africa and Sweden as done in the South Africa Sweden University Forum (SASUF) are essential to support this approach by learning from one another.

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