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TECHVIEW REPORT

MEMBRANE TECHNOLOGIES FOR WATER AND WASTEWATER TREATMENT ON THE EUROPEAN AND INDIAN MARKET

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TECHVIEW

Membrane Technologies for Water and Wastewater Treatment on the European and Indian Market

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Content

1
Overview and technology taxonomy

1.1
Technology taxonomy

Membrane separation is currently used as support or replacement for traditional water and wastewater treatment technologies such as physical filtration or biological and chemical treatment. It is rapidly gaining acceptance throughout the world as the most effective and economical water treatment method available.[1] Originally it was used for preparation of process water, but its employment has expanded due to its usefulness in wastewater treatment and drinking water purification practices with the aim of retaining of microorganisms for water softening and desalination. Membrane separation is based on selective filtration through pores of different sizes and consists of four main membrane types: microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. All these types differ in operation pressures and permeability and can therefore filter back different particles from the feed water.[2] Micro- and ultrafiltration are deployed typically for particle removals whereas nanofiltration and reverse osmosis are used for softening and desalination practices. Membranes for water filtration vary in terms of pore size. The smaller the pore, the greater the applied pressure differential must be to press the water through the membrane. Comparatively large particles can be separated through micro- and ultrafiltration. But especially in the case of softening and desalination, there are smaller particles which require elimination. In such situations the most suitable solution is to deploy nanofiltration or reverse osmosis. These membranes are not porous materials with defined pore size, but homogeneous polymer layers that retain certain substances due to their specific structure. The technology taxonomy of membrane-based water filtration is summarized in the table 1.

Tab. 1: Taxonomy of membrane-based water filtration

Membrane-based technology market segmentation			
	Membrane Type	Configuration	Material
Membrane	Microfiltration (MF)	Pipe-shaped membranes: capillary, hollow fiber or tubular plate-shaped membranes: flat plate or spiral	Organic (Polymeric)
	Ultrafiltration (UF)	Plate-and-frame, spiral-wound, and tubular	Inorganic (Mineral)
	Nanofiltration (NF)		
	Reverse Osmosis (RO)		
Applications	Water Treatment (incl. Desalination) and Wastewater Treatment		
End Users	Industries, Municipalities and Communal Applications, Desalination Plants		

Source: Based on Frost & Sulivan, 2013

[1] Pall Corporation 2015
[2] Frost & Sullivan 2013

1.2 Definitions & key application of membrane-based technologies

Microfiltration (MF)
Microfiltration is the most basic of the four membrane separation types with multiple applications. The MF process is based on a simple permeable membrane which allows for the separation of large molecular weight suspended or a colloidal compound from dissolved solids.[3] Due to these attributes it is overwhelmingly used for sterile filtration, to reduce the turbidity of feed water and remove suspended solids and bacteria. There are several key applications of MF systems including for use in water treatment plants, pre-treatment in desalination plants, the preparation of sterile water for industries such as pharmaceuticals, the concentration process in the food and beverage sector and microelectronics sectors.[4] MF might also find its function in the desalination process as it is used to reduce the turbidity of feed water and remove suspended solids and bacteria.[5]

Ultrafiltration (UF)
UF is a current state-of-the-art water and wastewater filtration technology which as a low pressure driven membrane is extremely effective, with the added benefit of low energy consumption.[6] It uses a membrane which allows particles smaller than 20 nm to pass through it and the pore size varies between 20 nm and 0.1 microns.[7] The role of the UF membrane system, is increasing both in the water and wastewater treatment sectors, as well as in industrial process separation. Some of the key applications for UF's membrane systems are used in drinking water treatment, the pre-treatment process in desalination, and membrane bioreactors.[8] In the industrial sector, there are some specific preferences such as, for example, an emphasis on excellent pH and temperature resistance. A demand for low fouling tendencies of filters is also an important, although not a specific industrial demand. The key applications for UF systems are in the food and beverage sector (including a strong demand in the dairy industry for such products), the concentration of macromolecules in biotech, the production of ultra-pure water for microelectronics, in oil emulsion waste and general industrial waste water treatment."[9]
UF-membranes are produced by various suppliers with specific configurations which depend on the shape and material of the membrane. These configurations have a specific use that is accompanied by advantages and disadvantages. The most decisive influences on the configuration are mechanical stability of the system and required hydrodynamic and economic constraints.
The UF membrane modules come in tubular, capillary or hollow fiber configurations (pipe-shaped membranes) and plate-and-frame or spiral-wound configurations (plate-shaped membranes). For high purity water, spiral-wound and capillary configurations

[3] GEA Process Engineering 2012
[4] Frost & Sullivan 2013
[5] Van der Vegt, Helena and Iliev 2012
[6] Solar Spring 2015
[7] Flemish Region (VITO) 2015
[8] Flemish Region (VITO) 2015
[9] Synder Filtration 2015

would typically be used.[10] The optimization of the system depends mostly on the flow velocity, pressure drop, power consumption, membrane fouling and module cost.[11]
Besides the specific membrane configurations, there are also several set-ups to identify. The most commonly used methods include dead-end, cross-flow filtration set-ups. The combination of both – dead-end and cross-flow – also represents a possible type of the filtration process. The fourth possible set-up is a filtration chamber with submersed membrane filter. This method was originally developed for ultra- and microfiltration during wastewater treatments where the membrane in combination with the chamber/tank created a membrane bioreactor (MBR). There is now a range of MBR systems available, most of which use submersed membranes.[12]

Nanofiltration (NF)
Nanofiltration provides finer filtration than UF, but it is commonly referred to as a "loose" reverse osmosis (RO) because of its membrane pore structure. The structure of the membrane is still relatively large compared to RO membranes, and unlike them it allows the passage of salts.[13] NF membranes have pores with a size of approximately 1-5 nm and the molecular weight cut-off for a typical membrane lies between 150 and 500 Dalton.[14] The membranes have significantly higher water permeability than that of reverse osmosis (RO) and operate at much lower pressures. Due to its lower energy consumption and higher flux rates, nanofiltration could replace RO in many applications.[15] NF applications are largely used in tackling organic contaminants and some inorganic salts as they can retain ions and low molecular weight organics.
Other than tackling organic contaminants in freshwaters, NF membrane systems are also used for the concentration of sugars, dyes, and others substances. There are a number of industrial applications using nanofiltration as it is quite common in the food and dairy sectors, in chemical processing and in textiles. Nevertheless, the chief application continues to be in the treatment of fresh, process and wastewaters and desalination pre-treatment.[16] Similar to ultrafiltration, there are also different shapes of nanofiltration membrane such as tubular, spiral or flat.

Reverse Osmosis (RO)
RO is a form of membrane separation which uses pressure to force a solution through a membrane that retains the solute and allows the pure solvent to pass to the other side. Typically, this membrane is designed to allow only water to pass through while the solutes (for example salt ions) are being separated.[17] Capable of separating dissolved solids, bacteria, viruses, and other selected dissolved substances, it is largely used for the desalination of seawater."[18] RO membrane is essentially non-porous, and it preferentially passes liquid and retains most of the solutes including ions.[19] Reverse osmosis emerged together with electrodialysis as new technologies in the second half of 20th century and became an alternative to commonly used techniques of evaporation and distillation. Since that time, there have been several advancements of all major technologies including low temperature distillation, membrane distillation, pressure retarded osmosis, biomimetic and graphene membranes.[20]

[10] Lenntech 2015
[11] Dhawan 2014
[12] Rippenger 2009
[13] Rippenger 2009
[14] Flemish Region (VITO) 2015
[15] Shon, Phuntsho, Chaudhary, Vignesaran, Cho 2013
[16] Sutherland 2009
[17] Bakalar, Bugel, Gajdosova 2009
[18] Frost & Sullivan 2013
[19] Shon, Phuntsho, Chaudhary, Vignesaran, Cho 2013
[20] International desalination Association 2013

Tab. 2: Permeability overview and key applications for water membrane technologies by type

Membrane type	Particle capture size	Typical contaminants removed	Typical operation pressure ranges	Key applications
Microfiltration	0.1-10 µm	suspended solids, bacteria, protozoa	0.1-2 bar	water treatment plants, pre-treatment in desalination plants, the preparation of sterile water for industries, such as pharmaceuticals, etc.
Ultrafiltration	ca. 0.003-0.1 µm	colloids, proteins, polysaccharides, most bacteria, viruses (partially)	1-5 bar (cross-flow) 0.2-0.3 bar (dead-end and submerged)	drinking water treatment, the pre-treatment process in desalination, and membrane bioreactors
Nanofiltration	ca. 0.001 µm	viruses, natural organic matter, multivalent ions (including hardness in water)	5-20 bar	treatment of fresh, process and wastewaters
Reverse osmosis	ca. 0.001 µm	almost all impurities, including monovalent ions	10-100 bar	treatment of fresh, process and wastewaters, desalination of sea water

Source: Based on Frost&Sullivan 2013

Considering the rising trend of membrane use in alternative water source treatment, including desalination plants and wastewater recycling, the membrane-based water and wastewater treatment processes hold a great potential for the future.[21] Especially in regions with water scarcity, the provision of water from seawater desalination plants is becoming increasingly important. However, the treatment of the surface water to chemically and bacteriologically innocuous drinking water will play an increasingly important role in the future as well.

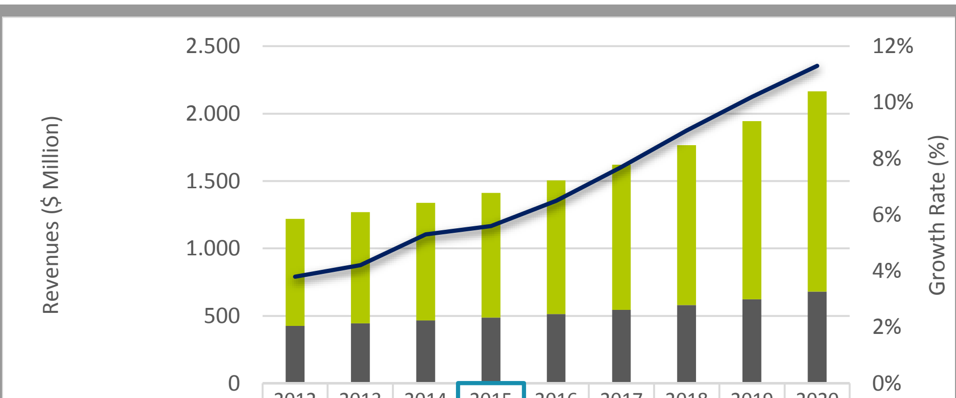
[21] Frost & Sullivan 2013

2
European Market Overview

2.1
Current status of the European membrane technology market

Europe has traditionally occupied a strong position in the membrane market in terms of scientific and technical excellence, which is expected to remain the case in coming years. Due to a wide range of water reclamation purposes based on this technology, membrane systems have received international recognition as reliable and proven technology. As the technology offers operating savings and reduces water and energy footprints, it has also been acknowledged for its sustainable approach.[22] The European aim to mitigate water scarcity and drought situations has earned this technology still further recognition and has established the issue as crucial because that there exists some regions with water scarcity where salinity management appears to offer the only suitable solution. The membrane-based water filtration market will be influenced by several trends including population growth and water pollution. Some of these will be crucial for Europe as well (e.g. water stress based on climate changes).

Based on the upcoming trends influencing the general market as well as the European share of that market (22 percent in 2012), the region is considered an established market where the water and waste water treatment branch is a mature industry that has been continuously influenced by tightening of water quality regulations.[23] The European membrane market for water and waste water filtration is expected to grow until 2020 as demonstrated in the chart below, with the relocation of core membrane investments from the Western to the Eastern part of the continent as some traditional treatments are replaced. The future depends mainly on the European regulations, but new opportunities might also emerge from the introduction of sustainable practices.



	2012	2013	2014	2015	2016	2017	2018	2019	2020
MF and UF	792,6	825,9	872,2	923,6	990,1	1076,3	1186,1	1321,3	1486,4
NF and RO	426,8	444,7	465,2	488	513,8	544,2	579,5	624,1	679,7
Growth Rate (%)	3,8%	4,2%	5,3%	5,6%	6,5%	7,7%	9,0%	10,2%	11,3%

Fig. 1: Membrane-based water and wastewater treatment market: revenue forecast by membrane type, Europe 2012-2020 / CAGR = 7, 4 %

Source: Frost&Sullivan 2012

[22] European Commission 2010
[23] European Commission 2011

The European market is dominated by large companies with significant control and influence across the whole supply chain.[24] The largest technology producers are also the largest technology users (e.g. utilities) at the same time. Such a market consolidation, together with the risk averse nature of the water utilities, limits the scope of innovation in this market. Instead of radical innovation in terms of the development of completely new technologies, the innovation activities are mainly incremental and focused on the refinement of the mature technologies and processes; processes which must be strictly proven to meet industry expectations. The main market drivers for European water and wastewater treatment are stricter regulations and requirement for reduction of energy cost. Therefore, many emerging applications concentrate on the production of high quality water at lower costs.[25]

In the water treatment membrane field a network of EU-based small and medium-sized enterprises are active.[26] These innovative companies, spin-offs from universities and start-ups devise new breakthrough technologies and business models focusing on Cleantech solutions, often for niche end-user segments and regions. Two examples of innovative SMEs and their technologies - SolarSpring GmbH and Akvolution - will be showcased later in this report.

The EU´s strengths lie also in the competitiveness of its engineering industry, especially with regard to system integration for *desalination* and *wastewater treatment*.[27] The following chapter describes the market developments, key players and technology evolution for these two applications on the European market.

2.2
Membrane technologies for desalination

Market development and characteristics

In its latest report on the membrane world market, McIlvaine Company assumes that in 2015 global desalination will account for 35 percent of the USD$11 billion membrane market. This share will be influenced by water reuse and the necessity for pre-filter systems. The increasing use of ultrafiltration pre-filters for reverse osmosis is considered as the main market driver.[28]

The market of desalination plants by end-user applications is divided mainly between municipal (63 percent) and industrial users (29 percent) but it is geographically dispersed between several key countries - Saudi Arabia (17 percent), UAE (13 percent), USA (13 percent), and Spain (8 percent).[29] European companies are very active on this market and many are among the global players, although EU countries are not on the top of demand for desalination plants. The nature of the market is complex and rests predominantly on a global supply chain, which will be explained on the following example.

24 European Commission 2011
25 European Commission 2011
26 European Commission 2010
27 European Commission 2010
28 Water World 2014
29 Frost & Sullivan 2013

Global supply chain

The Indian conglomerate holding company Reliance Industries Limited (RIL) has ordered seawater reverse osmosis solution (SWRO) for its Jamnagar oil refinery in the state of Gujarat.[30] The company has partnered with Israel-based global water treatment specialist IDE Technologies for a multi-effect distillation (MED) seawater desalination solution. IDE has developed a cooperation with Inge GmbH, a specialist on ultrafiltration and a subsidiary company belonging to BASF Water solutions (both based in Germany).[31] Inge GmbH was hired to protect the sensitive reverse osmosis (RO) membranes and minimize the energy footprint of the plant through deployment of its ultrafiltration technology. This contract led to an order of more than 4.000 Inge ultrafiltration modules and became the biggest project in the company's history.[32]

While desalination projects in India are primarily found in the private sector servicing industrial customers, in Europe the largest recent desalination projects were announced by public authorities.[33] In 2004, the Spanish Government introduced the program Programa Agua, which signified a significant shift in national water management away from large water transfers to a commitment to desalination. The government aimed to increase the availability of water mainly through sea water desalination and thus reduce water transfers from "water-rich" regions.[34] The Spanish water and wastewater treatment market is divided mainly in two segments: industrial and municipal end-users. Desalination belongs to municipal segment and is usually contracted by municipal or governmental authorities. The overall demand from municipal end-users represented approx. 80 percent of the total market (the share of desalination activities is about 20 percent).[35] The market has grown rapidly since 2004 on account of state-funded investments in the desalination sector. Nowadays, desalination in Spain amounts to approx. 1.200.000 m3/day, with 700.000 m3/day pertaining to seawater and 500.000 m3/day corresponding to groundwater.[36] The largest desalination plant foreseen by the plan "Agua" was the seawater reverse osmosis Torrevieja Plant with a production capacity of up to 240.000 m3/day, allowing for the annual contribution of 80 hm3.[37] The Spanish Ministry for Environment and Rural and Marine Affairs pushed forward the plan but it was public water operator Acuamed who was the contracting entity. A private company Acciona Agua won the contract for the design and construction of the facility *(nevertheless, the public water operator was responsible for the operation of the plant)*.[38] The pretreatment configuration in the plant is based on dual media filters, which have two stage filtration systems on the dual bed.[39] Normally the two filtration media are sand and anthracite, which is also the case in the Torrevieja Plant.[40] Acciona Agua is a Spanish based global leader in the water treatment sector and belongs to Spanish Acciona group. The company offers end-to-end services covering every stage in the water treatment process.[41]

[30] Alle 2013
[31] WaterWorld 2014a
[32] Inge 2014
[33] Copenhagen Cleantech Cluster 2012
[34] European Commission 2006
[35] Frost & Sullivan 2009a
[36] AEDyR 2015
[37] Acuamed 2014
[38] Water Technology 2013
[39] Acciona Aqua 2014
[40] Acuamed 2014a
[41] Acciona Aqua 2015

Key Players

European market leading companies such as Accoina (Spain), Suez (France) and Veolia (France) are builders of desalination plants and simultaneously users and developers of desalination technologies.[42] The market is becoming more vertically integrated since the whole supply chain of desalination from the construction of the plant to the distribution of processed water is increasingly operated by global firms.[43]

Tab. 3: Leading EU desalination technology producers

Company name	Country
Veolia	France
Accionia	Spain
Befesa Agua	Spain
Biwater	UK
Suez	France
Fisia Itlimpianti	Italy

Source: European Commission 2011

Technology trends, evolution and diffusion

The original methods for large-scale desalination of seawater such as thermal distillation are associated with high energy costs. More recently, reverse osmosis (RO) has become the fastest growing method for seawater desalination and is the most widespread in Europe. The emerging solutions are the hybrid desalination systems combining RO with thermal technologies, such as multi-stage flash and multi-effect distillation. The technological evolution over the years is illustrated in the figure 3. Moreover, the nanofiltration (NF) pre-treatment process was integrated into the desalination process to prevent the formation of the alkaline and nonalkaline scale so as to increase water production and performance ratio through high temperature operation of the thermal processes. Membrane technologies are becoming increasingly competitive as current research continues to lower the cost barrier.[44]

[42] European Commission 2011
[43] European Commission 2011
[44] European Commission 2010

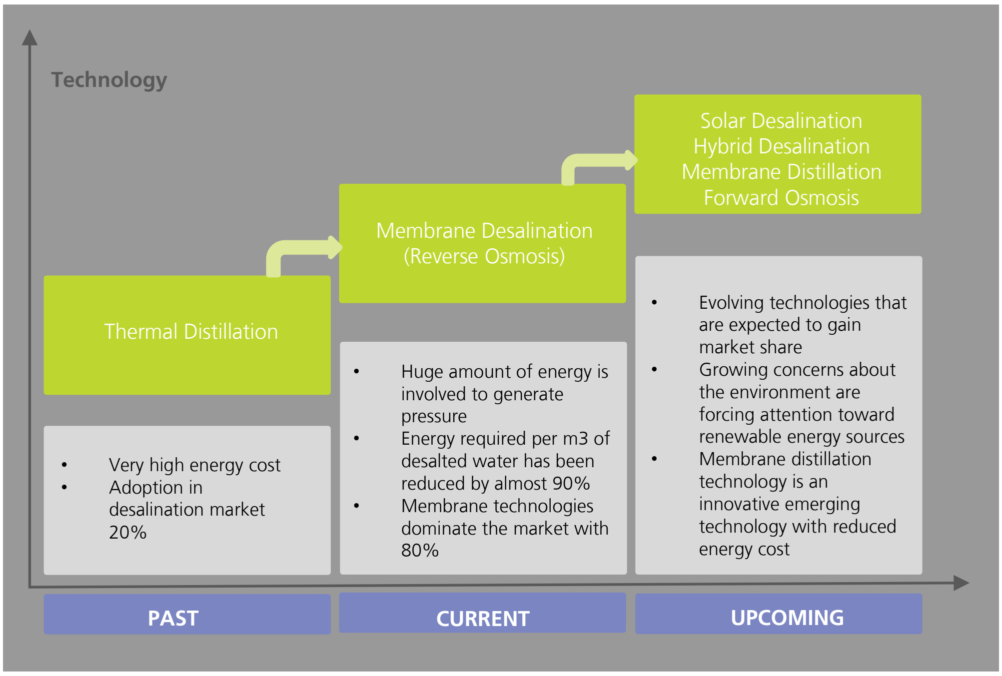


Fig. 2: Evolution of desalination technologies

Source: Based on EBTC 2012

According to the types of water desalination plants by installed base, there are 20 percent of thermal desalination plants and 80 percent of membrane desalination plants (in the terms of capacity, the ratio is 50 percent thermal desalination to 50 percent membrane desalination).[45] In particular, reverse osmosis (RO) dominates the market. Spain has the largest market demand for desalination in the EU (8 percent of the global market).

One of the most important challenges in facilities based on reverse osmosis is the energy consumption (up to 44 percent of overall operational costs). The consumption has been significantly lowered by using advanced membrane materials, decreasing pressure losses or deploying more efficient water pumps. Energy consumption and other issues pertaining to the filters will be key areas for research and development for membrane manufacturers.

Since the introduction of membrane processes for filtration and purification, innovation in the desalination market has been slow and rather incremental due to consolidation and risk aversion.[46] When considering technology trends, three areas of new technologies arise: improved membrane materials such as ceramic membranes with robust features, hybrid and solar desalination, forward osmosis, and membrane distillation. Forward osmosis and membrane distillation represent new paradigms in water desalination that will have to face conservatism of water customers and find new business models.[47]

Membrane distillation (MD) is a very innovative membrane technology with a wide range of applications. In particular it is used for water desalination and treatment of industrial

[45] Frost & Sullivan 2013
[46] European Commission 2011
[47] European Commission 2010

wastewaters. MD is capable of desalting highly saline waters. It is a thermally driven process in which only vapor molecules are able to pass through a porous hydrophobic membrane. Some of the attractive features of this process include low operating temperatures and low hydrostatic pressure which translates into less demand from the membrane characteristics and cost-efficiency. Membrane distillation technology can improve the current technology spectrum and make it more energy efficient.[48] Nevertheless, more research is still necessary in order to establish the technology as a common solution.

One of the European innovative technology providers of membrane distillation is SolarSpring GmbH. SolarSpring is a German company and a spin-off of Fraunhofer Institute for Solar Energy Systems (ISE) with its headquarters in Freiburg. The company is a developer of clean-energy water systems. Their solutions desalinate and treat seawater and non-potable water using solar energy or waste heat. These clean energy sources are used to power technologies such as membrane distillation, ultrafiltration and UV disinfection. SolarSpring is one of the four providers of membrane distillation technology worldwide that offer whole membrane distillation systems.[49]

2.3 Membrane bioreactors for wastewater treatment

Market development and characteristics

Wastewater treatment, similar to desalination, is divided between private and public sector providers. Approximately 14 percent of the world's population today (and up to 27 percent of the urban population) have some part of their water or wastewater managed by a private sector company.[50] There has been a switch of major market activity from OECD countries to markets which were previously considered peripheral e.g. China, Brazil, India and Russia. This change also shifted market shares towards other non-European companies. Nevertheless, the EU is still home to the top utilities in the global water and wastewater treatment industry; these companies include Suez, Veolia, SAUR, Agbar and RWE. These largest utilities are both the leading technology suppliers and users of such technologies.[51]

In 2012, there was a global market for water and wastewater solutions and services worth some USD$180 billion, while the share of treatment equipment on this market was valued at only $34,59 billion.[52] The global water and wastewater filtration systems market was valued at $6, 117 million in 2012.[53]

[48] SolarSpring 2015
[49] Solar Spring 2015
[50] Pinset Masons 2012
[51] European Commisson 2011
[52] Royan 2012
[53] Frost & Sullivan 2013

Effects of population explosion and water scarcity combined with increasing wastewater treatment consciousness will undoubtedly influence the filtration system market.[54] Another characteristic of the market is its highly fragmented structure, so the inevitable outcome might involve consolidation with some notable acquisitions. One example of such activities is the global leader in filtration and separation, the America-based Pall Corporation. In February 2014 the company completed acquisition of ATMI LifeSciences (bioreactors for pharmaceutical industries)[55] and subsequently announced in May 2014 its acquisition of Filter Specialists Inc. (a leader in innovative, state-of-the-art filtration products and solutions).[56] Pall Corporation is currently dominating the global market with its extensive product portfolio mainly catering to niche industrial applications.

The European share of the global market is slowly declining and will probably soon drop to below 30 percent. The structure of the European market is not markedly different from the global version as the market leader with more than seven percent share of sales is Pall Corporation; other important companies include Eaton Filtration and GE Power and Water.[57] The consolidation of the global market has also substantially influenced the European competitive landscape. One of the most significant European market players – Dutch company Norit (activated carbon specialist) was acquired by American Carbon Corporation in 2012.[58] Other important European companies were Germany-based Siemens and French Degremont SA.[59] Siemens decided to focus on other parts of the water business and left the market by selling its unit, which offered solutions for treating and processing municipal and industrial water and wastewater (Siemens Water Technologies Business Unit).[60]

The European wastewater market is a mature market where Germany is the largest exporter of water and sewage treatment technologies. Germany is not only investing in domestic production of sewage systems, but also becoming an exporter of sewage centered technologies.[61] The next four largest intra-EU exporters are Belgium, Netherlands, France and Italy.[62]

Key Players

Tab. 4: Leading EU membrane-based water and wastewater treatment technology producers

Company name	**Country**	**Tier**
Veolia	France	II
Degrémont	France	II
Keppel Seghers Belgium NV	Belgium	III
OSMO Membrane Systems	Germany	III
Novasep	France	III
Membran-Filtrations-Technik GmbH	Germany	III
Membranteknikk AS	Norway	III

Source: European Commission 2011, Frost & Sullivan 2013

[54] Frost & Sullivan 2013a
[55] Pall Corporation 2014
[56] Pall Corporation 2014a
[57] Frost & Sullivan 2013a
[58] Cabot 2015
[59] Research and Markets 2014
[60] Siemens 2015
[61] hwww.dw.de/germany-leads-the-way-in-wastewater-technology/a-16599085 [access on January 8th]
[62] European Commission 2011

Technology trends, evolution and diffusion

As shown in the next figure, the conventional methods used in Europe have been sand and anthracite filters and chlorination. Membrane Bioreactors (MBR) represent a mature technology for industrial wastewater treatment used predominantly across the EU.[63] The global market for MBR technology is projected to grow by 15.21 percent over the period 2013-18.[64] Europe holds a market share of 21 percent and continues to be one of the significant MBR markets. The MBR technologies are often used among the municipal sectors in Germany and Benelux. This technology combines conventional activated sludge treatment with a separation of the biological sludge by micro- or ultra-filtration membranes with pore size of typically 10 nm to 0.5µm used to produce the particle-free effluent.[65] The membrane prevents the penetration of suspended solids and can be used for replacement of conventional secondary clarification and potential tertiary sand filtration.[66]

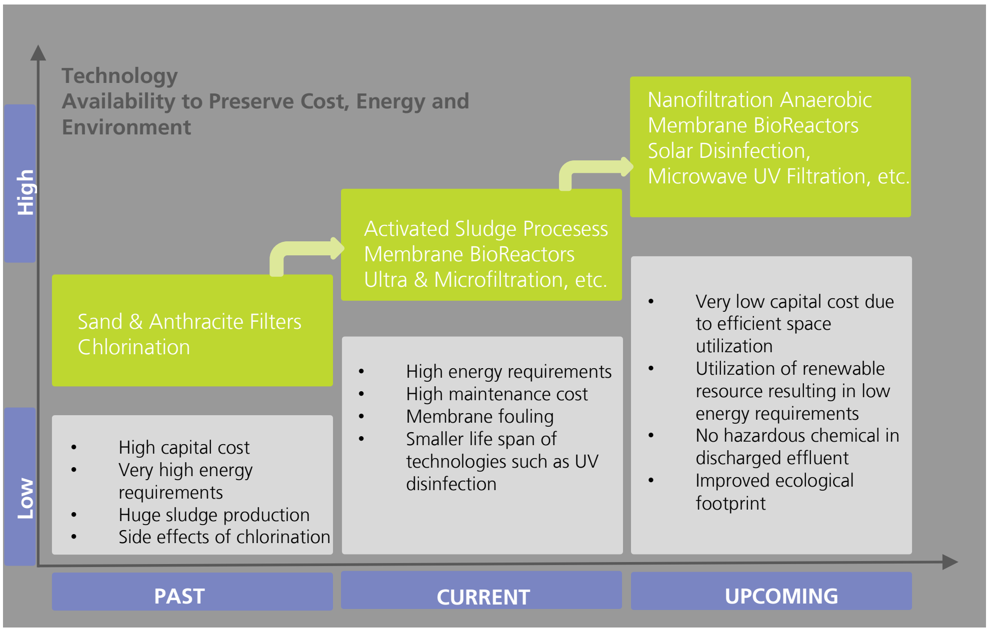


Fig. 3: Evolution of desalination technologies

Source: Based on EBTC 2012

Membrane treatment for wastewater was first applied around 30 years ago. However, these technologies were previously considered uneconomical.[67] Lately, a new generation of MBR units have been developed working with low negative pressure (out-to-in permeate suction) and membrane aeration to reduce fouling. These are based on the so-called immersed filtration system and are less costly to install and operate than the previous technology.[68] Additional benefits in comparison to conventional processes include a small footprint, easy retrofittability for the upgrade of old treatment plants, complete solids removal effluent disinfection and no problems with sludge bulking.[69]

[63] European Commission 2010
[64] PR Newswire 2015
[65] http://mbr-network.eu/mbr-projects/index.php [access on February 10th]
[66] European Commission 2010
[67] http://goo.gl/k6XB6V [access on February 6th]
[68] Lesjean/Huisjes 2007
[69] European Commission 2010

3
Indian market overview

3.1
Water demand in India

India is the seventh largest country in the world with more than 1.2 billion inhabitants. Obviously, such a huge population places a strong burden on all of its natural resources - especially its water, much of which is contaminated by sources such as sewage, agricultural runoff and industrial chemicals. India has made progress in the supply of safe water to its people, but gross disparity in coverage is omnipresent across the country.[70] The average availability of potable water in India is constantly reduced with the increasing population, fast economic growth and industrialization, and it is expected to become a water stressed nation in the near future. Although access to potable water has improved, 75 percent of India's rural population still does not have access to clean and safe drinking water and more than 80 percent of India's diseases and 33 percent of deaths are caused primarily by contaminated drinking water.[71] The worst affected Indian regions are Rajasthan, Karnataka and Gujarat, where more than 40 million people have been suffering from fluorosis due to the high amount of fluoride. In West Bengal many people are suffering from arsenicosis because of the high level of arsenic. Considering the current status of the available water in India, it creates various opportunities for companies to enter to the water filtration market.[72] In order to counter this issue, the Indian government budgeted around USD$26.5 billion in the period 2012-2017 for providing potable water to all rural and urban Indians. Thus, treatment of wastewater, solid, chemical and liquid waste, and sewage treatment and desalination of water are necessary services that India will require to solve its upcoming water deficit.[73]

According to a study from Frost & Sullivan, wastewater recycling, reuse and desalination have the greatest potential to satisfy India's growing water demand. While desalinating water has high potential, wastewater reuse still in its formative stages and needs more time to develop its full potential.[74]

3.2
Current status of the Indian membrane-based market

Due to the high demand for membrane-based applications for desalination, water purification and wastewater treatment, the Indian membrane technology market is expected to encounter stronger growth than those in other parts of the world. The following figure depicts the membrane market growth of 15 percent in 2012 in India in comparison with Europe, the United States and MENA regions.[75]

[70] Water.org 2015
[71] The World Bank Group 2011
[72] Government of India, Desalination Division 2010
[73] Avalon global research 2011
[74] D&WR 2014
[75] Frost & Sullivan 2013b

Source: Frost & Sullivan, 2012

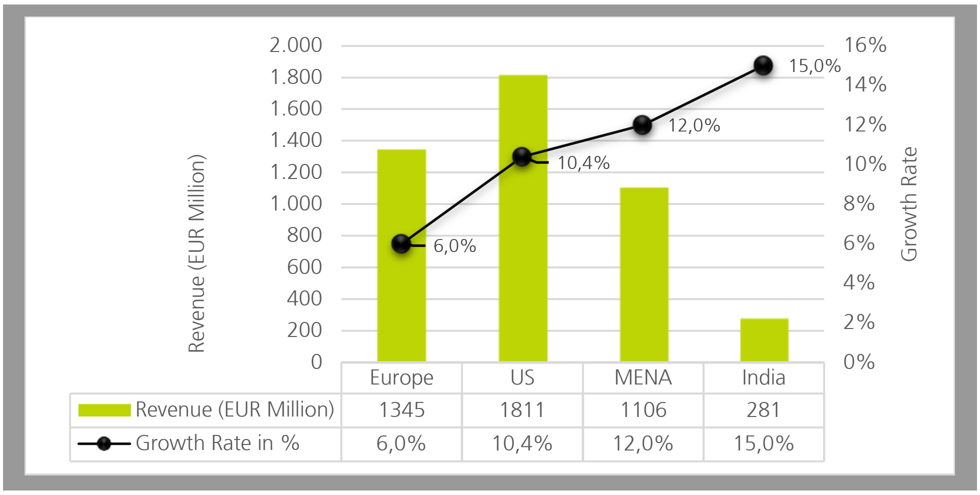


Fig. 4: Membrane systems market in water & wastewater treatment industry: market revenue by region, global 2012

In the period 2014-19 the Indian membrane market is expected to grow at a rate of around 14 percent and the entire market value is projected to surpass US$ 404 million in 2017.[76] "The availability of affordable and effective membrane technologies is a core enabler for cross-industry growth."[77] The leading global membrane manufacturers mainly dominate the Indian membrane technology market. These global manufacturers are importing membranes from their own production facilities located outside the country, and with their high competence and technical knowhow are targeting not only conventional but also other potential applications of membranes in different commercial and industrial processes.[78] Currently, companies like Uniflux, Permionics, Ion Exchange, and Driplex are important players in the Indian market that have established a significant presence there.[79] The market is being mainly driven by the rising demand and focus on clean technologies, breakthrough innovations in the design and structure of membranes and the rapid growth of branches using membrane technology for various industrial processes and applications. Over the past few decades the membrane technology has not only gained widespread acceptance but also witnessed significant market transformations and technological changes.[80]

In India's membrane market RO membranes are one of the key growth drivers. The demand in various Indian regions for RO membranes is increasing due to the high total dissolved solids (TDS) level. Consequently, in the upcoming years the domination of the RO membranes segment will likely continue to grow in India's membranes market.[81]

[76] http://www.techsciresearch.com/2124 [access on February 8th]
[77] Sustainability Outlook 2014
[78] WQP 2014
[79] Sustainability Outlook 2014
[80] http://www.techsciresearch.com/2124 [access on February 8th]
[81] Frost & Sullivan 2012

3.3
Membrane technologies on Indian desalination market

Market developments & characteristics

India’s desalination market is among the top ten worldwide and is facing a huge expansion in capacity addition, driven mainly by municipalities, corporations and private sector participation. Besides the accelerated economic rise, industrialization and increasing population, the other main driver is that India has an extremely long coastline (7.517 km).[82] Many of the coastal municipalities are looking to invest in desalination. According to a report from Tech Sci's, India's desalination market market will experience an annual growth rate in the period 2014 - 2019 of around 19 percent, and the market's current worth is in the neighborhood of US$660 million.[83]

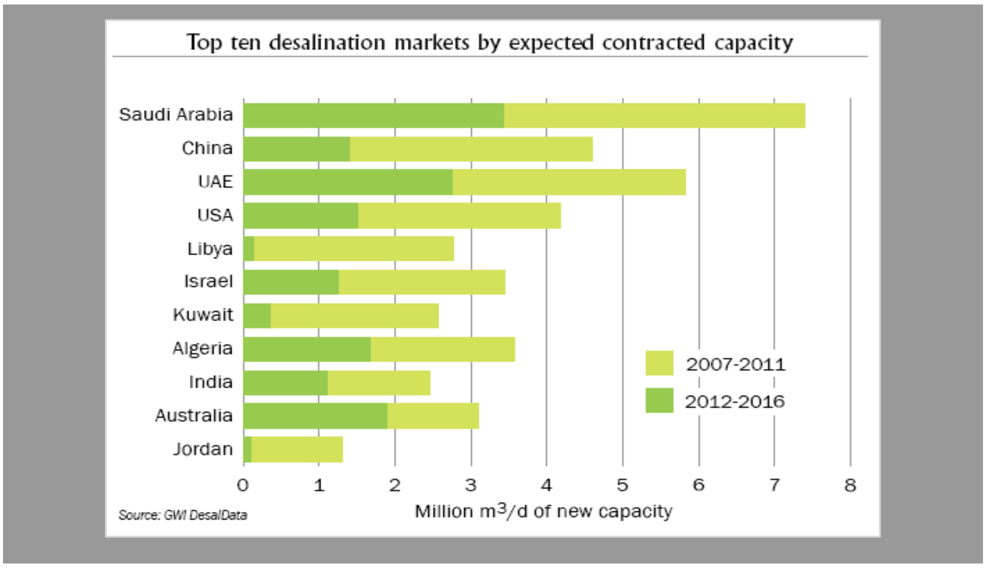


Fig. 5: Top 10 desalination markets by expected contracted capacity

Source: GWI 2011

Due to the unequal water distribution in India, the aim of the government is to concentrate the desalination technology in areas where water resources are very scarce such as in Gujarat, Rajastan and Tamil Nadu.

The market is mainly dominated by global companies, primarily from Spain, France, Israel, Singapore and the US.[84] The key players are VA Tech Wabag, IDE Technologies, Doshion, BGR Energy Systems, Ion Exchange, GE Water & Process Technologies, Degremont, Befesa Agua, IVRCL Infrastructures, and Aquatech International.[85]

[82] EPC World 2014
[83] http://www.techsciresearch.com/3018 [access on February 8th]
[84] D&WR 2014
[85] Frost & Sullivan 2009

Technology trends, gaps & opportunities

The growing desalination market creates opportunities for the membrane water and wastewater technology suppliers in both municipal and industrial segments in India. Thus, in the coming years it is expected that India will act as a growth engine for the global water desalination industry.

The technology for desalination mainly diffused across India is similar to Europe's reverse osmosis. Multi-stage flash distillation (MSF) and multi-effect distillation (MED) are also technologies followed on the limited scale, especially by the industrial units and municipalities. Membrane-based desalination is generally preferred by industrial end users such as power plants and refineries.[86] Due to the lower cost of membrane-based desalination plants compared to conventional thermal technologies, 85 percent of the Indian desalination plants are membrane-based.[87] Currently India has around 1,100 functional membrane based desalination plants of various capacities.[88] Recently, small community-based desalination plants have been constructed in coastal areas in the states of Tamil Nadu and Andhra Pradesh through various governmental initiatives.[89]

Upcoming innovative technologies like hybrid and solar desalination or membrane distillation are currently insignificant in India, but they are expected to gain a market share in the near future due to their immense potential.

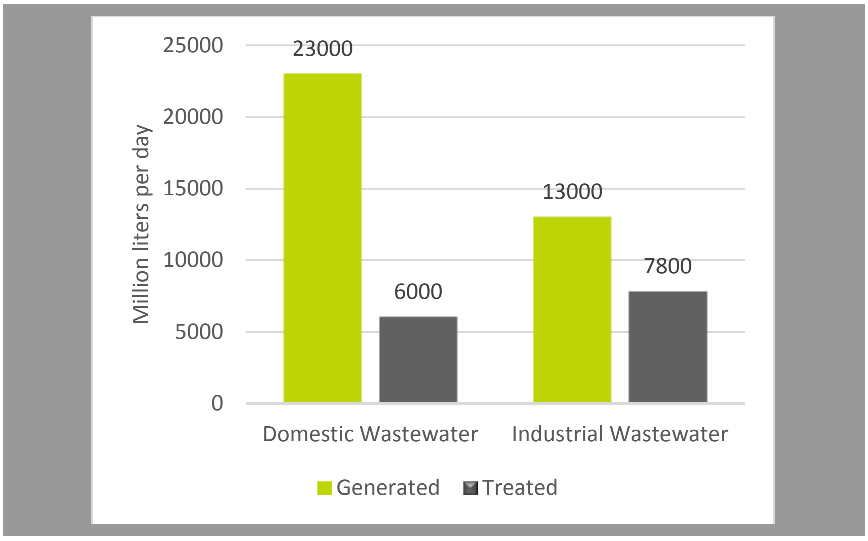
3.4 Membrane technologies on the Indian wastewater treatment market

Market developments & characteristics

Due to increasing health awareness in India, wastewater treatment has become a key focus area. Althought government support and private participation accelerated growth of the sector in the last decade, the need for improvement remains tremendous. It is estimated that only about 20 percent of domestically generated sewage and 60 percent of industrial generated wastewater is treated.[90] Furthermore, large cities treat around 29 percent and small cities only 3.7 percent of their wastewater.

[86] EBTC 2012
[87] D&WR 2012
[88] EPC World 2014
[89] Avalon global research 2011
[90] Eldho 2014

Fig. 6: Domestic and industrial wastewater treatment in India



Source: Avalon Global Research, 2011

Currently there are more than 230 sewage water treatment plants. Most of these plants in India were developed under various governmental river action plans and are located in cities along the banks of major rivers, according to a CPCB report.

Large global and Indian players have operations in India including: Veolia Water, Suez de Lyonnaise (Degremont) and VA Tech Wabag, Nalco and GE Betz-Dearborn. India's water treatment equipment industry is reasonably well established and cost-competitive.

The wastewater market is highly fragmented and dominated by many small-scale industries lacking in expertise, for instance food and beverages, sugar, distilleries, automotive component manufacturing and pharmaceuticals. Besides these industries, the commercial sector, for instance hotels, hospitals, institutions, etc. has accelerated its growth potential for European companies.

Technology trends, gaps & opportunities

In comparison to Europe, in the majority of the Indian tier I cities, activated sludge or oxidation pond processes and chlorination are the most commonly used technologies covering around 59.5 percent of total installed capacity. This is followed by up-flow anaerobic sludge blanket technology, which covers around 26 percent of total installed capacity. Moreover, waste stabilization pond technology is also installed in many wastewater treatment plants.[91]

The trend is evolving to the greater use of membrane technologies that enhance the quality of water available for reuse and and which already have a wide presence in Europe. Therefore, there is strong potential for European companies to replace conventional methods in India, especially the chlorination process. This new generation of wastewater treatment technologies is able to treat the industrial and domestic sewage similar to the quality of river water. However, the costs of maintaining and implementing activated sludge processes, which are currently used in many industries and municipalities, are far lower than MBR.[92] Therefore, alternative cost effective solutions

[91] Kamyotra/Bhardwaj 2011
[92] Kamyotra/Bhardwaj 2011

for water applications, for example nanotechnologies like nanoporous polymers, nanomembranes, forward osmosis and membrane distillation could hold even higher potential for the Indian market.

3.5 Membrane technologies on the Indian water purification market

Market developments & characteristics

Besides desalination and wastewater treatment, membrane technologies in India hold great potential for water purification for end-users. This is especially the case with households due to the fact that many of them, especially in rural areas, have often no or limited access to municipal water and are thus forced to treat their own water. In the recent years the Indian water purifier market has experienced vast growth opportunities. According to Research Gate, it is expected to grow around 25 percent until 2017 and worth some US$ 760 million by the end of 2015.[93] One of the main reasons for this tremendous growth rate is rising product awareness across rural and urban markets. The vital water sources in the big states like Rajasthan, West Bengal, Bihar, Orissa, Andhra Pradesh, and Tamil Nadu still have a high metal content and thus the demand for water purifiers is further growing in many tier II and tier III cities in these states.

Until recently, the water purifier companies have not taken notice of the rural markets due to the low income level, weak distribution networks and sales of the manufacturers and companies in these areas. However, many global players and local companies are now penetrating the Indian rural market with innovative low-price and low-cost products, especially the offline water purifier industry.[94]

Technology trends, gaps & opportunities

India's water purifier market is dominated by small technologies for households, which are mainly based on the reverse osmosis design for filtration of fresh water. Water purifiers for households are mainly distributed and sold in outlet stores, while approximately 30 percent of UV and RO based water purifiers are sold via the 'direct to home' channel. Therefore, many well established key players set up their own exclusive branded water purifier outlets.[95] Most of the new as well as the existing companies are focused mainly on membrane based -especially on RO based- water purifiers, which is also the fastest growing application in the Indian water purifier market.[96]

The RO water purifier market is mostly consolidated, with around 70 percent of the market share being held by ten global players. The market leaders of this segment in

[93] ResearchGate 2013
[94] http://www.techsciresearch.com/2959 [access on January 15th]
[95] Market Pulse 2013
[96] Frost & Sullivan 2012

2013 were Eureka Forbes and Kent RO with a market share of around 50 percent. They are also pioneers that have steadily developed the water purifier market by introducing new products and continuously expanding their distribution network. Two further players operating in this segment are Nasaka, HUL and Ion Exchange. HUL is a specialist for the offline category[97] and experienced the explosive growth in the last few years. Another significant company in this market is TATA Chemicals' Swach. Recently, the market has also witnessed the entry of new domestic and global players like Livpure, a Luminuous Technologies brand. The growth of Eureka Forbes's RO segment was mainly driven by its relatively low product pricing strategy, a continuous development of its products such as launch of mobile water purifier and the distribution through direct sales.[98]

Ultrafiltration represents an alternative technology to RO technologies for water purification. It is easy to maintain, has low operating costs and is very adaptive. But in India it is also relatively unknown. The company SolarSpring, which was already mentioned in previous chapters offers for Indian end-users solar water filtration based on the ultrafiltration technology. The focus of the company lies on small-scale projects in rural areas. Due to the low income of households in these areas, SolarSpring is not active for particular households but rather small municipalities. The whole municipality receives a central place where the water is treated. This is a more economical solution and provides EU technologies with higher quality standards and higher prices a chance to establish their businesses in India.

The advantages of the technology of SolarSpring is that it is very innovative, decentralized and 100 percent solar-powered. Consequently, it is a suitable technology for the Indian market, especially for rural areas with limited access to power.

[97] Offline = without electricity use
[98] PR Newswire 2014

4 EU-India comparison and strategic recommendations

4.1 EU-India market drivers & challenges

The demand for fresh water in India has continued to grow dynamically, primarily due to a rising population level and rapid increase in urbanization. This in turn leads to pressure upon the agriculture sector which requires adequate water sources. Economic growth and the emergence of a new industry set up put pressure on water requirements and treatment.[99] Continuous investment in water and wastewater improvement by municipalities and industries drives EU companies and providers of membrane-based water and wastewater technologies to enter the Indian market.[100]

Moreover, in 2014 Prime Minister Narendra Modi sharpened India's focus on water and sanitation projects, especially for water supply and protection, waste management, pollution control, sanitation and clean air. The government has already increased its emphasis on infrastructure, public transport, solid waste disposal, sewage treatment and drinking water.[101] Therefore, new technologies such as ultrafiltration and other membrane technologies are needed in India. Further demand for membrane technologies can be expected also due to the planned increase of desalination projects along the coastal areas.

Different end-user segments offer varied opportunities for membrane technology providers. Commercial sectors (e.g. hotels, hospitals, institutions, etc.) with increased market growth are a promising end-user segment. The growth of small and medium sized industries (food and beverages, sugar, distilleries, automotive component manufacturing, pharmaceuticals) has supported the high purity process water markets. A great scope for potable water and solid waste management arises in the municipal segment. Furthermore, private equity funds are increasingly interested in investing in water and wastewater treatment companies.[102]

Despite of the fact that the business environment is improving, the industry has to overcome several challenges including the slow pace of implementation of policy reforms in India, reluctance of the enterprises in the implementation of the norms and underdeveloped infrastructure. The next table summarizes the main drivers and challenges of the Indian membrane water and wastewater treatment market.

[99] Avalon Global Research 2011
[100] Chemtec 2012
[101] Projectmonitor 2014
[102] Chemtec 2012

Tab. 5: Drivers & Challenges

Drivers	Challenges
- Increasing efforts towards ensuring water supply and protection, waste management, pollution control, sanitation and clean air - Many coastal municipalities like Mumbai, Surat, Chennai, Kolkata, and Vizag are also willing to invest in desalination, thus many desalination projects can be expected to be developed and planned in the next decade - Decreasing water quality - Indian firms are searching for joint ventures and licensing with European companies to apply their technical capabilities on Indian market - Industrial and economic growth, particularly in chemical, pharmaceutical, power plants, food and textile industries and commercial sectors like hotels, hospitals, etc.	- High energy consumption of desalination plants – large-scale desalination uses extremely high amounts of energy as well as specialized, expensive infrastructure, making it very costly - Environmental issue – greenhouse gases are released during desalination due to high energy requirements - Reluctance of the enterprises in the implementation of the norms - Slow paced implementation of legislation and regulation - High price sensitivity of the Indian market - Insufficient infrastructure

4.2
EU-India policies and regulatory framework

In India water and sanitation is constitutionally defined as a state subject. Each federal state manages, controls and administrates its implementation as well as the water policy itself. There are many institutions responsible for different tasks dictated by the water policies in each state. The primary task of the central government in New Delhi is to maintain harmony and navigate disputes through a five-year plan. There are three levels of execution of established water policies – central government, federal states, and city governments.[103]

Moreover, a set of standards regulates the quality of the drinking, surface and ground water as well as water for various industries and sewage treatment plants in India. These are national and therefore mandatory standards, such as for drinking water (IS 10500-1991) or for water quality for irrigation of agricultural land (IS 11624-1986) and are subject to many different norms adopted by rural local and urban bodies. However, the most central water quality standard in India is the Bureau of Indian Standards (BIS-IS:10500) which was implemented not only to assess the quality of water resources but also to check the effectiveness of wastewater and water treatment and the provision of all involved authorities.[104]

The regulation of water and wastewater treatment is managed by following Indian institutions:

– ***Ministry of Water Resources, Government of India*** - responsible for development, conservation and management of water as a national resource (http://wrmin.nic.in/)

[103] Alex 2007
[104] Working Group on Urban and Industrial Water Supply and Sanitation for 12th Five Year Plan 2011

- ***Bureau of Indian Standards*** - recognition, implementation, and monitoring of Indian statutory standards (www.bis.org.in)
- ***Central Pollution Control Board*** - aims to promote cleanliness of streams and wells in different areas of the States by prevention, control and abatement of water pollution, and to improve the quality of air and to prevent, control or abate air pollution in the country (http://cpcb.nic.in/)
- ***Central Water Commission*** - monitors water quality at 396 key locations covering all the major river basins of India (http://www.cwc.nic.in/)

Even though the drinking water standard IS 10500 - 1991 in India is geared to recommendations of the WHO, it does not completely meet the European standards for drinking water. In recent years, the increased extraction of groundwater has meant that certain parameters such as the limits for particular minerals could not be kept. Accordingly, the limits have been increased for these components. Water quality - even if it satisfies the Indian guidelines does not therefore necessarily reflect the requirements of the WHO for drinking-water.

The 74^{th} Constitution Amendment Act provides a legal framework and enables urban local bodies to provide urban areas with sanitation and water supply facilities. The Ministry of Environment and Forests (MoEF) provides the financial and technical support schemes for wastewater treatment of small scale industry units which are located in clusters.

The regulation of wastewater is manifested in policies based on certain legal provisions and policies as well as on certain environmental laws such as:

- Water Prevention and Control of Pollution Rules, 1975
- National Environment Policy, 2006;
- National Sanitation Policy, 2008
- Hazardous Waste (Management and Handling) Rules, 1989
- Municipalities Act; District Municipalities Act etc. [105]

Furthermore, industries should follow the Zero Discharge (ZD) or the Zero Liquid Discharge (ZLD)[106] Policy -both of which describe the wastewater quality requirements for specific concentration spaces of discharged wastewater- which has been drafted by the Central Pollution Control Board (CPCB) and Ministry of Environment and Forest (MoEF). The State Pollution Control Boards (SPCBs) are responsible of the implementation of this policy. Currently, only specific industrial consumers such as automobile and textile manufacturers as well as breweries and a few states are mandated to obtain ZLD status. In the coming years it is expected that the ZLD status will be implemented uniformly across India.[107]

These recent regulation trends are supported by administrative, legislative, and judicial initiatives; thus, regulations in the Indian environmental segment are becoming more comprehensive.[108] While all of these attempts will help to immensely improve the water

[105] Eldho 2014
[106] Zero Liquid Discharge (ZLD) is a concept where after appropriate treatment the entire industrial effluent is reused without discharging sewage into any river.
[107] CEW India 2012
[108] Kamyotra/Bhardwaj 2011

quality in India there are still many government agencies responsible for water management which is a huge hindrance for effective policy implementation and development. Moreover, all the different existing water policies and tariffs across the states should be standardized in order to foster the efficiency of water and wastewater treatment processes and to one day guarantee clean and safe drinking water to all end-users in India.[109]

Tab. 6: EU – India policies and regulatory framework: Comparison

	
Water Framework Directive (WFD) – adopted in 2000. Integration and tightening of water regulations across policy areas and watersheds that have created the need for more efficient and higher quality water and wastewater treatment processes. The WFD also established a combined approach for regulation of point and non-point sources of contaminants and set specific compliance deadlines for a number of regulations. **Related directives** - Bathing Water (76/160) (now replaced by 2006/7), Drinking Water (80/778, as amended by 98/83), Urban Wastewater Treatment (91/271), Nitrates (91/676), Integrated Pollution Prevention & Control (96/61, codified as Directive 2008/1/EC), Sewage Sludge (86/278)	**The National Water Policy (NWP)** – formulated by the Ministry of Water Resources of the Government of India to govern the planning and development of water resources and their optimum utilization. The first National Water Policy was adopted in September 1987. It was reviewed and updated in 2002 and once again in 2012. **Major programs:** - Accelerated Urban Supply Program - increased coverage of water services in urban areas - Accelerated Irrigations Benefit Program – dams and canals - Jawaharlal Nehru National Urban Renewal Mission – financial support for development of urban infrastructure in 63 cities - Urban Infrastructure Development Scheme for Small and Medium Towns - for towns not covered under JNNURM - Project Implementation Agencies – access to finance from private players and capital markets - Pooled Finance Development Schemes financial and know-how support to Urban Local bodies for preparation of projects

[109] Osec 2010

4.3
SWOT analysis from an EU company perspective

There are various opportunities in the Indian water and wastewater treatment market for membrane technology providers, but the industry must overcome several challenges as well. **The following table shows a SWOT analysis of the Indian membrane-based water filtration market from the perspective of European technology providers:**

Tab. 7: SWOT-Analysis of water filtration market [110]

Strengths	Weaknesses
- Dynamic market with high growth levels of 14 percent in the period 2014-19 (growth is expected to further scale up within the next three years with increasing demand for water) - Lower competition compared to EU markets - Technological innovation and affordability of the systems are expected to drive more demand	- Lack of awareness of end consumers about European technologies - Uncertainty of partnerships - Local technological know-how for operation, maintenance and installation missing - Price sensitivity of the market might discourage EU companies with focus on product quality - Intransparent public tenders - Membrane systems are cost intensive
Opportunities	**Threats**
- High growth of middle class, its purchasing power and economic growth - Length of the Indian coastline - Strong market hotspot with dynamic growth rates - High demand for high-end treatment - Growing opportunities for membrane systems in desalination plants and industry applications (especially growing pharmaceutical segment with CAGR of 15.6 percent)	- Insecurity in long-term governmental regulations - Slow pace of implementation of policy reforms - High administrative burden - High competition in large scale desalination plants and waste water treatment plants through big players (dominated by the leading global membrane manufacturers) - The water and wastewater treatment market is highly fragmented and disorganized

4.4
Strategic recommendations for validation and commercialization of the EU technology in India

Water scarcity, tightening regulations in India and the current gap between the state of the art of the technology in European and Indian markets are creating enormous growth opportunities for EU companies to enter the Indian market and offer their technologies and equipment for the water and wastewater sector. The specifics of the Indian market

[110] Expert interviews 2015

dynamics and competition landscape suggests that rapid market access and project implementation cycles are critical in order to successfully gain a market share and establish a strong competitive position on the global scale. Nevertheless, expanding business activities in India means facing different market conditions, business practices and culture. In order to succeed on the Indian market, companies should take these challenges into consideration, conduct a market analysis of the country and specific region, and gather comprehensive information from companies with similar experiences.

As the SWOT analysis above shows one of the main challenging factors on the Indian market is the price sensitivity of local customers, which can discourage EU companies - usually focused on product quality and high-tech features - from market entry. Furthermore, the EU technologies are mostly developed, produced and exported from Europe to foreign markets, which increases prices even more and limits their competitiveness in India. Indian customers often opt for cheaper product alternatives because they lack long-term experience with the high quality and longer durability of European products in comparison to cheaper alternatives. According to Mr. Rolletschek, CEO of the company SolarSpring, an important factor that enables EU SMEs to succeed on the Indian market is the development of new business models or adaption of current business models to different conditions in India, specific regions (e.g. rural or urban regions) and individual customer needs. In addition, companies have to develop suitable marketing and sales strategies for the Indian market in order to increase customer acceptance of their higher quality products despite higher prices. This includes building and strengthening reliable customer relationships, company reputation and upholding this reputation and quality standards in the future.[111]

Besides the adaption of a business model, in most cases it is necessary to adapt the technology according the Indian market specifications and the particular customer needs.[112] The EU technologies usually have to be downsized, fitted to the specific market and end user requirements and be built more economically than for the European market.

The main end users in India's water market are the municipal authorities, the public health departments, the major industries connected with the water sector (cement, chemicals, fertilizers, food & beverage, paper, pharmaceuticals, power, refineries, sugar, tanneries and textiles) and commercial entities including hospitals, hotels and housing developments.[113] Since multinational companies (MNCs) are mostly active in large projects for large municipalities and industries, the potential for innovative EU Cleantech technologies can be seen in small scale projects for municipalities with poor access to the fresh water (e.g. in rural and less developed peripheral regions), for commercial end users such as hotels or smaller industry end-users (which have weaker water regulations than public actors).[114]

Moreover, European companies entering the Indian market must deal with several legal challenges, in particular a complex customs and tax system with many exemptions.[115] These administrative barriers and government inefficiencies often discourage foreign investors. Therefore, to establish a business in India is associated with more obstacles than in Europe. A competent local partner can provide support with understanding these bureaucratic processes. To cooperate with Indian firms as a joint venture or Indian sales partners can be one possible option.[116]

[111] Expert Interview SolarSpring 2015
[112] Expert Interview SolarSpring 2015
[113] Avalon Global Research 2011
[114] Expert interview Solar Spring 2015
[115] Startupoverseas
[116] Avalon Global Research 2011

One further challenge hindering EU SMEs from entering the Indian market is the missing technological know-how for operating, maintaining and installing of water applications. In comparison to MNCs, SMEs possess limited personal and financial resources to carry out these activities by themselves. One option in this scenario would be the cooperation and training of competent local partners which can also be difficult for the EU SMEs.

When seeking to overcome the market specific challenges, find competent partners and gain important market insights, international institutions with a mandate to support EU SME wishing to internationalize towards India can be very supportive. One of these institutions is the European Business and Technology Center (EBTC)[117] which offers incubator services, an IPR helpdesk, funding advice, market validation trips and much more. Additionally such institutions have a network of European partners that effectively enable companies to already make their decisions in Europe which results in lower costs and minimizes the risks of market entry.

Despite several obstacles, India is the fastest expanding economy in the world, with keen interest in new innovative solutions, particularly for water and wastewater treatment. However many of the recently used solutions are associated with high energy and maintenance costs. Currently, energy-efficient and environmental friendly processes are increasingly required and technologies such as ultrafiltration, forward osmosis, hybrid desalination, solar desalination and membrane distillation will grow increasingly important in the future.[118] Therefore, companies providing Cleantech energy-efficient adaptive solutions with easier maintenance and at competitive costs are likely to play a central role in Indian water and wastewater treatment market.[119]

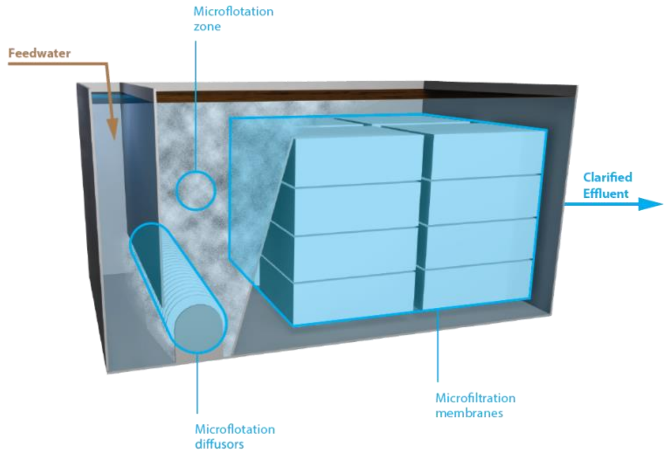
[117] http://ebtc.eu/
[118] Chemtech Foundation 2012
[119] Chemtech Foundation 2012

5
Case Study

5.1
Company profile & technology

Akvola Technologies is a Berlin-based, company offering innovative water treatment process design and plant construction. The company's main offerings are solutions for seawater desalination pretreatment and for produced water treatment (oil-water separation) in the oil and gas industry. Both are based on in-house developed akvoFloat technology.

Fig. 7: akvoFloat technology



Source: akvola Technologies 2014

The flotation-filtration system developed by the company is innovative mainly in the way it lowers energy consumption and footprint. The system consists of two stages, which are integrated into the same tank. There is first a flotation zone, where the suspended matter is carried to the surface. This matter builds a floating sludge layer on the surface which is continuously removed from the tank. Under the floating layer there are submerged ceramic membranes. These membranes are superior to polymeric membranes as they provide higher flux rates without the need for frequent cleanings and have some further advantages such as mechanical and chemical stability.

5.2 Internationalization strategy & Indian market

Several features of akvola Technologies' products are suitable for the Indian market and the company is considering an international expansion in the near future into India as well as other countries in the Middle East, US and Europe (North Sea). Nevertheless, most of the considered markets are suitable only for one of the two current company's main products. Markets for oil-water separation in the USA and Europe (North Sea) do not offer many opportunities for seawater desalination pretreatment. On the other hand

Middle Eastern countries which have a 70 percent share of the world's desalination plants have expressed interest in the desalination branch of akvola Technologies´ core business, but not in oil-water separation. Thus akvola Technologies is forced to differentiate the markets for its business branches. As an additional measure, the company is considering widening its product portfolio towards further applications in industrial wastewater treatment.

The patent application for its products in India could be interpreted as a first sign of akvola Technologies' interest in the Indian market. Several internal considerations have already been discussed regarding how to enter the market based initially on the type and size of the applications.

For seawater desalination, akvola Technologies' akvoPre systems have a capacity of up to 800 m3/day, which is a small-scale application.[120] As 70 percent of facilities worldwide are small-scale applications under 1000 m3/day, the company can reach a great number of customers. In the next step, it is crucial to locate the regions with water scarcity and understand their priorities – e.g. approximately 95 percent of water supply in Qatar is produced by desalination of seawater. Unlike countries in the Middle East, India has progressed only through relatively smaller, decentralized desalination capacities. One could expect to set up large capacities to tap sea water on India's 7500 km coastline in the near future. This brings us to another crucial step for any expansion plans - clear definition of end users for its technology. Large-scale projects are not the priority for akvola Technologies, since they are targeting small-scale applications.

Regarding the market entry strategy, one of the key objectives of the company is the adaption of the business model on the target market. Construction of facilities for desalination or water treatment is highly dependent on the kind of business model the company operates. There are several scenarios based on the value chain "finance, design, build and operate". For SMEs it´s unusual to execute all parts of the value chain. Thus, the particular stages of the value chain can be taken over by different market players such as the company itself, an O&M company (specialized on operation & maintenance), the end-user or an investor. Against this background, several business models are conceivable, e.g. the plant is designed and built by the technology provider, operated by an O&M and financed by an end-user or the company builds and rents a plant to an O&M or an end-user. These and several other options depend mostly on the size, financial possibilities and risk-taking willingness of the company.

5.3 Challenges & opportunities

The first and most important challenge for akvola Technologies is a lack of knowledge regarding the Indian market. The level of knowledge the company currently has is not sufficient to develop any long-term plans. Nevertheless, the company could identify some of the market's possible challenges. First, they are facing competition from global leaders as GE, Veolia or Suez Environment. Traditionally, such "big players" participated mainly on large projects but this has recently changed as the General Electric water department now also offers solutions for small-scale projects. Another problem might arise from legal barriers, for instance when public authorities require certifications or permissions for the processing of water. akvola Technologies intends to work for industrial or commercial customers as this would minimize the requirements of such certifications.

[120] The large-scale applications have capacity of 20.000 up to 200.000 m^3/day.

Several further issues are linked to the practical challenges of opening a business abroad: intercultural communication, building a new supply chain, finding potential sales partners and finally, the financing difficulties. In comparison to global companies, SMEs are limited by their financial and personnel resources. Nevertheless, there are several possibilities for SMEs to build and eventually operate a plant. First, they can develop a strong and reliable partnership in which the partner would be willing to take over the initial investments or undertake the maintenance of an application. Another pattern seen in the US oil industry is where fracking companies do not own technology for oil-water separation but simply employ filtration services from an external company. Such a functioning model, which reduces the financial burden for smaller companies, could allow for a faster foreign market expansion.

The most suitable starting point for akvola Technologies would be to develop a simple strategy that might be successful also for the Indian market. The company would not outsource production abroad but rather sell "plug and play" solutions first. These solutions should be highly standardized with minimal technology adjustment requirements. Although it is not possible to sell fully standardized solutions in this business, there is a good chance to develop pre-engineered systems suitable for a single market. Such a strategy requires collaboration with local partners (e.g. system integrators) for the sales abroad.

There are several suitable business models for European SMEs that can be applied for foreign markets. The challenge lies in identifying and developing the right one in accordance to company's products and target markets.

Considering the opportunities, akvola Technologies and their akvoFloat technology filtration units based on microflotation and ceramic membrane filtration offer several benefits. Ceramic membranes possess mechanical and chemical stability, which helps to eliminate fouling of the membranes more efficiently and [longer lifespan]. These membranes also provide higher flux with low pressures. This leads to lower energy consumption during the filtration process and thereby contributes substantially to energy-savings of the whole application. The technology used for seawater desalination is capable of saving up to 90 percent of energy consumption in the pre-treatment desalination phase, which can lead to a 20 percent energy savings in the whole application.

Another advantage the company brings to the market is the reliability and innovative characteristics of its products. The flotation-based technology surpasses in many ways the conventional sand-filters and means a notable comparative advantage because many customers demand solutions based on new technologies. Such a demand is still limited however by the costs they are willing to expend on innovative solutions. Compared to other innovative competitive products, the technology from akvola Technologies has lower operating costs despite relatively equal capital investments.

Finally, in emerging countries the regulations for water treatment, and in particular for wastewater effluent disposal are tightening, but the technical know-how for water processing is low. Innovative companies like akvola Technologies offer products which can fill niches in the market, overcome imperfections of existing products and help to comply with upcoming regulations. It is the superiority of the product performance and high development of their technology, which makes akvola Technologies confident that they will find success on markets abroad.

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