


Patent Landscape Report on

Membrane Filtration and UV Water Treatment

A report on selected water treatment technologies and their application in desalination systems

MARCH 2012

PATENT LANDSCAPE REPORTS PROJECT

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The purpose of each report is three fold:

- It attempts to research and describe the patterns of patenting and innovation activity related to specific technologies in various domains such as health, food and agriculture, climate change related technologies, and others.
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Patent Landscape Report on Membrane Filtration and UV Water Treatment

A landscape report on selected water treatment technologies and their application in desalination systems prepared

for the
World Intellectual Property Organization (WIPO)

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1 Introduction[1]

1.1 Report objectives

Clean, potable water is a necessity in a wide range of residential, industrial and agricultural uses. This patent landscape report focuses on the production of clean water for municipal and rural uses. It aims to examine patterns of patenting activity and innovation in the area of water treatment. The landscape report focuses on a selection of water treatment technologies – UV disinfection and micro-, ultra- and nanofiltration.

The report is a follow-on from an earlier WIPO patent landscape focussing on desalination technologies and the use of alternative energies[2]. During that report the focus technologies were identified as potentially meriting further investigation both from the context of desalination and water treatment more broadly. In this report, both instances where these technologies were used to treat non-saline water, as well as instances where they form part of a desalination system were identified. The search covered both complete technology systems and components or details of systems if these components are specifically adapted to desalination.

Components which can potentially be used in water treatment for production of potable water may not be included if they were not specifically claim water treatment application. The report identifies patent families (including utility models) that claim inventions related to the water treatment technologies of interest and additionally identifies those which claim to supplement desalination in particular.

The report is intended to:

- assist WIPO and its stakeholders in assessing the relevant technologies that support the implementation of water treatment systems,
- facilitate technology transfer to developing countries in the water treatment technology area,
- provide best practice examples of patent landscaping techniques for users of technology analysis in developing countries.

It was commissioned on the basis of WIPO's Development Agenda project DA_19_30_31_01 ("Developing Tools for Access to Patent Information") described in document CDIP/4/6 adopted by *WIPO Committee on Development and Intellectual Property* (CDIP) at its fourth session held from November 16 to November 20, 2009. Patent landscape reports of the aforementioned DA project focus on particular technology fields and industrial application relevant to the Development Agenda. They highlight technologies, know-how, processes and methods that are necessary to meet the basic development needs of developing countries[3]. Unless expressly stated

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[2] WIPO Patent Landscape Report on *Desalination technologies and use of alternative energies for desalination,* 2011

[3] A full list of patent landscape reports under this WIPO initiative (both commissioned by WIPO and developed by third parties) can be found here: http://www.wipo.int/patentscope/en/programs/patent_landscapes/pl_existing_reports.html

otherwise, the findings, interpretations and conclusions expressed in the Report are those of the external contractors to WIPO who prepared the work, and do not necessarily represent the views of WIPO.

1.2 Water treatment and water technologies - the global context

1.2.1 Water treatment - beyond the Millennium Development Goals

In 2012 access to safe drinking water became the *very first* Millennium Development Goal to be met by the international community[4]. The original goal set in 2000 was to halve by 2015 the proportion of population without sustainable access to safe drinking water and basic sanitation[5]. This encouraging achievement should underscore the progress that can be made through the deployment of often simple and cheap technologies in low income economies. At the same time, it can be expected that the challenges related to water systems will continue to increase, requiring further investment and technological innovation to meet global needs.

Access to clean water is a basic human need and an important driver of social and economic development[6]. A predictable and consistent access to clean drinking water is universally seen as a core function of states, as it is crucial to a society's public health, economic vitality and national security[7]. Chronic water scarcity is already a reality in many countries, with the water systems of an increasing number of countries seen as vulnerable (see Figure 1). While basic access to potable water is the minimum requirement toward which low-income economies strive, much higher access is required to sustain growing incomes in many developing economies, growing food supplies and industry.

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[4] http://www.who.int/mediacentre/news/releases/2012/drinking_water_20120306/en/

[5] UN (2010) 'The Millennium Development Goals Report', pp.58-60

[6] UN-Water: United Nations Educational, Scientific and Cultural Organisation. *Water, a shared responsibility: the United Nations World Water Development Report 2.* World Water Assessment Programme, 2006.

[7] M.Elimelech and WA Phillip. "The Future of Seawater Desalination: Energy, Technology, and the Environment ." *Science 33 (* 2011): 712-717.

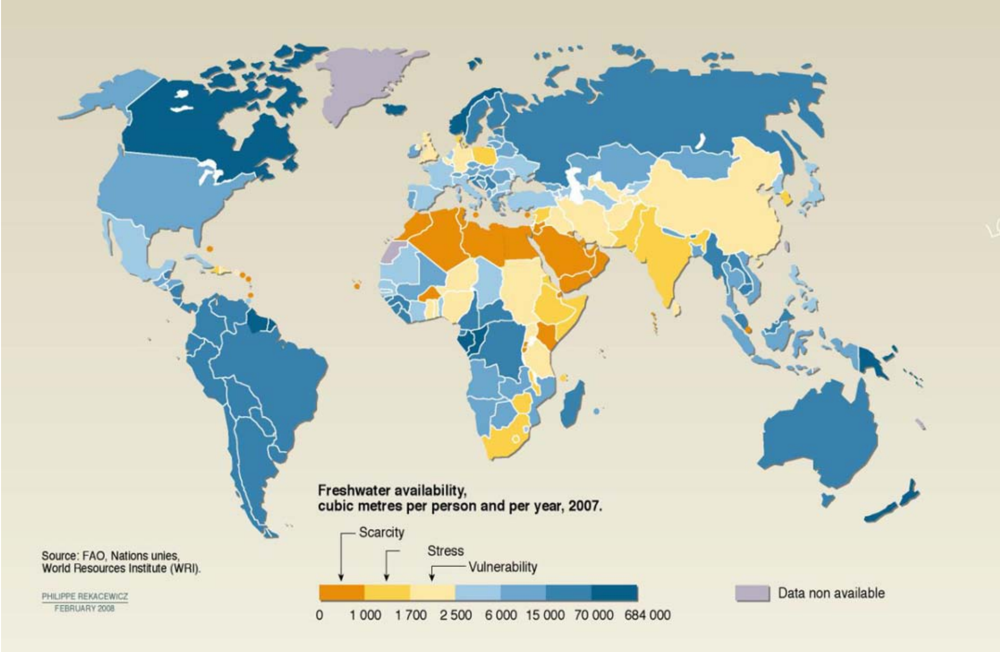

Figure 1: Global fresh water availability (UNEP 2008)

Even countries with overall secure water systems may face regional shortages. Access to clean water is particularly problematic in the least developed countries (LDCs), but is also an increasingly important issue in middle-income and developed economies due to rising consumption levels and continued urbanisation and industrialisation. In the coming decades it is anticipated that continued population growth, rising incomes in emerging economies and continued urbanisation and industrialisation, as well as climate change pressures will put further pressure on existing water treatment infrastructure and resources. These changes in the requirements on water systems will be translated into increased investments in water technology and infrastructure. Market research shows that the forecast 3% increase in annual demand for fresh water would convert into *annual* investment requirements of up to €400–500bln in water infrastructure in the very near future[8].

1.2.2 Different uses of water

Fresh water uses includes both potable water ready for consumption and water which is clean enough to be used for industrial and agricultural purposes, but which may not be suitable for consumption.

Insufficient water supply would therefore not only have an impact on the availability of drinking water, but also a potentially significant impact on global food and energy supplies as well as other economic consequences through its connection with industrial processes. Downstream water services such as clean water supply in municipal services, waste-water services and sanitation are dependent on sufficient upstream water supply[9].

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[8] E,Heymann. *Water: Investments of EUR 500 bn required - every year!* Frankfurt: Deutsche Bank Research, 2011.

[9] McKinsey & Company. “Charting Our Water Future: Economic frameworks to inform decision-making.” 2009

Water conservation, water reuse and improved catchment and distribution systems will play an important role, but ultimately offer a finite solution, and one that may be insufficient to secure adequate water supplies in many regions globally. As water demand continues to grow, and with it the scarcity of renewable natural water resources, we will need to find alternative water sources to *complement* better water management measures. The treatment of previously unusable water sources is likely to become a key component of the solution to long-term water supply shortages[10].

One way of improving water availability is by improving water quality of existing freshwater sources, both through desalination and other treatment methods. However, the deployment of these systems is costly, requiring high upfront capital expenditure and operating costs through the system's lifetime. In addition, traditional systems are very energy intensive, leading to high deployment and operational costs.

Some of the areas where improving and increasing water treatment can have the biggest impact are also the areas with least resources for the deployment of such technologies. At the same time, given that existing infrastructure is either inadequate or non-existent, these economies have the opportunity to invest in new water infrastructure, gaining access to the latest generation of water treatment technologies.

1.2.3 Water treatment technologies overview

Inventions in water treatment methods hold the promise of reducing the investment and running costs for improved water systems. Patent-based analyses can identify the emerging technologies, players and value chains associated with next generation water treatment technologies which, if deployed at mass scale, can rapidly improve experience globally, lead to further innovation and take the technologies down the cost curve.

Figure 1 illustrates water treatment technologies for both physical and chemical water treatment processes; it indicates the vast number of technology types used in water treatment.

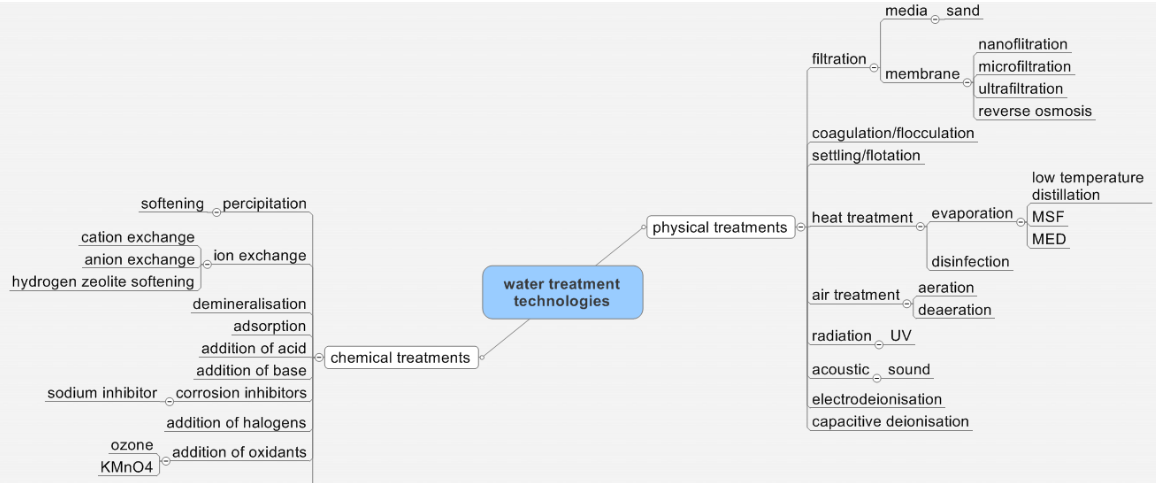

Figure 2: Chemical and physical water treatment processes and example technologies.

[10] M.Elimelech and WA Phillip. "The Future of Seawater Desalination: Energy, Technology, and the Environment ." *Science 33 (* 2011): 712-717.

Technology focus area choices: A wide range of water treatment technologies exist. A report of the whole water treatment technology field was deemed unpractical for a patent landscape report that has some depth in analysis. The patent landscape was focused on UV and membrane-based water treatment as examples of innovative and high-impact fields of water treatment technology. The key reasons for selecting these fields include:

- rapid pace of innovation
- associated high rate of patenting
- its relevance as supplementary technology in desalination technologies
- potential impact on decentralisation of water systems
- market activity and perceived importance by industry experts
- complementarity between membrane- and UV-based water treatment

The technology choices should not be taken to imply that other technologies are any less important for the water treatment system, or that there is no scope for innovation in these. We recommend that the patent landscaping approach showcased here be extended to other water treatment technologies.

Technology system boundaries: The scope of the search does not extend to specialised applications such as the production of ultra pure water for the medical industry, or partly desalinated water for cooling of power plants, even though some of the technologies and patents covered may indeed be used in such applications. It also does not focus on waste-water treatment or water reuse, although when such technologies were found and related to desalination technology systems, they were included.

Patent analysis boundaries: Since the report aims to provide an overview of patenting activity in the general technology field (membrane and UV water treatment), it has not focused on aspects of validity of patent protection or Freedom to Operate. It was not investigated, for instance, whether a patent that has been granted for a particular patent application has entered into force or is still valid, or what the exact scope of protection is. Claims were only used as general guidance as to the type of subject matter was claimed as the invention. Such questions can only be examined in the context of a specific industrial application question, whether relating to the acquisition or licensing of a technology, building a business case for technology commercialisation, or supporting R&D strategy development. For more information on the uses of patent-based business intelligence, please refer to Appendix 1.

1.2.4 Water Treatment and Desalination

The report also investigates instances where these water treatment systems supplement desalination processes. While desalination technologies have been in use for many years, its mass deployment has a number of challenges including upfront capital expenditure, high operational costs and environmental impact. Not surprisingly, the bulk of installed desalination capacity globally has been in high-income economies and high-water shortage economies with high-incomes such as the Middle East. Yet many of the areas at increasing risk of water scarcity are in low-income economies, or economies with higher usage requirements than what we have seen thus far.

It is widely accepted that technology will play an important role in making desalination a feasible solution to water scarcity more widely, including in low-income economies. In an earlier WIPO-commissioned patent landscape report on desalination technologies it was shown how technology improvements and integration with renewable energy sources are reducing the deployment and exploitation costs of desalination systems, as well as their environmental impact[11]. For instance, technology improvements around modularity can decrease the capital expenditure required, as operators can add capacity as needed and off-grid deployments in rural areas (and small island locations) become more economically feasible. Improved control systems and technology design can improve efficiency and maintenance requirements. In the case of island and remote off-grid locations integration with renewable energy can decrease logistical and fuel costs, by for instance decreasing the need for diesel-based power generation. In short, innovation in this field can improve the investment profile of such projects, making it easier to finance and deploy.

Water treatment technologies can be an important enabler for desalination technology implementation. Much of the water pre-treatment technologies used in desalination have been developed outside of the desalination technology field. At the same time there may be desalination-specific challenges which may have given rise to more specific patents in the field. Knowledge of the patent landscape in this area can assist with accelerated technology deployment.

1.3 Background on patent landscapes

Patents registered around the world together represent a global technology library that contains information on:

- technology concepts,
- the implementation of those concepts,
- details of who created and owns them.

Patents are a useful indicator of commercially valuable inventions. Usually, individuals and companies are only prepared to invest in securing patents where they believe there is commercial advantage in doing so. This information can be used to:

- promote innovation,
- enable access to technical information,
- foster other activities that support development.

Patents are therefore an important source of structured and highly accurate information about technology, innovative activity, inventors and technology organisations globally. Aggregating patents around an industry or a specific technology can reveal important trends and comparisons about the origins of a technology, how a technology area is evolving and the changing composition of industry players, as well as identifying the most important (commercially or scientifically) patent documents in a field. Information based on the analysis of patent data can be a highly reliable information source to support and accelerate decision-making in both the public and private sector.

Patent landscape reports integrate expert-led patent database searches, patent dataset analysis and market information. They can provide a more accessible reference framework for technology, policy and business insights in a particular field. For instance a patent landscape can be used to:

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[11] T.Mezhe, H,Fath, Z.Abbas, and A. Khaled. "Techno-economic assessment and environmental impacts of desalination technologies." *Desalination* 266 (2011): 263-273.

- support the development of a company’s IP strategy (including freedom to operate, white space and patentability analysis),
- understand the competitive landscape in R&D-intensive fields,
- identify emerging technologies and technology trends within an industry,
- support improved targeting of innovation and industrial policies, and evaluation of their impact,
- identify networks of inventors and knowledge flows within industries and between countries.

2 Water treatment: existing technologies and future outlook

No two technology systems are entirely alike. Therefore, patent landscaping exercises need to take into account technology/application specific factors and the project objectives when technology grouping is done.

Figure 3 illustrates key elements in the water treatment technology value chain. There are different players in the water treatment value chain who are in the position to implement new water treatment technologies as well as integrate these technologies to improve the quality of water, reduce both the impact on the environment and the cost of the water.

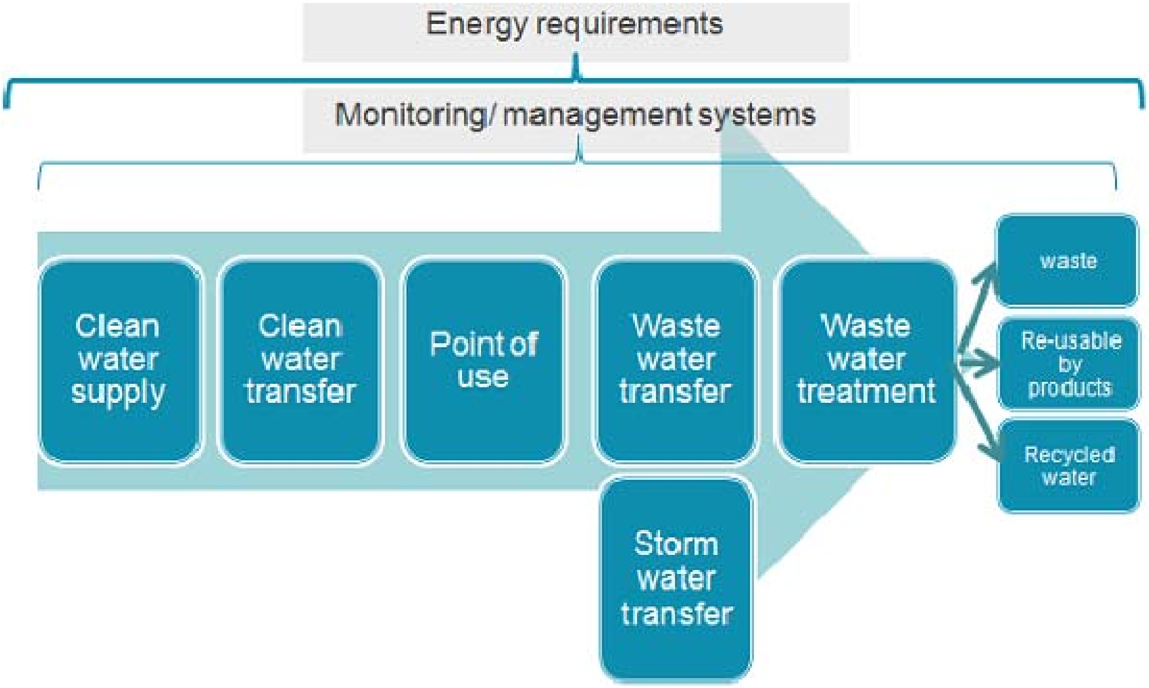

Figure 3: Water treatment value chain

When deciding on the most relevant water treatment technology for a particular system, it is important to match the types of feedwater with the appropriate water treatment technology dealing with its specific challenges in order to produce a suitable water output.

2.1 Water treatment technologies

Water can dissolve a very wide range of substances, either partially or completely. Although this is a useful quality in many instances, it also means that water typically needs to be treated in order to be suitable for domestic or agricultural use, or alternatively to render waste water safe enough to allow it to be released back into the environment.

2.1.1 Problems addressed by water treatment technologies

The main problems caused by untreated feedwater are:

- deposits
- scaling

- corrosion
- embrittlement
- health effects
- smell

As shown in Table 1, constituents in the feedwater which cause these problems can be divided into three categories' suspended solids; dissolved solids; and micro organisms. We provide here a basic overview of the challenges, but a more in depth description is provided in Appendix 2.

Table 1: Problems associated with untreated feedwater and their causes

	Deposits	Scaling	Corrosion	Embrittlement	Health Concerns	Smell
Suspended Solids	✓					✓
Dissolved Solids	✓	✓	✓	✓	✓	✓
Micro organisms	✓				✓	✓

Suspended solids do not only cause water to have an unsightly appearance. It can also cause deposits to form in waterlines and the suspended solids interfere with most of the other water treatment processes.

Dissolved solids can cause health concerns (such as excessive fluoride content in the water), and pose serious risks to the water treatment and transfer systems caused by deposition and corrosive actions (such as hardness and pH). Hardness of the feedwater can cause scaling in the system - closely related to the water alkalinity. Alkalinity as well as free mineral acids and carbon dioxide, can have corrosive effects on different parts of the system. A variety of other chemicals dissolved in the feedwater can also cause scaling, corrosion and other deposits in the system. These chemicals include sulphate, chloride, nitrate, sodium, silica, iron, manganese, aluminium, oxygen, hydrogen sulphide and ammonia. These issues can be addressed by a number of physical and chemical treatment processes.

Micro organisms such as bacteria, viruses and protozoa present in the water can cause health problems. These can be removed by disinfection processes such as chlorination, UV irradiation or heat treatment.

Whether the feedwater is surface- or ground water also impacts the types of treatment processes that should be applied and the sequence in which they should be carried out (see Figure 4)

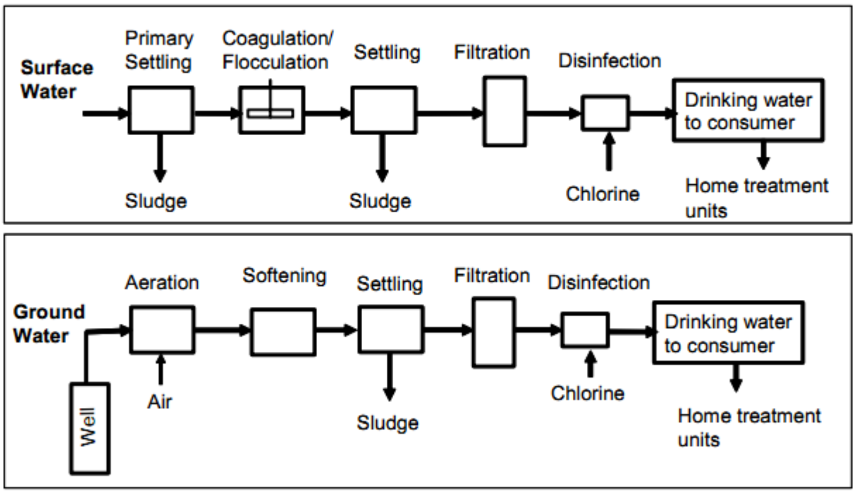

Figure 4: Typical processes for water treatment for surface and ground water sources[12]

2.1.2 Application of water treatment technologies

Table 2 lists the various water treatment technologies and how they address the three challenges associated with feedwater. It also shows how these treatment methods can be separated into chemical and physical processes.

Table 2: Chemical and physical processes used in water treatment

Technologies		Suspended Solids	Dissolved Solids	Disinfection
Physical Treatment	Coagulation	✓	✓	
	Settling/Flotation	✓		
	Filtration (Media or membrane)	✓	✓	✓
	Electrodialysis		✓	
	Heat Treatment		✓	✓
	Aeration/ deaeration		✓	
	Radiation (UV)			✓
	Acoustic			✓
Chemical Treatment	Precipitation		✓	
	Ion exchange		✓	
	Demineralization		✓	
	Adsorption		✓	
	Addition of acid		✓	✓
	Addition of Alkaline		✓	✓
	Corrosion inhibitors		✓	
	Chlorination		✓	✓
	Halogens			✓
	Metals			✓

[12] B.Tansel. “New Technologies for Water and Wastewater Treatment: A Survey of Recent Patents.” Recent Patents on Chemical Engineering (2008): 17 – 26

	Oxidants			✓

The overall patent landscape of water treatment technologies is too large to be considered in its entirety within the constraints of this project. We have chosen to investigate in-depth two methods of physical water treatment which, when used in combination, can address all 3 classes of water treatment problems:

- Membrane filtration (to remove suspended and dissolved solids) and,
- UV treatment (for disinfection of water).

Membrane filtration

Membrane filtration can be used to remove both suspended and dissolved solids. The primary focus of the report is on micro-, ultra-, and nano- filtration processes. Reverse osmosis is also a type of membrane filtration, but will not be explicitly included in our search as it is mainly a desalination technology and has already been covered in WIPO's previous report on desalination technologies and the use of alternative energies[13]. The current report will not focus on media filtration processes (such as sand filtration).

Overall the membrane filtration field is relatively mature with the involvement of both large multinationals and smaller more focussed players. Certain companies develop membrane filtration technologies which can be used in a range of application areas.

Certain membrane processes can be used as pre-treatment of feed water before the desalination process. The main membrane separation techniques for pre-processing feedwater for desalination plants are:

- Microfiltration,
- Ultrafiltration,
- Nanofiltration.

The main difference between these techniques is the size of the membrane pores and therefore the sizes of the suspended/dissolved molecules they allow to pass through. This is summarised in Figure 5.

[13] WIPO Patent Landscape Report on *Desalination technologies and use of alternative energies for desalination,* 2011

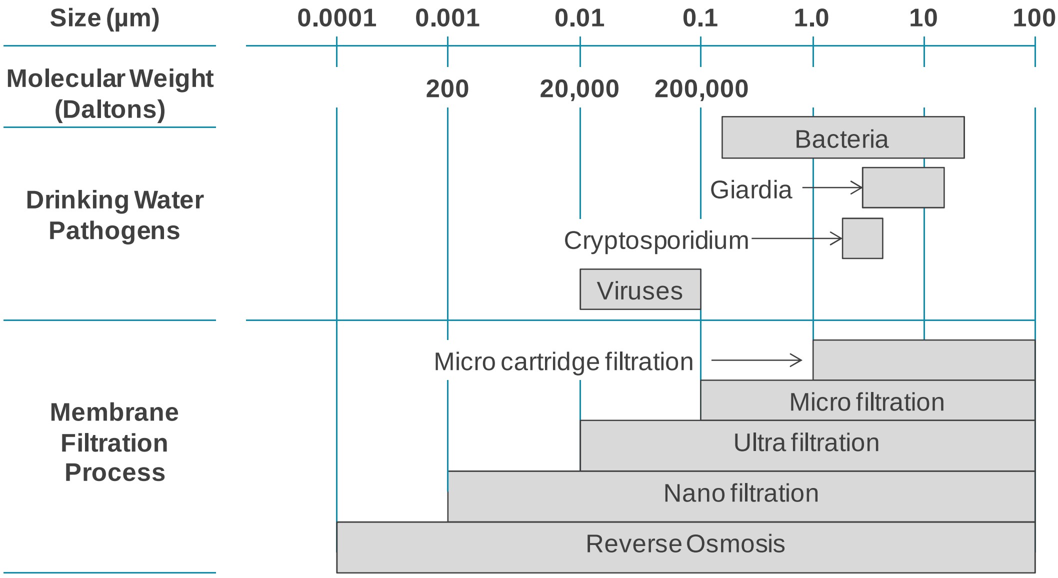

Figure 5: Comparison of different membrane filtration technologies[14]

Microfiltration

Microfiltration (MF) is sometimes used to reduce the turbidity of feed water and remove suspended solids and bacteria. MF membranes generally have pore sizes between 0.1 to 0.2 microns (µm).

Ultrafiltration

Ultrafiltration (UF) uses hydrostatic pressure to force liquid against a semi-permeable membrane. The membrane pores are slightly smaller than in a microfiltration membrane and it can therefore be used for the removal of suspended solids; high weight dissolved organic compounds, bacteria and some viruses. UF membranes generally have pore sizes between 0.01 to 0.05 microns (µm).

These technologies are particularly useful in areas such as the Gulf, with where the feedwater is of high temperature and comes from shallow water with little water movement close to the desalination location.

Nanofiltration

Probably the most commonly used pre-treatment membrane process for reverse osmosis desalination is nanofiltration (NF). It is used in water softening and removing dissolved contaminants, sulphates, organics and viruses. The water softening in particular helps protect the RO membranes from scaling and improve their lifetime. Nanofiltration membranes generally have molecular weight cut-off (MWCO) in the range of 200 to 1000 Daltons. MWCO is a measure of a membrane's removal specifications in terms of atomic weight or mass as compared to the membrane's pore sizes.

UV disinfection

Also known as ultraviolet germicidal irradiation (UVGI), UV disinfection uses short wavelength (100-280nm) UV radiation to destroy the nucleic acids in the organisms, disrupting their DNA which removing their reproductive capability.

[14] US EPA. "Membrane Filtration Guidance Manual." Office of Water (2005)

UV disinfection uses UV radiation to disinfect the feedwater either before or after suspended or dissolved solids have been removed.

UV water treatment units contain either a specialised low pressure mercury vapour lamp to produce high energy UV radiation, or a medium pressure UV lamp which produces a polychromatic output. Low pressure lamps are around 40% efficient, while medium pressure lamps operate at around 12% efficiency. The UV lamp is not in direct contact with the water, but usually housed in a quartz glass sleeve inside a chamber where the water flows through. An example of UV water treatment technology is shown in Figure 6.

Already a number of major corporations are investing in these technology systems integrating membrane filtration and UV technologies to provide user devices for clean water. There are also smaller companies focussed mainly on UV water treatment.

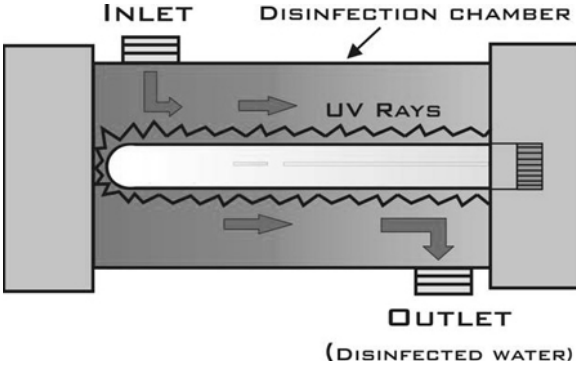

Figure 6: Example schematic of a UV water treatment system[15]

2.2 Supplementary water treatment for desalination systems

Desalination systems aimed at producing potable water do not only decrease or eliminate the saline content of the feedwater. There are usually a number of other suspended and dissolved solids as well as microorganisms which need to be removed in order to make the water safe for consumption. Other treatment process the water prior to desalination in order to remove substances which can damage the desalination system. Various processes and chemicals are used for the pre- and post-treatment of water, of which the actual desalination process is only a part. The selection of these processes depends on the type of desalination technology used as well as the quality and composition of the feedwater.

Given the focus of this report on water treatment, we identify improvements in pre- and post-treatment of water around desalination processes. Inappropriate quality of water feed into the desalination process may reduce the efficiency of the system, or even damage the expensive equipment, such as in installations applying reverse osmosis (RO). Improved water quality can reduce the operational costs. Moreover, well designed pre-treatment processes can enable the uses of similar types of technologies across different contexts - helping desalination technology developers capture economies of scale.

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[15] Agriculture and Agri-Food Canada: Water Treatment. Ultraviolet Disinfection of Private Water Supplies for Household or Agricultural Uses. 18 January 2012. http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1241475412160&lang=eng

The two main types of desalination techniques (reverse osmosis and thermal) are slightly different and discussed further below. Typically reverse osmosis installations have more associated challenges due to the nature of the membranes.

2.2.1 Feedwater for desalination

The feedwater for desalination can contain suspended and dissolved solids, which need to be removed in order to produce potable water. These may require different types of water treatment equipment prior to the desalination process. The specific equipment may vary by feed water type, and even by region. Depending on their location desalination plants use two types of feed water: seawater (typically TDS[16] of 30,000–50,000 ppm) and brackish water (typically TDS of 500–30,000 ppm).

Seawater varies significantly in salinity levels between regions. Land influence means that the composition of the water close to the shore can be very different from the composition of water taken from the open sea. For instance, due to the high level of river run-off into the Baltic Sea and its closed geography, salinity levels on the surface may be as low as 6,000-8,000 ppm (essentially brackish water). By contrast, salinity in the Red Sea can reach 45,000 ppm.

Brackish water is found in estuaries, lakes, and marshes. Its composition can vary greatly depending on location, given the impact of soils and other rocks and sediments, with higher salinity brackish water found in areas with high sea water mixing, such as estuaries and mangrove swamps.

2.2.2 Challenges associated with desalination systems

Problems associated with reverse osmosis desalination

Modern reverse osmosis installations use sophisticated and expensive membranes which are highly sensitive to the feed water quality. Insufficiently pre-treated water can lead to bio-fouling, scaling, membrane plugging and system overload. Such problems may necessitate more frequent cleaning and changes of membranes and other equipment at a high capital cost. Hence for the preservation and effective functioning of RO installations a sufficient pre-treatment of the feed water is required.

Problems associated with thermal desalination

Thermal desalination plants are more robust that RO installations, and have few problems associated with them. They operate at high temperatures, are mainly troubled by depositions and corrosive effects in the system. The type of pre-treatment needed will depend on the source and composition of the feed water, its temperature, and on the type of desalination technology used.

2.2.3 Supplementary water treatment methods for desalination systems

Various processes and chemicals are used during the pre- and post-treatment of water during the desalination process. Certain membrane processes can be used as pre-treatment of feed water before the desalination process. Microfiltration (MF) is sometimes used to reduce the turbidity of feed water and remove suspended solids and

[16] Total dissolved solids (TDS) refers to the total amount of mobile charged ions, including minerals, salts or metals, dissolved in a given volume of water as parts per million (ppm), or mg per unit volume of water (mg/litre).

bacteria. Additionally ultrafiltration (UF), where the membrane pores are slightly smaller that microfiltration, can be used in the removal of high weight dissolved organic compounds, bacteria and some viruses. One of the most commonly used pre-treatment membrane processes reverse osmosis desalination is nanofiltration (NF).It is used for water softening and removing sulphates, organics and viruses. The water softening in particular helps to protect the reverse osmosis membranes from scaling and helps improve their lifetime. In addition to processes, chemicals typically used in pre-treatment include NaOCl, $FeCl_3$/$AlCl_3$, H_2SO_4/HCl/$NaHSO_3$ and scale inhibitors[17].

[17] T.Mezhe, H,Fath, Z.Abbas, and A. Khaled. “Techno-economic assessment and environmental impacts of desalination technologies.” *Desalination* 266 (2011): 263-273.

3 Research Methodology

3.1 Patent landscape dataset creation methodology

Below is a description of the key steps undertaken to create the patent datasets underpinning this patent landscape. The purpose of the report is to disseminate information to both experts and non-experts alike.[18]

3.1.1 Defining the focus of the patent search

The first and perhaps most critical step in the development of a patent landscape is the development of a clearly defined and sufficiently focused area of technologies to be investigated.

This patent landscape report focuses on a selection of water treatment technologies - namely UV disinfection and micro-, ultra- and nanofiltration. The investigation focuses on instances where these technologies are used on their own, but also in particular where they form part of desalination systems. The scope of the search does not extend to specialised applications such as the production of ultra pure water for the medical industry, or partly desalinated water for cooling of power plants, even though some of the technologies and patents covered may indeed be used in such applications. It is also not focusing on waste-water treatment or water reuse, although when such technologies were found and related to desalination technology systems, they were included.

3.1.2 Patent search strategy

Using interviews with industry experts, desktop research, and the report authors' knowledge base around water treatment technology, a technology matrix of the different technology subsystems, or subsectors in the technology field was built. This information was used to develop a patent search strategy. The patent search strategy followed in this report uses a combination of keyword based searches and patent classification codes.

The patent searches were conducted in December 2011. Searches were performed on title, abstract and claims across all available patent databases, using a combination of our in-house patent search database Boliven.com, and publicly available patent database services such as Espacenet[19].

The methodology followed does not rely only on classification codes. As illustrated in Figure 7, a multi-pronged search strategy based on different techniques was developed using IPC codes and keywords, in order to minimise the risk of false negatives, described in more detail below.

[18] The authors of the report are happy to provide further information on this report, or to benchmark our processes to those of other organisations.

[19] See Appendix 3 for detailed patent coverage information.

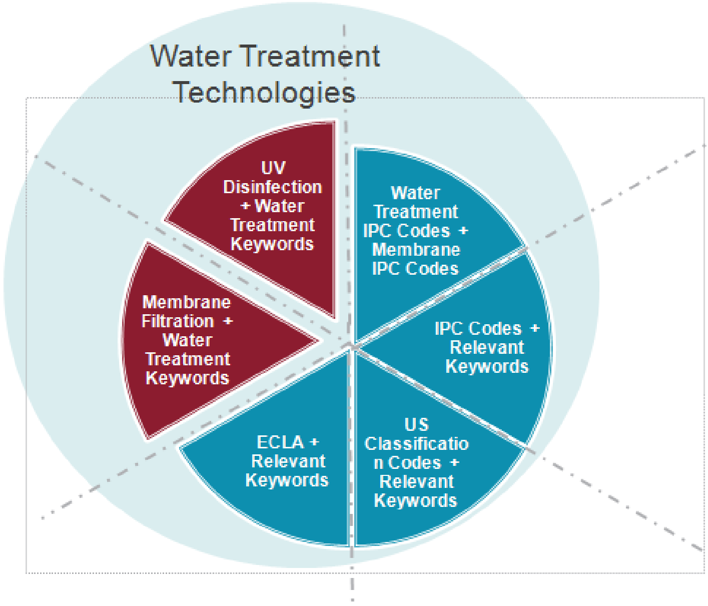

Figure 7: Patent search strategy for water treatment

Table 3 shows the evolution of the dataset as various search string categories were added.

Table 3: Example evolution of a dataset - Membranes and UV

Data search	Nr of patents	Nr of additional patents
UV-based water treatment		
Keywords and IPC codes (UV)	4,754	4,754
Keywords and US classification (UV)	425	140
Keywords and ECLA codes (UV)	1,248	131
Keywords only	5,532	2,585
Total UV water treatment	**7,610**	
Membrane-based water treatment		
IPC codes only (membrane water treatment)	18,789	18,789
Keywords and IPC codes (membrane)	6,996	2,547
Keywords and US classification (membrane)	240	121
Keywords and ECLA codes (membrane)	6,422	3,554
Keywords only (membrane)	2,333	1,026
Total membrane water treatment	**26,037**	

Keyword-based Searches

A list of keywords was developed for technology categories as well as general technology systems (Figure 8)[20]. We used this to develop keyword-based search strings to create a wide patent dataset. Most of these categories and combinations generated not only relevant patents, but also patents outside the technology focus areas. One of the key issues is that many of the relevant technologies have been developed *outside* of

[20] Full algorithm descriptions available in Appendix 3

the water treatment field. For this type of landscaping exercise it is therefore useful to supplement classification based searches with at least one keyword only search string.

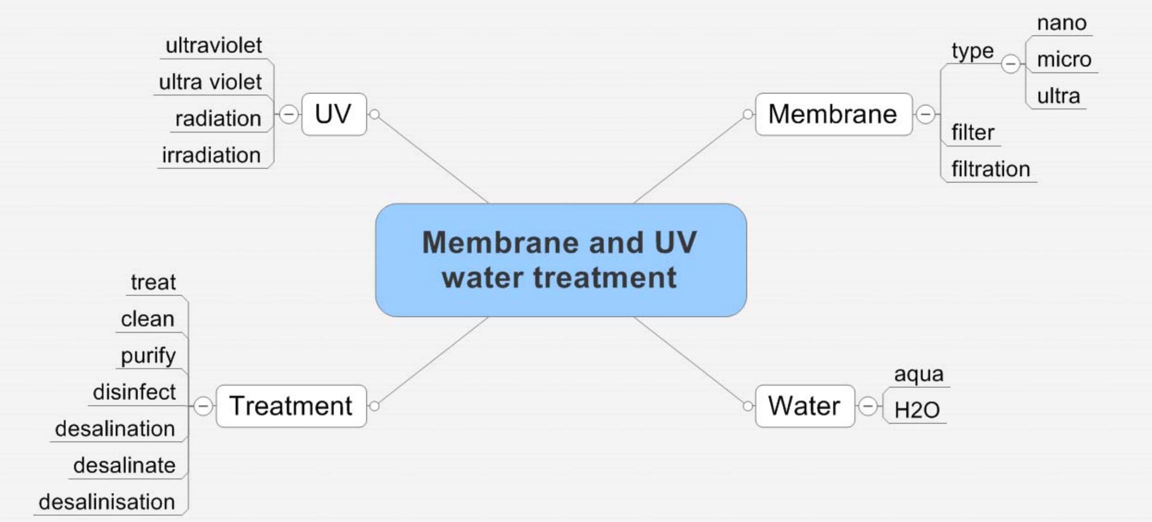

Figure 8: Keywords used for the keyword based searches as well as the IPC-keyword combined searches

Classification Code-Based Searches

Patents are tagged by various classification codes by the patent examiners dealing with their application, for example IPC (International Patent Classification) codes, ECLA (European classification), USPC (US classification codes). Appendix 3 provides a further description of the classification codes implemented.

The keyword-based search was supplemented by additional search strings using patent classification codes. The classification code-based searches were used as a way of limiting the scope of the search. A full list of the classification codes used can be found in Appendix 3.

3.1.3 Patent dataset cleaning, categorisation and expert review

The patent dataset for analysis was built on the back of Boliven and RedEye workflow and analytics platform.

Using this workflow system we focused on patent family cleaning (see Appendix 4 for definition of patent families or the patent family description on Espacenet[21]). One patent per simple family was kept for analysis, where simple family implies that all priority numbers of the related patents match (as opposed to extended families where members are related through one or more priority number). This dataset of simple patent families was cleaned of false positives using a combination of patent keyword ranking and expert review, leaving only the most relevant patents. The reason that simple rather than extended families are chosen is because certain patents in the extended family can be of peripheral relevance to the focus technology area. Expert cleaning using simple families avoids the accidental removal of relevant families based on a potential peripheral parent patent. Once the dataset had been cleaned of non-relevant patents, the remaining patents were further simplified into their extended families. This resulted in a dataset of

[21] http://www.epo.org/searching/essentials/patent-families/definitions.html

4,773 patent families relating to membrane water treatment and 1,829 patent families relating to UV water treatment (for full patent dataset please refer to Appendix 5).

The final clean dataset underwent strict quality control procedures to deliver patent datasets categorised as follows:

- Membrane filtration water treatment
- Membrane filtration water treatment applied in desalination systems
- UV water treatment
- UV water treatment applied in desalination systems

Patents were categorized using automated keyword analysis and searching procedures which consider patent title, abstract and claim data, in conjunction with expert review. Subsets were built, focused on the usage of the technologies in desalination. This resulted in datasets of:

- 571 patent families relating to membrane technologies (majority nano-, micro- and ultrafiltration) used in desalination;
- 36 patent families relating to UV water treatment and desalination.

Further expert-led identification and removal of false positives of all the patent datasets was carried out through a number of automated and semi-automated steps.

A number of false-positive categories were identified due to the strict definition of the focus area, technology language proximity, or similarity of technologies across a number of industries.

The final cleaned patent dataset is of a ‘commercial grade’ quality appropriate for industry-level analysis. The dataset is *not* appropriate for freedom-to-operate analysis, but can be used to accelerate such analyses by providing a detailed and well-defined entry point in this field.

Table 4: Catgories of false positive patents removed from the datasets

Technology	False positive categories
Membrane filtration water treatment	• Oil and gas industry related • Ultra pure water • Water treatment for industrial use only • General membrane separation (not specific to water treatment) • Waste water treatment • Water reclamation/ recovery/ re-use
UV disinfection of water	• Industrial water use application • Wastewater • Cosmetics/skin treatment • Drug • Printing • Medical treatments • Ink • Food and beverage industry • Treatment of air

3.2 Patent landscaping analysis methodology

We used several patent datasets in generating the patent landscape analyses:

- **extended patent family dataset:** the dataset including all members of the extended patent families (granted patents and published applications)
- **patent families dataset:** one parent patent from each of the extended patent families that make up each dataset and subset, also including single publication families; each family being identified by a parent patent which is that carrying the earliest filing or priority date.
- **core patent dataset:** core patents related to water treatment **and** desalination. This is a subset of the extended patent families dataset, since within the full set of all extended patent family members, some family members may relate to peripheral technologies. Appendix 5 (the patent family dataset) lists these core patents

Data analysis was performed using the RedEye™ workflow and analytics platform, and was supplemented by expert analysis.

Note that the patent family definition we used means that a single patent can form a patent family. Patent analysts differ in their views of whether a single publication patent family should be seen as similarly meaningful as a patent family with many publications.

For instance, for many major US companies the majority of their patent portfolio consists of single publication patent family, where the patent is filed through the US PTO. Furthermore, where the analysis is focused on more novel technologies, it is likely that we will observe 'younger' patent families which are likely to expand as the technology matures. On the other hand where smaller economies are concerned, it may be that only when a patent family is extended outside the parent country that we can see a commercialisation commitment by the owner.

Table 5: Summary of the analytics carried out for this project

Analysis	Explanation
Overall trends	• Application time trends showing the number of new families per year based on application date of the parent patent. • Fraction of families including a granted patent and including a PCT application • Provides data drawn from both the extended patent families dataset and core focus dataset
Applicant and inventor analysis	• Conducted on the parent patent dataset • Applicant only counted once for each patent family. • Although applicants can sometimes vary through the patent family (e.g. due to reassignment), we have included here only the parent patent's application as the source of the innovation
IPC code analysis	• Indicates how research focus in a field has changed over time • Conducted on the core patent dataset (as patents in the same family may have different IPC codes)
Geography analysis	• The office of first filing was determined from the priority number of the parent patent in each patent dataset • The earlier priority date does not have to correspond with the first published patent/application in the family, as the initial application is often submitted in a convenient priority country, while the published application is later submitted in a jurisdiction of more strategic importance to the technology. • The offices of second filing were obtained from the extended patent families dataset. Each country in which an application or granted patent occurs is counted once per family, and the office of first filing is omitted. This means that if there is more than one US application in one family, the US will only be counted once. However, if the two US applications fall within two different patent families it will count for two occurrences.
Network Diagrams	• Indicates the links between patent applicants and inventors • The thickness of connecting lines relate to the number of collaborative patents shared by the linked entities

3.3 Patent landscape limitations

Below we list the limitations of the analysis, as well as possible measures that can be taken to mitigate these in future work.

3.3.1 Lag in patent publications

There is a lag of up to eighteen months or more in the publication of patent data by various patent offices. In a fast-moving field there may be rapid changes, and so future updates to this analysis may be required if it is to be used to support policy objectives. There may also be opportunities to integrate third-party patent landscape datasets with WIPO and national patent offices' internal datasets to achieve live/real-time information updates.

3.3.2 Language

The search strings were developed in English. This should capture the vast majority of commercially relevant patents and patent families, at least from their entry into the PCT system, when they were filed with the EPO, or through the translated titles and abstracts made available in many jurisdictions. However, owing to language differences a number of patents in the national phase are likely to have been missed. To address this the search strategy can be extended through translation of the search strings across major non-English language patent offices, or by searching with language independent classification codes in combination with manual screening of the search results, e.g. by inspection of the drawings.

3.3.3 Applicant names

A well-known problem in patent landscaping is that of ensuring accurate and consistent applicant names. We have undertaken several steps to address this. CambridgeIP's proprietary RedEye™ workflow and analytics system includes a name merge facility which can be automated to search for potential matches, which are then confirmed by an operator. It also integrates a library of applicant name variations developed through 160+ previous patent landscaping projects, including past M&A information, company renaming and patent document spelling errors. However, there may be remaining mismatches due to recent M&A activity, applicant name changes or spelling errors not captured by our system. Up-to-date and accurate applicant name harmonisation is ultimately an industry challenge. We are aware of initiatives underway that could lead to unique applicant (and inventor) IDs which would partially address this problem.

3.3.4 Technology definition

The process of definition of the technology area was thorough and combined multiple approaches and quality control steps. Yet in selected fields, where there are new technologies under development not widely known to the market, it is possible that technology descriptors may have been missed. In addition, the boundaries of the technology field shift over time – technology is ultimately a social artefact, and its uses shift and change constantly.

As technology systems are often patented as a group of distinct inventions, there are likely to be technologies and technology subsystems that we have not identified, especially where the subsystems are used more generally than in desalination.

Additionally, due to the diverse applications of both membrane and UV water treatment technologies their patents could be broad and not specify water treatment as an application and do not mention water explicitly, but refer more generally to the treatment of fluids. These patents may not have been included in the dataset.

3.3.5 Data sources

It is well known that there are limitations for electronic data availability across many jurisdictions, especially where this relates to patent claims data. Patent citation data was only available for US patents, as we have not yet integrated this data for other authorities with our in-house system.

Finding patent data for LDC countries (listed in Appendix 6) is very difficult. Of the LDC countries, only Malawi and Zambia's information is included in this dataset. Many of these countries will be covered through African Regional Intellectual Property Organization (ARIPO) and Organisation Africaine de la Propriété Intellectuelle (OAPI) filings. When considering the results, it is important to take into consideration that South Africa is not part of ARIPO.

3.3.6 Differences in technology definition and wording

Patent applicants can use different wordings to describe the same technologies. This may be due to genuine differences between how a technology is described in different companies (or countries), but may also be due to attempts to make less obvious to competitors what the technology is. In other circumstances, technologies developed for multiple uses may not list the application of interest explicitly in the claims, and it would be very difficult to include all such patents. For freedom-to-operate (FTO)-grade analyses there are more intensive expert-led and semantic techniques that can be used for addressing such problems, but these are not feasible at the level of analysis appropriate for the present report.[22].

3.4 Survey methodology

Patent data is a strong and reliable source of information about technology and innovation activity. However, frequently valuable context for interpretation of patenting trends can be gained through interviews and surveys of industry participants. To support the interpretation of the patent landscape results we performed an internet-based survey of industry participants in the water industry. The three themes of the survey were:

- The role of IP in the water treatment technologies field
- Areas of innovation in water treatment technologies
- Policy measures to support innovation and technology diffusion

The survey included both open and closed questions. The questionnaire was distributed to various water industry professionals and online water technology communities. The targeted community population size is estimated at around 5000. We obtained 57 responses, which corresponds to a response rate of just over 1% - comparable to

[22] FTO-type analyses ensure that the commercial production, marketing and use of a new product, process or service does not infringe the intellectual property rights of others and thus requires more rigorous and focussed analysis. For a case study, ref. E.Burrone 'New Product Launch: Evaluating Your Freedom to Operate', http://www.wipo.int/sme/en/documents/freedom_to_operate.html

industry survey response rates. All respondents will be provided with a summary of the survey results and a copy of the final report.

The analysis was based on interpretation of the statistical results of the closed questions, and context provided by respondents in the open questions. The results were contextualised using results of the patent landscape, known industry features of the water treatment industry and the outcomes of previous surveys by CambridgeIP in other industries.

4 Patent landscape results

4.1 Patenting trends and patent family analysis

Patenting time trends

The patent landscape results suggest that both the membrane and UV technology field are experiencing accelerating rates of patent filings (see Figure 9). Within these, there is a higher level of patenting activity in membranes compared to UV - not surprising given the larger number of technology sub-systems within the membranes field[23]. Interestingly we also identified a growing subset of patents combining membrane and UV technologies - possibly suggesting the modularisation of water treatment technologies.

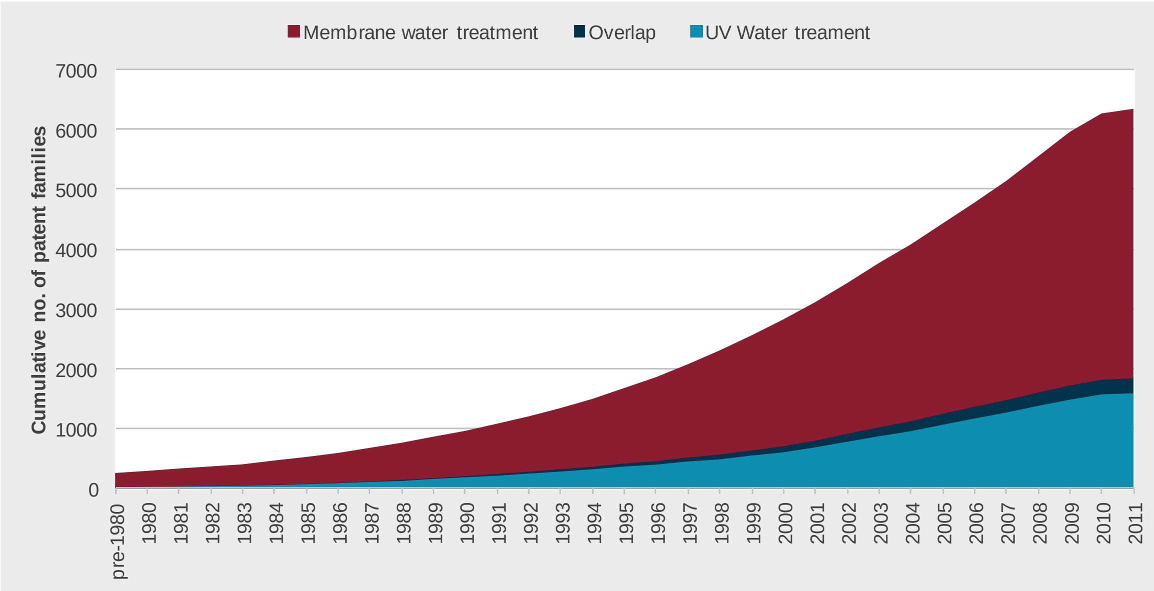

Figure 9: Cumulative patent filings in membrane and UV water treatment technologies by patent families

As **Figure 10** indicates, membrane water treatment technology had a lot of patent activity even before 1980 (260 patent families). While UV patenting trends appears to have reached a plateau around 2005, the patenting trends in membrane water treatment space have accelerated and are significantly higher.

[23] The application date for the analysis here is the application date for the parent patent listed for each family in the spreadsheet (Appendix 5).

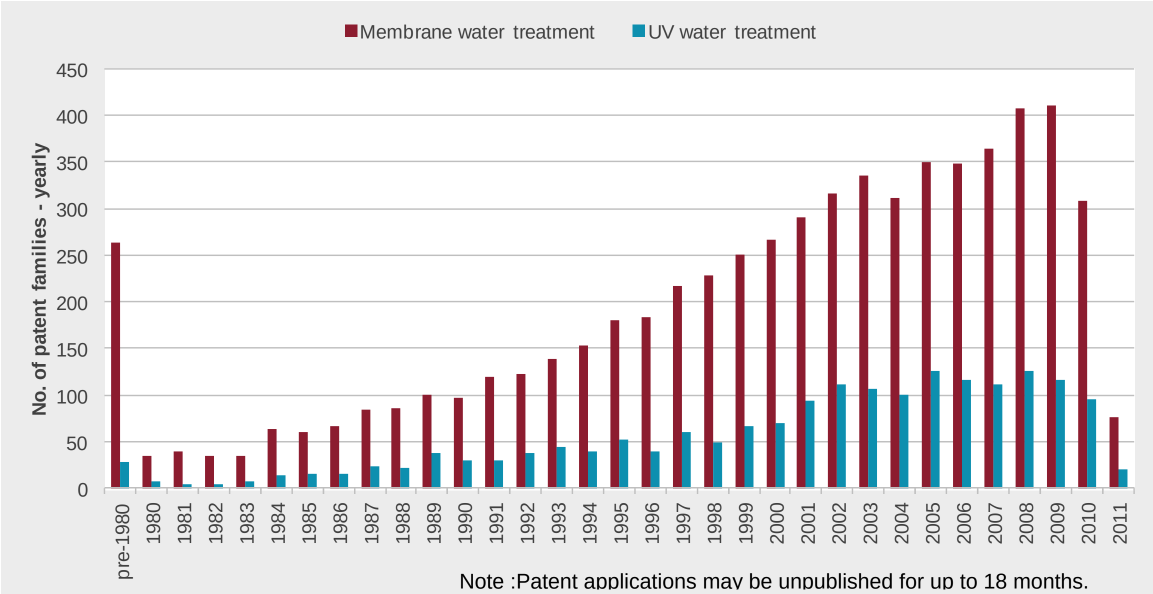

Figure 10: Annual patent application trends for membrane and UV water treatment.

Patent family analysis

Overall datasets: We performed a range of additional analyses around the patent datasets to examine the trends underpinning the patent datasets (see Table 6). For instance, we analysed the average patent family size[24] with *more than 1 member* - thus stripping out the 'noise' from patent families with a single publication. We found that for the membrane and UV datasets the average patent family has 9 or 10 members in both the membrane and UV water treatment datasets. However for the membrane-UV 'combination dataset the average family size was much smaller at 4 and 2 patents for the overall and desalination-focused datasets. We also saw some very large extended patent family sizes (in the 'largest patent family' category). Possible interpretations of these findings could be that:

- more dynamic technology areas have a higher number of SMEs, who due to resource constraints may only file one patent or abandon experimental technology,
- a 'younger' technology or product would have had less time to develop 'mature' patent families
- presence of several core product technology of very high importance for a corporate player justifying significant investment in a large extended patent families

Desalination: We also found that for both the membrane and UV fields, a higher proportion of desalination related patents were filed in the last 5 years compared to the overall datasets. It was also interesting to find that 15% of all membrane-related patents relate to desalination - compared to 2.8% for UV technologies. This finding would confirm that integration with desalination is a recent trend in water treatment; and that while

[24]The average patent family size was calculated for extended patent families. For further information on definitions of patent families please refer to EPO's website: http://www.epo.org/searching/essentials/patent-families/definitions.html

membranes are a more important technology for desalination, there could be a growing role for UV technologies in desalination systems.

Table 6: Membrane and UV water treatment patent datasets - key results

Dataset	Nr Families	% families – last 5 years	Extended patent families dataset	Core patent dataset	Families with single patent	Largest family size	Average family size[25]
Membrane-based Water Treatment Technologies							
Membrane filtration	4,773	24%	22,698	11,480	45%	652	9
Membrane filtration for desalination	571	30%	3,184	1,792	38%	275	9
UV-based Water Treatment Technologies							
UV water treatment	1,829	26%	8,457	2,886	54%	1,713	10
UV water treatment for desalination	36	36%	186	83	46%	54	10
Combinations of UV and Membrane Technologies							
UV and membrane water treatment	250	27%	1,862	551	25%	42	4
UV and membrane for desalination	9	33%	94	17	33%	3	2

4.2 Key patent applicants and inventors

4.2.1 Membrane water treatment

It was striking that 15 out of the Top 20 patent applicants over all time are Japanese corporations. Many of these were also Japanese corporations identified as highly active in the desalination field in the earlier WIPO patent landscape report on desalination[26] - confirming the proximity of the technology development between membrane water treatment technologies broadly and Reverse Osmosis desalination. Companies which *did not* feature in the top 20 applicants in the aforementioned desalination report include Toray Industries and Nitto Denko. These two companies in particular are well known to be among the leading membrane providers worldwide for a wide range of water treatment solutions. Metawater may be an even stronger player in this field should they have taken over all of the NGK patent portfolio after their integration 2008[27]. With the exception of Kuboto and Panasonic, we found that most of the companies with large patent portfolios on membranes for desalination pre-treatment are also leaders in membrane technology overall. Companies where the membrane water treatment patents

[25] Based on extended patent families of 2 or more members

[26] WIPO Patent Landscape Report on *Desalination technologies and use of alternative energies for desalination* 2011 http://www.wipo.int/patentscope/en/programs/patent_landscapes/reports/desalination.html

[27] The two portfolios were not integrated, as the NGK patent ownership was not investigated within the scope of this report.

are almost entirely focused on desalination include Hydranautics, Enercon and Desalitech.

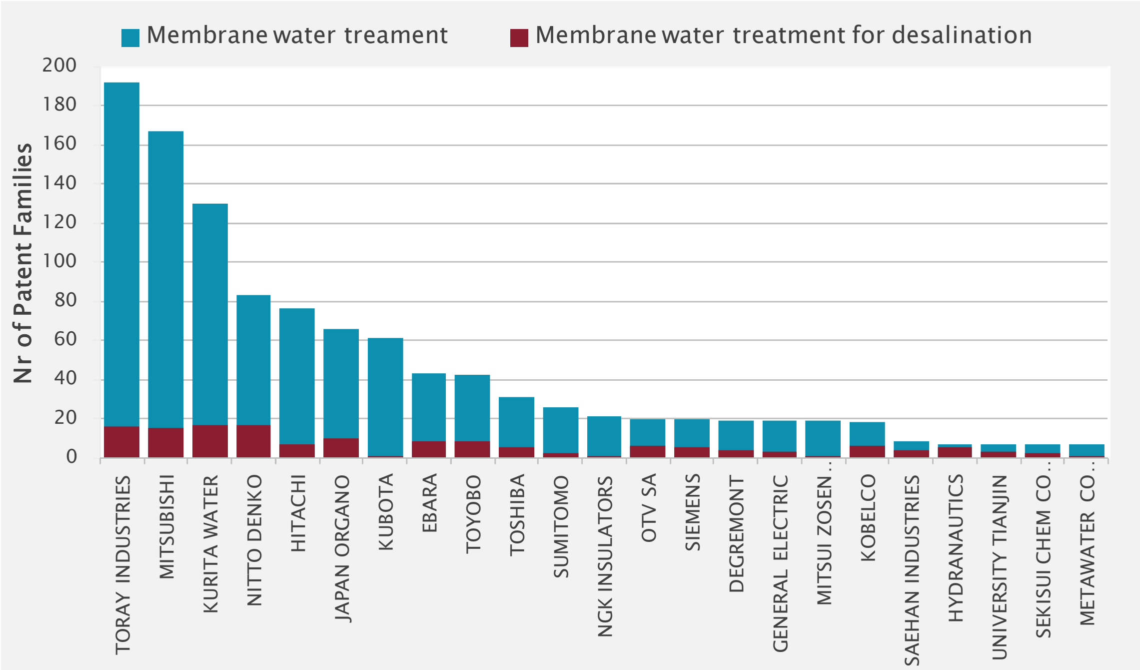

Figure 11: Top patent applicants for membrane-based water treatment technologies - overall and for desalination

Looking at patent filings for the last 5 years we found that Japanese companies continue to dominate the membrane water treatment patent landscape, albeit to a lesser degree than before. Some previously important players such as Kuboto, Japan Organo and Toyobo have shown a marked decrease in patenting actives. An interesting example of differing patenting strategies within the same country can be seen in the contrast between Japan's Toray Industries and Nitto Denko, both major players in the membrane technology area. While Toray Industries remains the largest patent applicant, Nitto Denko has filed much fewer patents in this field over the same time period.

It was interesting that many non-Japanese companies have expanded their presence in the area. In particular South Korea's LG Electric, Germany's Siemens, France's Degramont and the US’s General Electric Corporation have filed the majority of their patents in this field in the last 5 years.

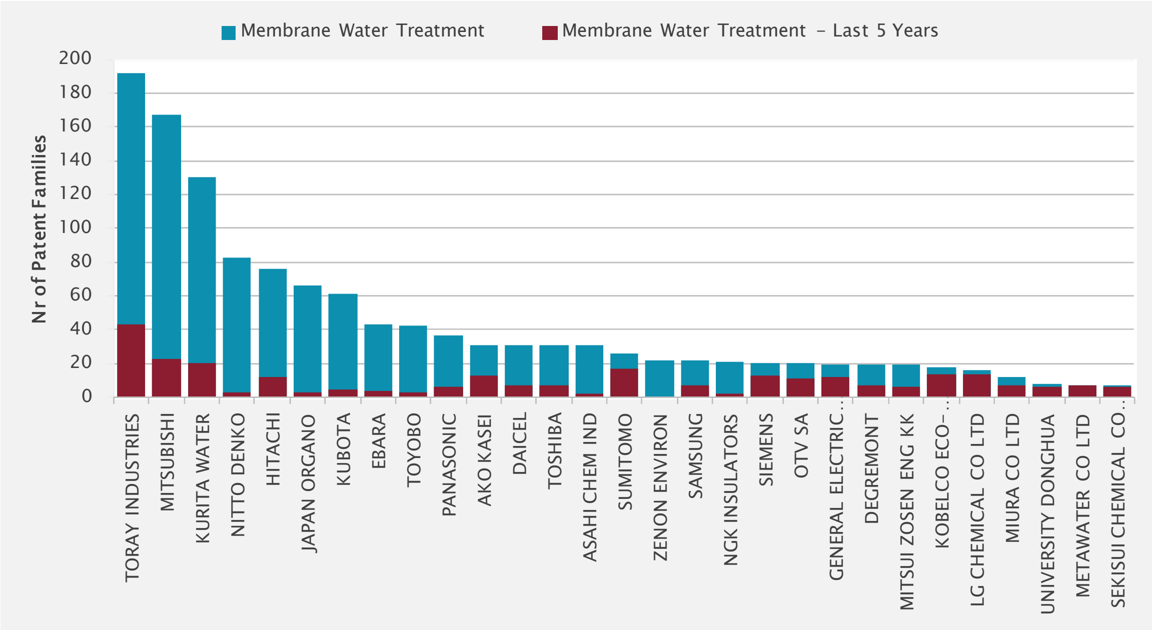

Figure 12: Top patent applicants in membrane water treatment - all time and last 5 years

Membrane water treatment patents specifically mentioning desalination are considerably fewer. Even the top patent applicants over all time have less than 20 families in this field. At the same time, there seems to have been a much greater proportion of patenting activity in the last 5 years. This may indicate that desalination-specific membrane technologies are increasing, as the expanding size of the desalination market justifies corporate R&D in developing specific membranes for pre-treatment solutions.

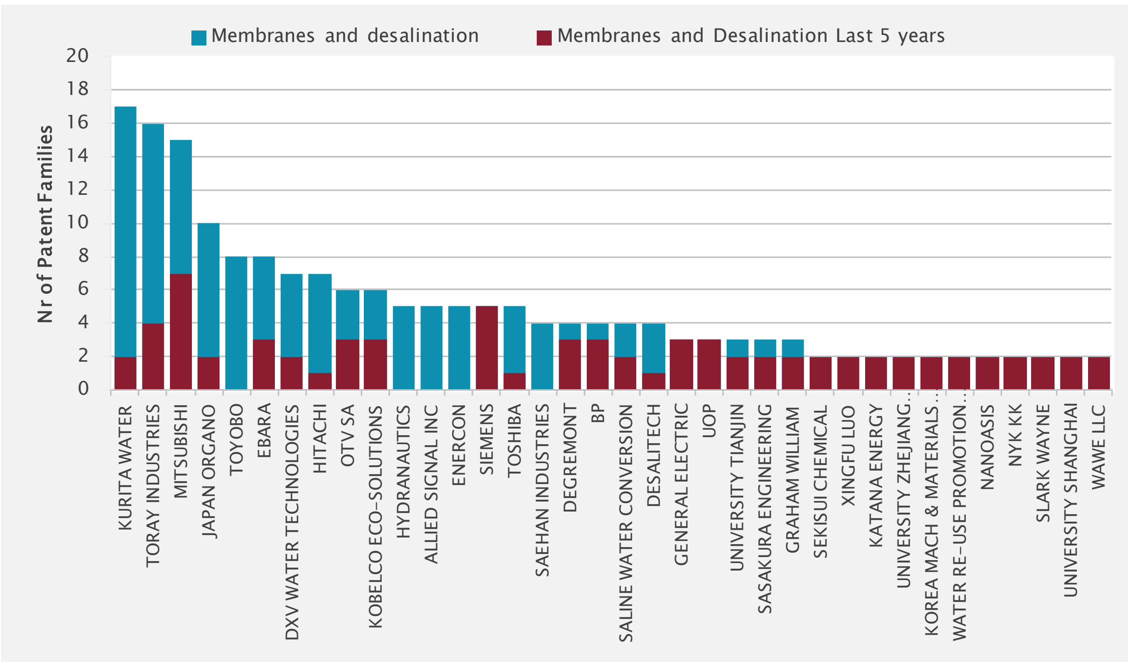

Figure 13: Top patent applicants in membrane water treatment for desalination - all time and last 5 years.

A complementary perspective around corporate patenting activity can be gained by examining the composition of inventors around the key patents identified. As illustrated in

Table 7, the top inventors in membrane water treatment technologies broadly reflect the top corporate applicants seen above, with inventors affiliated to Japanese multinationals dominating the ranking. The large patent portfolios of Toray and Mitsubishi are seen to be spread amongst a number of different inventors, but they also tend to list a larger number of inventors on their patents, which could be artificially increasing these inventor's portfolios.

In some cases the past affiliations of an inventor can indicate collaborations, or flows of knowledge between organisations. By way of example, Kawakatsu Takahiro (ranked 11) is linked both with the University of Tokyo, and large corporations (Kurita, Panasonic). His publication record suggests that he was associated with the university in 1993[28], and by 2008 with Kurita[29]. The patents on which he is listed as an inventor start from 2004 and are from Kurita, however some are in partnership with other applicants.

Table 7: Top 20 inventors in membrane filtration water treatment by patent families

Rank	Inventor	Patent families	Related applicants
1	Taniguchi Masahide	32	Toray Industries, Chiyoda Kako Kensetsu
2	Minegishi Shinichi	21	Toray Industries, Kawasaki heavy Ind.
3	Kobayashi Masumi	19	Mitsubishi
3	Nakatsuka Nobuyuki	19	Daicen Membrane Systems, Daicel
5	Izumi Seiji	18	Kubota
6	Kumano Atsuo	17	Toyobo
7	Cote Pierre Lucien	16	Zenon Technology Partnership, Omnium Traitement Valorisa
7	Kawada Ichiro	16	Nitto Denko Corp, Osaka City
7	Kihara Masahiro	16	Toray Industries
7	Sawada Shigeki	16	Kurita Water Ind. Ltd
11	Kawakatsu Takahiro	15	Kurita Water Ind., Tokyo Institute of Technology, Panasonic, University of Tokyo
11	Tsukamoto Teruyoshi	15	Ebara
11	Honjo Kenji	15	Mitsubishi
14	Hirose Masahiko	14	Hydranautics, Nitto Denko
14	Narukami Yoshihisa	14	Kubota
16	Kato Osami	12	Mitsubishi
16	Noshita Masanobu	12	Kobe Steel, Kobelco Eco-solutions, Nitto Denko
18	Iwahashi Hideo	11	Mitsubishi
18	Okuma Naoki	11	Hitachi, Maezawa Ind., HMY
18	Sakai Kenji	11	Toray Industries
18	Henmi Masahiro	11	Toray Industries
18	Manabe Atsuyuki	11	Miura
18	Hayakawa Kunihiro	11	Kurita Water Ind
18	Fusaoka Yoshinari	11	Toray Industries
18	Yamada Yutaka	11	Kubota
18	Murakami Mutsuo	11	Toray Industries
18	Tamura Makio	11	Japan Organo, Toyobo, Asahi Chemical

[28] T. Kawakatsu, *et al* "Effects of size and compressibility of suspended particles and surface pore size of membrane on flux in crossflow filtration." Journal of Membran Science (1993): 173 – 190

[29] H.Takaba *et al* "Development of Novel Molecular Modeling Technique for Membrane Fouling in Water Treatments." ICOM (2008)

4.2.2 UV water treatment

Many of the applicants in the UV field are consumer electronics companies who market home water treatment systems amongst a range of domestic appliances such as Philips, LG, Samsung and Panasonic (see Figure 14). Japanese applicants also play a dominant role in this field, as with in other water technology fields. In the last 5 years the companies to file the greatest number of UV water treatment patents were Toshiba, Hitachi and WoongJin[30]. The UV field is much smaller than that of membrane water treatment. Consequently Toshiba - the top patent holder - holds possessing 51 patent families. There is good correlation between the top assignees for membrane and UV water treatment technologies, with Kurita, Panasonic, Japan Organo and Mitsubishi appearing in the top 10 in both fields. This overlap is to be expected given the number of UV water treatment devices which incorporate a membrane filter.

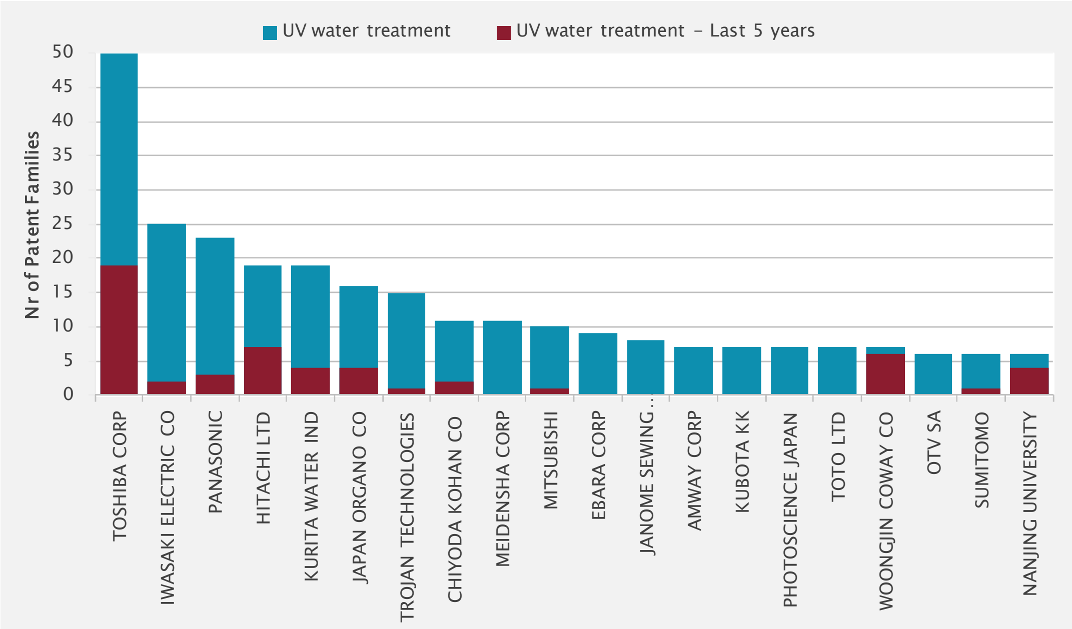

Figure 14: Top patent applicants in UV water treatment - all time and last 5 years.

The companies in the UV water treatment for desalination subset have only one patent family each (see Table 8). The only company in the top 20 UV water treatment patent holders which also holds a UV for desalination patent is Kurita. The players in this field are more diverse geographically, without the large presence from the Japanese applicants seen in the overall UV water treatment field.

[30] This South Korean company began as a publishing company in 1980, but around the mid 90s started to acquire a large portfolio of subsidiaries, including Coway (water treatment) and Ginseng (Beverages)

Table 8: UV water treatment with desalination patent holders and patent titles.

Applicant	Publication No.
Adiquimica SA	WO2009132727
Allied Signal Inc	WO9011821
Aqua-ion Systems Inc	US5728303
Bend Research Inc	US4851127
Daelim Ind Co Ltd	KR2011001224
Dayu water treatment equipment	CN2324920Y
Fujifilm	WO2011073641
Heraeus Noblelight	EP489184
Korea Agricultural & Rural Inf/Blue Environment Ntech	KR839026
Kurita Water Ind Ltd	JP2011110515
Marine Environmental Partners Inc	WO04024281
Moreno International LLC	US5997737
North China Municipal Engineer	CN101215072
Obshchestvo S ogranichennoj Otvetstvennostju Firma Akva-don	RU2293067
Ocean Power Corp	WO0218275
Rhodia Consumer Specialities Ltd	WO05023904
Sanitary Equipment Inst Academy	CN201220922Y
Seral Erich Alhauser GMBH	EP96377
Shanghai Material Research Inst.	CN87205507U
Singapore Technologies Dynamics PTD, Innovum Innovative Umwelttechnik	WO2008018837
US Filter Wastewater Group	WO05092799
Xinhuayu Sea Environment Technology	CN2367607Y

Table 9 shows the top inventors listed on UV water treatment patents. The ranking is dominated by inventors from Japanese electronics companies, especially Toshiba who own the largest number of patent families in this field by some distance.

Table 9: Top 20 inventors in UV water treatment technology by patent families

Rank	Inventor	Nr of patent families	Related applicants
1	Abe Norimitsu	25	Toshiba Corp
2	Murayama Seiichi	21	Toshiba Corp
3	Ide Kenji	16	Toshiba Corp
4	Soma Takahiro	14	Toshiba Corp
5	Shirota Akihiro	11	Toshiba Corp
6	Kobayashi Ikuo	10	Panasonic Corp
7	Morikawa Akira	9	Toshiba Corp
8	Taguchi Kenji	8	Toshiba Corp, Shokuhin Sangyo Kankyo Hozen Gijutsu Kenkyu Kumiai
8	Iyasu Kyotaro	8	Toshiba Corp
8	Tamaki Shojiro	8	Toshiba Corp
8	Kobayashi Shinji	8	Toshiba Corp
12	Hatano Akinori	7	Toshiba Corp
12	Yamagata Koji	7	Raizaa Kogyo KK, Shinshu Ceramics KK, Lizer Industry Co Ltd
12	Hara Naoki	7	Hitachi Ltd
12	Covaliova Olga	7	University de Stat din Moldova
12	Engelhard Rold	7	Vortex Corp, Life Spring Ltd Partnership
17	Suzuki Setsuo	6	Toshiba Corp
17	Ueno Osamu	6	Toshiba Corp
17	Yokoyama Yuji	6	Iwasaki Electric Co Ltd, Tokyo Electric Power Co Inc
17	Covaliov Victor	6	University de Stat din Moldova
17	Maiden Miles	6	Hydro Photon Inc
17	Nishigori Kosuke	6	Iwasaki Electric Co Ltd Electric Co Ltd, Tokyo Electric Power Co Inc
17	Kaas Povl	6	Kaas System Teknik APS H

4.2.3 Key considerations around interpretations of corporate patenting data

Data on corporate patent holdings in a particular industry can be a powerful source of competitive information about the structure of a value chain and changing corporate focus around technologies and the entry of new players. Before discussing the findings in this report, some caveats need to be outlined regarding the interpretation of such data relating to different IP strategy styles between corporations.

It is broadly accepted that patenting intensity can differ significantly between industries. Yet corporate patenting rates can differ significantly within the same industry between countries (e.g. Japanese and US corporations may have a higher propensity to patent than European corporations), or even within the same country, for similar product portfolios and levels of revenues. Such differences may be related to greater reliance on external networks (e.g. through licensing and open innovation programmes); or simply differences in broad vs. narrow patenting styles between corporations[31]. Consequently, corporate patenting activity and portfolio data should ideally be interpreted in the context of the broader market share, value chain and supplier structure of a focus company, and matching products to patent data.

Another key aspect is that a number of companies working on interesting and potentially disruptive technologies are unlikely to enter list of top applicants, as they have a smaller number of patent families (with a smaller size) than corporate competitors. Consequently

[31]See for instance Iliev *et al* (2011) on differences in corporate patenting styles in the medical devices and telehealth field; and Lee *et al* (2009) on such differences in the low-carbon energy space.

in patent landscaping exercises the most disruptive technologies can be found in the 'long-tail' of patent filings. Within the limits of this patent landscape report it is of course not possible to examine the full array of patent families by small players. However, the patent dataset provided in Appendix 5 can provide a fruitful source of information for further analysis by industry experts and observers.

4.3 Technology composition: patent dataset analysis by classification codes

The analysis of the patent dataset by classification code can assist patent examiners in identifying the most used codes in the water treatment field, patent analysts in preparing effective search strategies and in addition can sometimes indicate interesting shifts within a specific industry.

4.3.1 IPC code analysis for membrane filtration water treatment

Table 10: and Table 11 list the four most common IPC codes assigned to membrane water treatment technology patents, at level 3 and 5 respectively. At IPC level 3 almost all the patents (85%) fall into two IPC classifications, B01D, relating to separation by physical of chemical processes, and C02F, relating to water treatment.

Table 10: Top level 3 IPC codes for membrane filtration water treatment technologies

IPC code	Description	Occurrences
B01D	Physical or chemical processes>Separation	11,051
C02F	Treatment of water, waste water, sewage or sludge	8,376
B01J	Chemical or physical processes, e.g. catalysis; colloid chemistry; their relevant apparatus	445
A61L	Methods or apparatus for sterilising materials or objects in general; disinfection, sterilisation, or deodorisation of air; chemical aspects of bandages, dressings, absorbent pads, or surgical articles; materials for bandages, dressings, absorbent pads, or surgical articles	165
Other		2,706

When looking at level 5 IPC codes we get a more granular picture about which IPC codes are the most important. As would be expected, most of these IPC codes relate to various forms of membrane separation water treatment.

Table 11: Top level 5 IPC codes for membrane filtration water treatment technologies

IPC code	Description	Occurrences
C02F 1/44	Treatment of water, waste water, sewage or sludge >Treatment of water, waste water, or sewage > by dialysis, osmosis or reverse osmosis;	2,670
B01D 61/02	Physical or chemical processes>Separation > Processes of separation using semi-permeable membranes, e.g. dialysis, osmosis, ultrafiltration; Apparatus, accessories or auxiliary operations specially adapted therefore > Reverse osmosis; Hyperfiltration;	978
C02F 1/28	Treatment of water, waste water, sewage or sludge >Treatment of water, waste water, or sewage > by sorption;	778
C02F 1/00	Treatment of water, waste water, sewage or sludge >Treatment of water, waste water, or sewage;	713
Other		12,445

Figure 15 shows the changes in IPC classification of membrane water treatment patents over time. Clearly B01D and C02F represent the majority of the patents in this field, with similar growth trends - possibly due to a number of patents being classified under both IPC codes. There is some divergence around 1995 when there was an increase in patents relating to separation process technologies. The increase in the water treatment specific code is smaller than the increase in membrane specific codes. This could be an indication that the patenting in relation to general membrane technologies was starting to be used more broadly across a variety of fields.

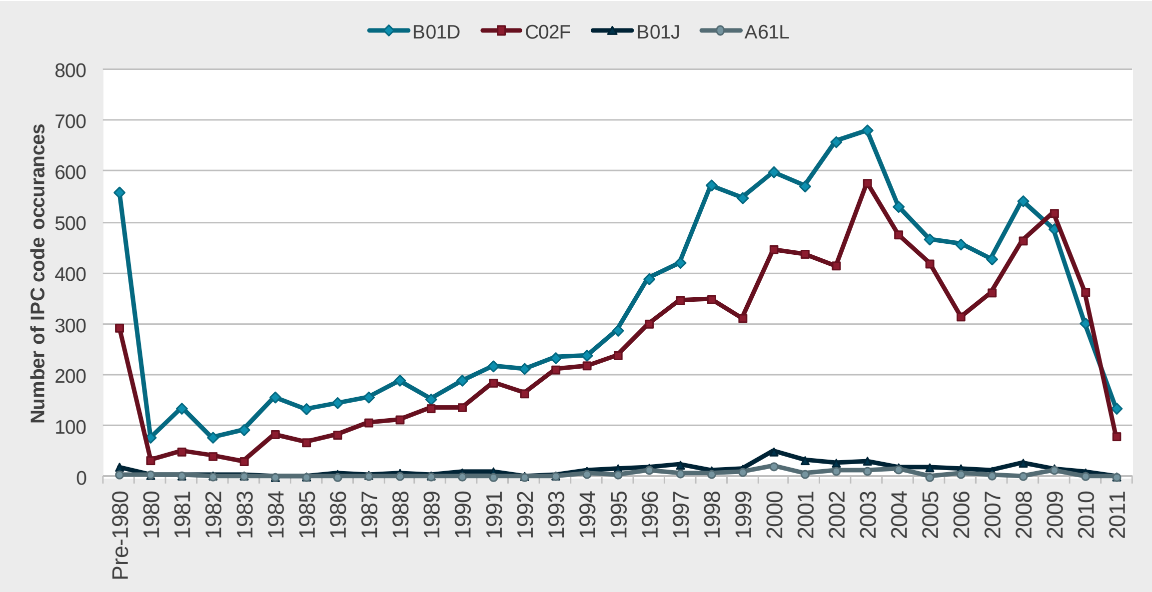

Figure 15: Membrane water treatment IPC level 3 trends over time

4.3.2 IPC code analysis for UV water treatment

Table 12 and Table 13 show the IPC classifications for patents relating to UV water treatment. The most common IPC code by some distance is C02F, relating to water treatment. This is to be expected considering the different approaches of the two treatment types. The top level 5 IPCs also all belong to the C02F classification.

Table 12: Top level 3 IPC codes for UV water treatment technologies

IPC code	Description	Occurrences
C02F	Treatment of water, waste water, sewage or sludge	3,958
B01D	Physical or chemical processes>Separation;	666
B01J	Chemical or physical processes, e.g. catalysis, colloid chemistry; their relevant apparatus;	322
A61L	Methods or apparatus for sterilising materials or objects in general; disinfection, sterilisation, or deodorisation of air; chemical aspects of bandages, dressings, absorbent pads, or surgical articles; materials for bandages, dressings, absorbent pads, or surgical articles	255
Other		1,294

Table 13: Top level 5 IPC codes for UV water treatment technologies

IPC code	Description	Occurrences
C02F 1/32	Treatment of water, waste water, sewage or sludge> Treatment of water, waste water, or sewage > with ultra-violet light;	1,181
C02F 1/78	Treatment of water, waste water, sewage or sludge >Treatment of water, waste water, or sewage > with ozone;	295
C02F 1/72	Treatment of water, waste water, sewage or sludge >Treatment of water, waste water, or sewage > by oxidation;	274
C02F 9/00	Treatment of water, waste water, sewage or sludge >Multistep treatment of water, waste water or sewage;	271
Other		4,463

The trend over time in IPC classification for level 3 IPCs are presented in Figure 16, showing the overall prominence of the C02F classification. The other top IPC codes do not relate to UV disinfection in particular, but rather to the overlap of UV disinfection with other water treatment methods.

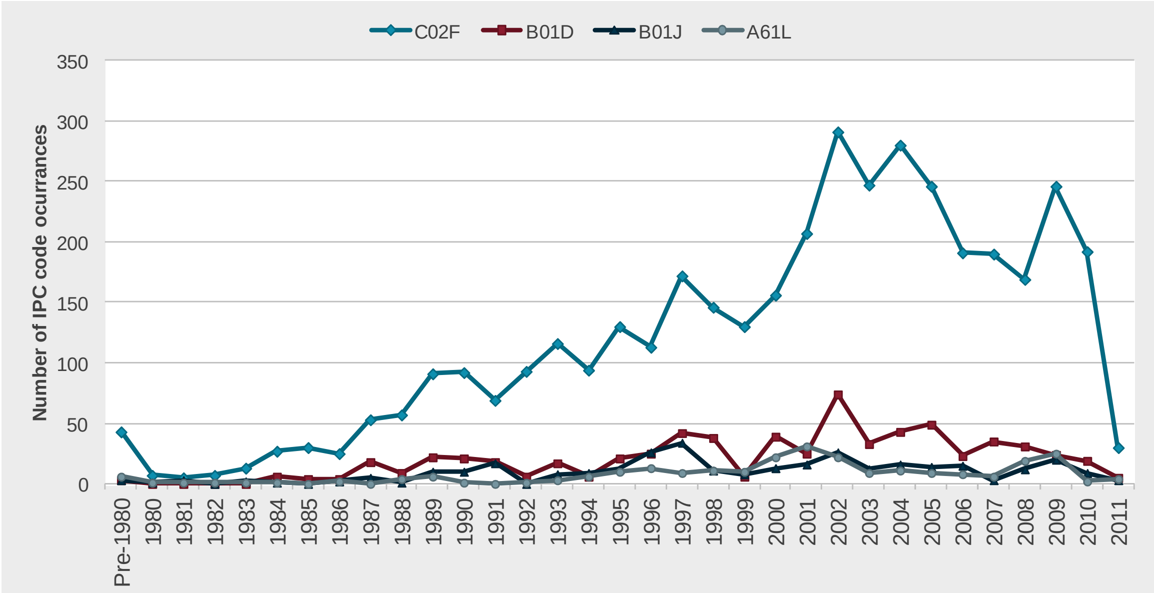

Figure 16: UV water treatment IPC level 3 trends over time for UV water treatment

4.4 Geographic analysis

In Figure 17 and Figure 19 show the location of the Office of First Filing (OFF) and the Office of Second Filing (OSF) for patent filings in the membrane and UV water treatment field. The OFF can often indicate the location of the initial innovation (or where the patent department of the company is located). This is especially the case for small to medium sized companies who have less scope for variation regarding OFF than large multinational enterprises. The OSF can provide a proxy for the regions where patent protection is most important either from a manufacturing or sales perspective. We do not include the country already listed as OFF in the OSF

Overall the most significant filing locations are (in order of patenting activity) Japan, China, the US, South Korea and Europe[32]. While Japanese companies dominate the water treatment patent landscape in terms of overall patents filed, Japan has become less prominent as a filing location but in terms of OFF and OSF filings in the last 5 years, while China has consistently grown as a location for patent filings. Overall South Korea has shown the greatest rise in the percentage of patent filings in the last 5 years as compared with overall. This has been the case in both UV and membrane water treatment.

South Korea is a much more prominent location as an OFF than OSF, indicating that it is a key R&D location in this field. The US and Europe remain key areas for OFF and OSF filings, though in the last 5 years filings in both water treatment sectors considered have decreased.

Countries in Africa and Southern Asia are not significant locations for patent filings in this dataset, either as an OFF or OSF.[33] Despite the importance of water treatment

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[32] Europe has been defined to include all countries geographically located in northern Europe as well as EPO patent filings.

[33] For more detailed information of the data coverage please refer to Appendix 3 and Appendix 6.

technology to these regions this data indicated that they are not innovation hubs in this field.

4.4.1 Geography analysis of membrane water treatment technologies

Office of first and offices of second filing (OFF and OSF)

Figure 17 shows the offices of first and second filing in the membrane water treatment field. China and South Korea have seen a proportional increase in patent filings both as OFF and OSF. China, constituting a larger proportion, has seen more intensive increases compared to South Korea, even though South Korea's activity has doubled as both an OFF and OSF.

As an OFF, the US and Europe have undergone some proportional decrease in activity, whereas Japan has undergone a significant decrease. However, the trend is different for OSF, where Japan has only lost a small proportion of its presence, the US has increased, and Europe has undergone a significant decline (potentially due to the large increase in proportion of PCT filings).

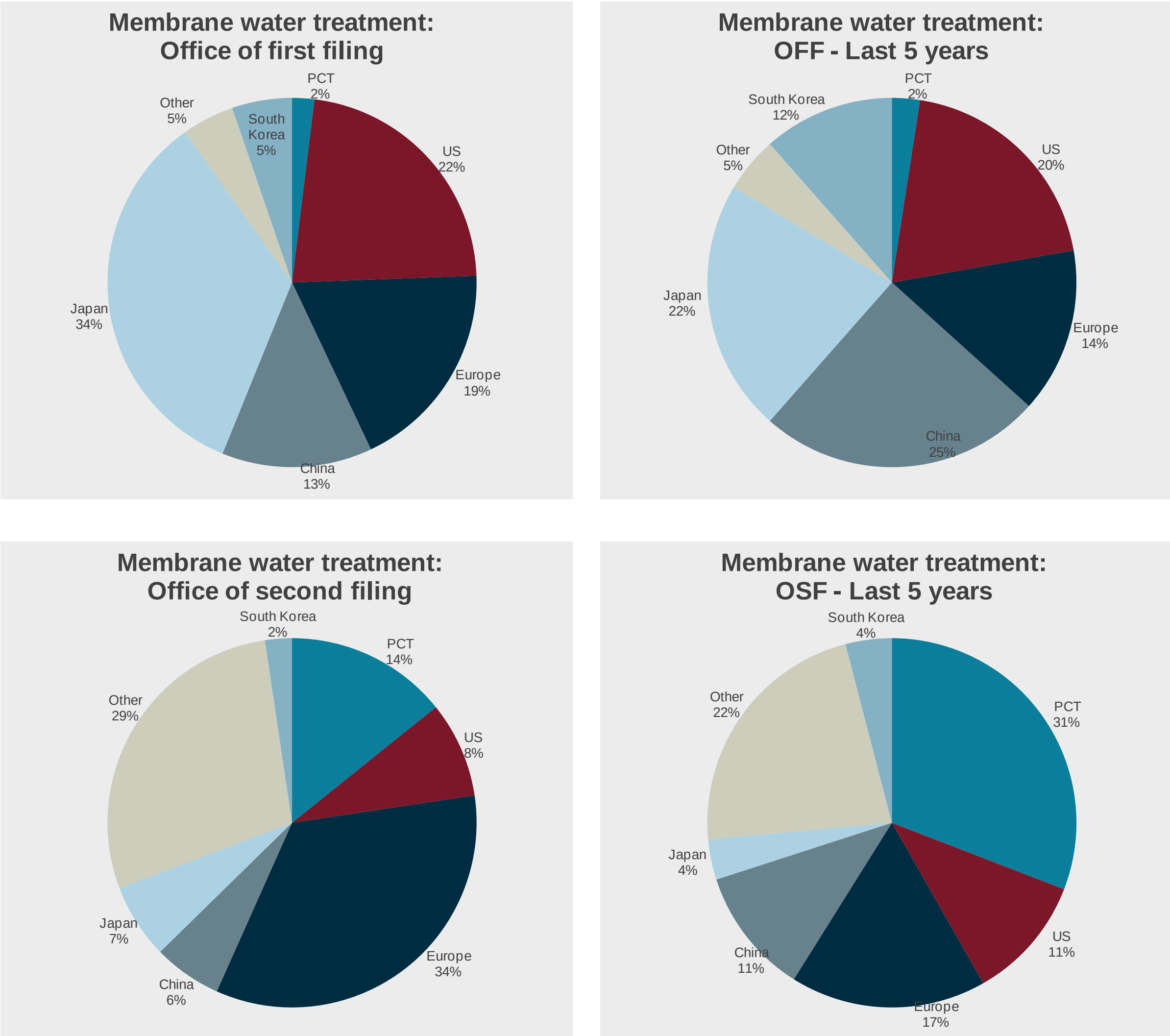


Figure 17: Analysis of patent filings by geography for membrane water treatment technologies

Table 14 provides more detailed data across all jurisdictions. As an OSF, Australia and the South Pacific, South and Central America as well as Canada have had a considerable number of filings in this field, both in recent years and over all time.

Africa:

Only one patent has been filed with the ARIPO as the office of first filing in this field. A further seven have been filed with South Africa as the OFF, however together these form only 0.17% of the total number of patents filed in this field of technology. A much greater number of patents have been filed with African jurisdictions as the office of second filing (2.3% of total OSF filings), constituting South African (1.3%), Moroccan (0.3%), Egyptian (0.3%) and ARIPO (0.3%) and OAPI (0.2%) filings; though very few of these have been filed in the last five years.

Middle East:

There are very few Middle Eastern jurisdictions listed as the OFF on membrane water treatment patents (0.5% of total patents filed), and all of the 24 patent filings have been in Israel. Similar to Africa a larger number of patents have been filed with the Middle East as an OSF but this still represents only 2% of the total number of patents in this field. Of these 164 (1.9%) were filed in Israel and 2 (0.02%) in the Gulf Cooperation Council.

Asia:

Japan's filings dominate this field, representing 34% of the global total overall. However China is rapidly catching up and more patent applications have been filed there than in Japan over the last 5 years both as OFF (25%) and OSF (11%). Other Asian countries make up only a small percentage of the OFF (1%) and slightly more of the OSF filings (3%). These are mostly filings from Taiwan and India, with 17 (0.36%) and 16 (0.34%) filings respectively and 6 each (1%) in the last 5 years. Patents have been filed with an OSF in Taiwan (1.6%), Hong Kong (0.6%), Singapore (0.4%), India (0.1%), Indonesia (0.1%), the Philippines (0.1%), and Malaysia (0.02%) and together these countries represent 3% of the total OSF filings. Among these Taiwan is by far the most prominent location as an OSF, with 142 filings, 45 of which were in the last 5 years (3% of total).

Table 14 Showing the OFF and OSF geographies of membrane water treatment all time and last 5 years

Geography	OFF	OFF - Last 5 years	OSF	OSF - Last 5 years
PCT	92 (2%)	28 (2%)	1230 (14%)	419 (31%)
US PTO	1067 (22%)	227 (20%)	726 (8%)	148 (11%)
Canada	30 (1%)	6 (1%)	598 (7%)	81 (6%)
European Patents	881 (19%)	166 (14%)	2945 (34%)	233 (17%)
Russia and USSR	52 (1%)	12 (1%)	95 (1%)	13 (1%)
China	626 (13%)	285 (25%)	519 (6%)	151 (11%)
Japan	1614 (34%)	254 (22%)	566 (7%)	48 (4%)
South Korea	250 (5%)	132 (11%)	203 (2%)	55 (4%)
Other Asian Patents	38 (1%)	15 (1%)	258 (3%)	53 (4%)
Middle East	24 (1%)	3 (<1%)	164 (2%)	20 (1%)
Africa	8 (<1%)	1 (<1%)	202 (2%)	18 (1%)
Australia and New Zealand	50 (1%)	16 (1%)	759 (9%)	77 (6%)
Central and South America	9 (<1%)	3 (<1%)	373 (4%)	42 (3%)
Other	7 (<1%)	0 (0%)	8 (<1%)	0 (0%)

Applicant and inventor country of residence

The majority of patent applicants in this field are based in the US, though in recent years it's proportional significance has decreased while there has been a dramatic increase in filings from South Korean applicants, representing 18% of applications in the last 5 years but only 11% overall. Europe has also emerged as a significant source of innovation in the last 5 years, with European applicants listed on around 24% of the patents in this field. The large percentage of other patents in this dataset is due to the lack of applicant country data on many patents. The inventor location data largely mirrors the applicant geography breakdown, with the exception of Europe, which has a much greater percentage of inventors overall than of applicants, perhaps due to the greater availability of inventor location data. This would indicate that Europe's role in this field has always been a significant percentage overall.

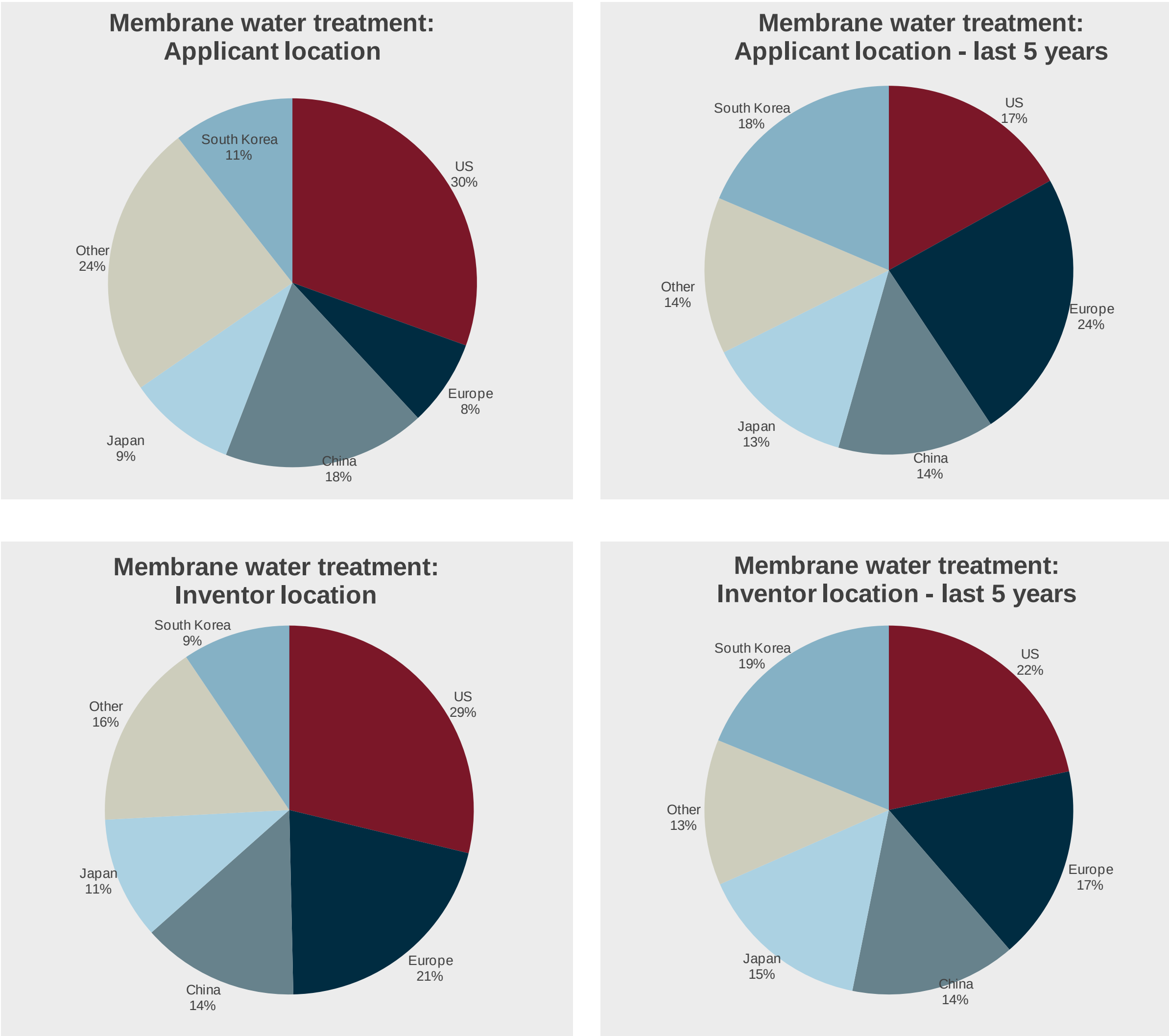


Figure 18: Analysis of applicant and inventor locations for membrane water treatment technologies

Table 15 shows a more detailed breakdown of locations of applicants and inventors listed on membrane water treatment patents. Canadian and Australian/New Zealand applicants appear to play a small role in this technology field, with 4% and 3% of overall patent filings respectively. Both these regions have made up a slightly lower percentage of patent applicants in the last 5 years, with both decreasing to 2% of the total.

Africa

Very few applicants for patents in the membrane water treatment field are listed as being based in Africa, Out of the 11 African patent applications 10 have come from South Africa and 1 from Egypt. Only 2 applications have come from (South) Africa in the last 5 years.

Middle East

A limited number of patent applicants in the membrane water treatment field come from the Middle East. Overall 34 patent applications have been filed with Middle East-based applicants, 27 from Israel and 7 from Saudi Arabia. In the last 5 years 8 patents have had an Israeli applicant and 3 have had a Saudi Arabian applicant.

Asia

Asian applicants play a significant role in this field and have together filed 42% of global membrane water treatment patents. In Asia Chinese players are the greatest patent holders overall, but in the last 5 years the majority of applications have come from South Korean players. Japan has continued to have a significant presence in this field, with 10% of the global patent filings overall, increasing to 13% over the last 5 years. Due to the predominance of Japanese companies in this field it could be expected that a large % of the patents without an application location listed are from Japanese applicants and that the true % is larger than seen here. A small number of additional patents have been filed by applicants from other Asian countries, most significantly Taiwan (32), India (26) and Singapore (13). Taiwanese and Indian applicants have each filed 7 patents in the last 5 years and 8 have been filed from applicants based in Singapore.

Table 15: Geographical breakdown of applicants and inventors - membrane water treatment technology[34]

Geography	Applicant location	Applicant location – Last 5 years	Inventor location	Inventor location - last 5 years
US	758 (31%)	142 (17%)	1684 (29%)	408 (22%)
Canada	88 (4%)	15 (2%)	231 (4%)	53 (3%)
Europe	188 (8%)	199 (24%)	1222 (21%)	321 (17%)
Russia and USSR	11 (<1%)	12 (1%)	137 (2%)	28 (1%)
China	442 (18%)	115 (14%)	807 (14%)	274 (15%)
Japan	236 (10%)	111 (13%)	628 (11%)	287 (15%)
South Korea	264 (11%)	156 (19%)	553 (9%)	355 (19%)
Other Asian Patents	76 (3%)	26 (3%)	159 (3%)	63 (3%)
Middle East	34 (1%)	11 (1%)	73 (1%)	25 (1%)
Africa	11 (<1%)	2 (<1%)	28 (<1%)	7 (<1%)
Australia and New Zealand	65 (3%)	14 (2%)	76 (1%)	39 (2%)
Central and South America	0 (0%)	3 (<1%)	16 (<1%)	4 (<1%)
Other	311 (13%)	32 (4%)	239 (4%)	22 (1%)

4.4.2 Geography analysis of UV water treatment technologies

This section discusses the geographical analysis of patents in the UV water treatment technology field. As with membrane water treatment China and South Korea have become much more prominent as OFF and OSF locations in the last 5 years as the percentage European and the US filings has declined. China and South Korea are more often locations for OFF than OSF filings and this is reflected in the applicant location data, which shows a large increase in patent applications from these countries in the last 5 years.

[34] Note that 39.4% of the patents in the dataset had no applicant location listed and 15.6% had no inventor location. Hence the analysis is likely to be an incomplete picture of the locations of assignees and inventors.

Office of first and offices of second filing (OFF and OSF)

Figure 19 shows the OFF and OSF filings in the UV water treatment field. As for membrane water treatment, Japan and the US are the major locations for OFF filings in the UV water treatment field. Another similarity is the increase in China and South Korea OFF filings, with China representing the most prominent location. Both fields both show a proportional decrease in European, Japanese and US filings in the last 5 years. South Korea is proportionally more active in this field than in membrane water treatment and Japanese and European OFF filings make up a smaller percentage of the total. The OSF filings show a very strong correlation with membrane water treatment OSF filings with similar percentage in all jurisdictions, though PCT patents make a small percentage of UV OSF filings.

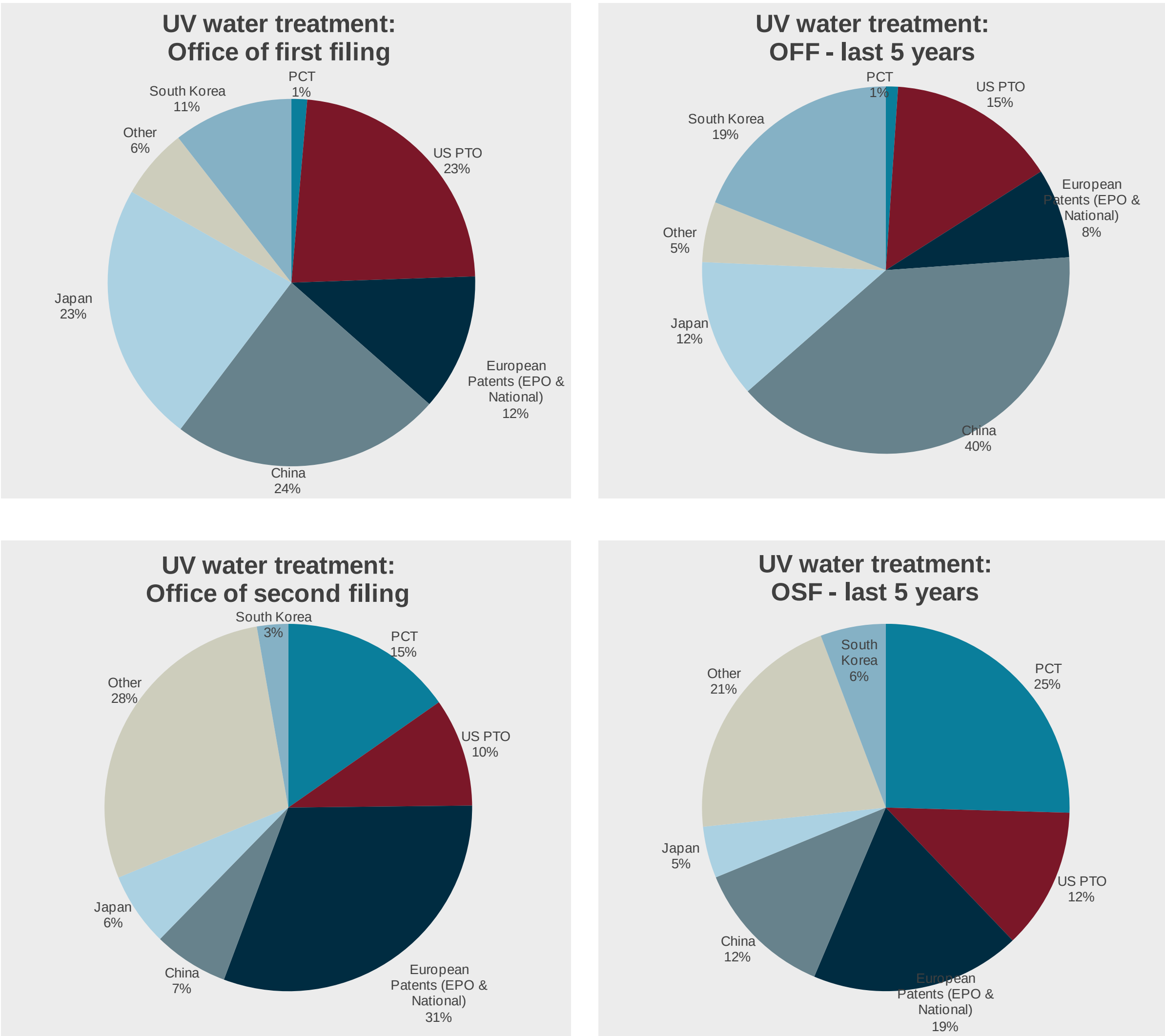


Figure 19: Analysis of patent filings by geography for UV water treatment

Table 16 provides a more detailed breakdown of the OFF and OFS locations listed on UV water treatment patents. Canada and Australia/New Zealand are significant locations for OSF filings, making up 8% and 9% respectively. This has been constant over the last 5 years, though Australian/NZ has declined in the last 5 years as an OSF. Both are not significant locations for OFF, this could indicate that there are important markets for water treatment technology in this field but they are not primary centres for innovation. The trend is very similar for UV filings as for membrane water treatment.

Africa

Only 3 patents have been filed with African states as the office of first filing connected to the field of UV water treatment, all of which were filed in South Africa. Of these filings none have occurred in the last 5 years. A larger number have listed African jurisdictions as the OSF, with filings in South Africa, Morocco and Egypt, however this still only makes up 2% of all OSF filings in this field.

Middle East

All Middle Eastern OFF and OSF filings in this field have been filed in Israel. There have only been 8 OFF (0.4%) and 22 OSF (1%) filings overall and very few in the last 5 years

Asia

China is the most prominent location for OSF filings, with slightly more OFF filings than the US and Japan overall and considerably more over the last 5 years. The percentage of filings in South Korea has also increased over this period, overtaking Japan as a location for OFF and OSF patent filings. The other Asian states are much less prominent as locations for patent filings, with the greatest contribution coming from Taiwan (7 OFF and 35 OSF filing corresponding to 0.4% and 1% respectively).

Table 16: Geography of OFF and OSF filings of UV water treatment technology

Geography	OFF	OFF - Last 5 years	OSF	OSF - last 5 years
PCT	25 (1%)	5 (1%)	373 (15%)	84 (25%)
US PTO	420 (23%)	70 (15%)	233 (10%)	41 (12%)
Canada	14 (1%)	3 (1%)	200 (8%)	26 (8%)
European Patents	219 (12%)	37 (8%)	753 (31%)	61 (18%)
Russia and USSR	49 (3%)	11 (2%)	27 (1%)	4 (1%)
China	433 (24%)	186 (40%)	161 (7%)	41 (12%)
Japan	417 (23%)	57 (12%)	158 (6%)	15 (5%)
South Korea	192 (11%)	89 (19%)	67 (3%)	19 (6%)
Other Asian Patents	13 (1%)	6 (1%)	76 (3%)	9 (3%)
Middle East	8 (<1%)	2 (<1%)	22 (1%)	3 (1%)
Africa	3 (<1%)	0 (0%)	56 (2%)	5 (2%)
Australia and New Zealand	23 (1%)	2 (<1%)	215 (9%)	12 (4%)
Central and South America	3 (<1%)	1 (<1%)	98 (4%)	10 (3%)
Other	0 (0%)	0 (0%)	1 (<1%)	0 (0%)

Applicant and inventor residence

The breakdown of applicant and inventor locations for UV water treatment patents is shown in Figure 20. Like in the membrane field, US applicants own the largest percentage of the overall IP in this field, though its share has decreased in the last 5 years as the percentage of South Korean patent owners has surged. Though South Korea has come to play a large role in the UV and membrane water treatment fields, its presence in the UV field is greater, with 33% of patents in the last 5 years. As for membrane water treatment the proportion of Japanese applicants in the field has remained fairly constant, however unlike in the membrane field in UV water treatment the fraction of applicants from Europe has decreased. The inventor location data reflects the applicant location data very closely.

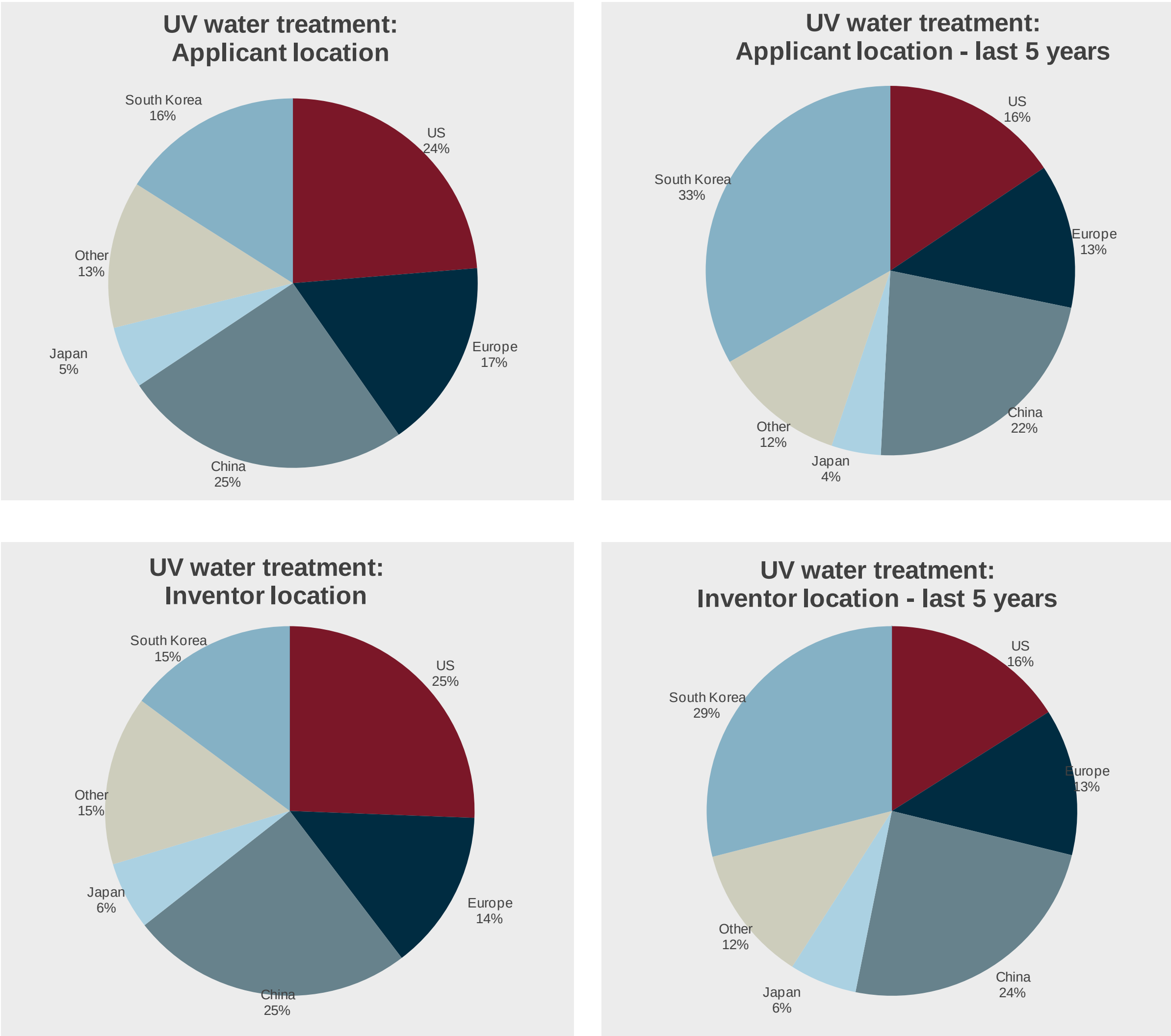


Figure 20: Analysis of applicant and inventor locations for UV water treatment

Table 17 shows a more detailed breakdown of locations of applicants and inventors listed on UV water treatment patents. 5% of the applicants are based in Canada, similar to the 4% in the membrane water treatment field and also like in that field the percentage has declined slightly in the last 5 years, to 3%. Applicants from Australia/New Zealand do not make up a significant percentage of all applications in this field with only 1% of applications. This reflects the OFF data, which also shows 1% of OFF filings where in Australia/New Zealand. Russia has produced a limited number of applicants in this field and has increased in the last 5 years, with 4% in that period and 2% overall. The inventor geography reflects the applicant geography analysis, though China and Korea has a high percentage of inventors compared to applicants, while this is the reverse for Japan.

Africa

The patent data does not indicate any involvement by African players in the UV water treatment field. There have been no patents filed with applicants based in Africa in this field and only one inventor was listed as being based in Africa.

Middle East

In the UV water treatment field, as with membrane water treatment there is only a small showing from Middle Eastern applicant, with 14 patents filed (1.2%), and mostly to applicants from Israel (13 Israeli holders and 1 Saudi Arabian). In recent years 3 patents (1%) from Israeli applicants represent the only activity in this field.

Asia

The patent data indicates that Asia is the most actively region for research into UV water treatment. Chinese applicants are the largest patent holders globally over time, with 307 patent applications (25%). However, South Korea players appear to be overtaking them, having filed more IP in the last 5 years than any other country. This trend was also seen for membrane water treatment. Japanese companies and research institutes continue to play a role, though a smaller one than in the membrane water treatment field. Of the other Asian countries, Taiwanese applicants have filed 10 patents overall (1%) and 6 have come from players based in Hong Kong (0.5%).

Table 17: Applicant and inventor locations listed on UV water treatment patents[35]

Geography	Applicant	Applicant – Last 5 years	Inventor	Inventor – Last 5 years
US	287 (24%)	47 (16%)	616 (26%)	114 (16%)
Canada	60 (5%)	8 (3%)	116 (5%)	17 (2%)
Europe	201 (17%)	38 (13%)	338 (14%)	91 (13%)
Russia and USSR	23 (2%)	13 (4%)	77 (3%)	33 (5%)
China	307 (5%)	68 (23%)	596 (25%)	173 (24%)
Japan	66 (16%)	13 (4%)	143 (6%)	42 (6%)
South Korea	194 (2%)	100 (33%)	357 (15%)	206 (29%)
Other Asian	23 (<1%)	5 (2%)	54 (2%)	17 (2%)
Middle East	14 (1%)	3 (1%)	26 (1%)	12 (2%)
Africa	0 (0%)	0 (0%)	1 (<1%)	0 (0%)
Australia and New Zealand	12 (1%)	3 (1%)	23 (1%)	3 (<1%)
Central and South America	0 (0%)	1 (<1%)	14 (1%)	3 (<1%)
Other	368 (30%)	2 (1%)	46 (2%)	0 (0%)

[35] Note that 30.7% of the patents had no applicant country listed and 10.8% did not have list an inventor country.

4.5 *Most frequently cited patents*

Table 18 shows the most frequently cited patents in both membrane and UV water treatment. The top cited patent has 115 forward citations and was filed in 1995. The top cited UV water treatment patent was from 1993 and has 113 forward references. None of the most frequently cited patents refer to desalination.

Table 18: Top cited US patents relating to membrane and UV water treatment

Publication number	# Citations	Applicant	Application date	Membrane dataset	UV dataset
US5639373	115	Zenon Environmental Inc.	1995-08-11	✓	
US5582717	113	Di Santo Dennis E	1993-04-26		✓
US5266215	110	Engelhard Rolf	1993-04-27	✓	✓
US4752401	106	Safe Water Systems International Inc.	1987-02-26		✓
US5783083	105	Zenon Environmental Inc.	1996-07-31	✓	
US4971687	103	Knight Jr John B	1989-04-24	✓	✓
US4969996	99	Brita Wasser-FilterI-Systeme GMBH	1989-02-28	✓	
US5045288	98	Board Of Regents Arizona State University	1989-09-15		✓
US4179616	93	Thetford Corp	1978-10-02		✓
US4160727	91	Foremost-Mckesson Inc	1976-12-07	✓	

5 Water industry: Market structure, policy options and the role of IP

Patents are a strong, but incomplete indicator of technology and innovation. It may take years for a patented technology to make its way to market as a commercial product, or it may never be commercialised at all. Many products are protected by multiple patents or a combination of third party technology (which may or may not be patented) and a company's own know-how or design. While it could be said that 'all patents are equal', the owners of those patents can differ significantly in size, commercialisation strategy and market positioning. In order to better contextualise the results of the patent landscape

- several case studies were developed to show how water treatment technologies are being deployed in *practice*
- a survey exploring different issues of the market structure and usage of IP in the water industry was completed by 57 industry experts

5.1 Likely focus of technology innovation

The report focuses primarily on the membranes and UV-based water treatment technologies. Yet as discussed in sections 1.2 and 2.1 there is a much wider set of water treatment technologies that could be the focus of future patent landscaping. In the survey respondents were asked to identify the technologies where they anticipate increased innovation will have the highest impact. As the results in Figure 21 show, the membranes field received the largest number of 'votes'. While radiation-based technologies (which includes UV) was among the top 5 technologies identified by respondents, but strong interest was also shown in coagulation, EDI and a range of other technologies. Participants felt that R&D in UV water treatment could help to create better UV disinfection for large scale municipal plants. UV was said to be useful because it reduces the amount of DBP (disinfection by products) from chemical disinfection. EDI, ion exchange and adsorption technologies was viewed as a younger technology with lots of scope for improvement. Heat treatment processes can be further optimised through improvements in process efficiency, construction materials and process chemicals.

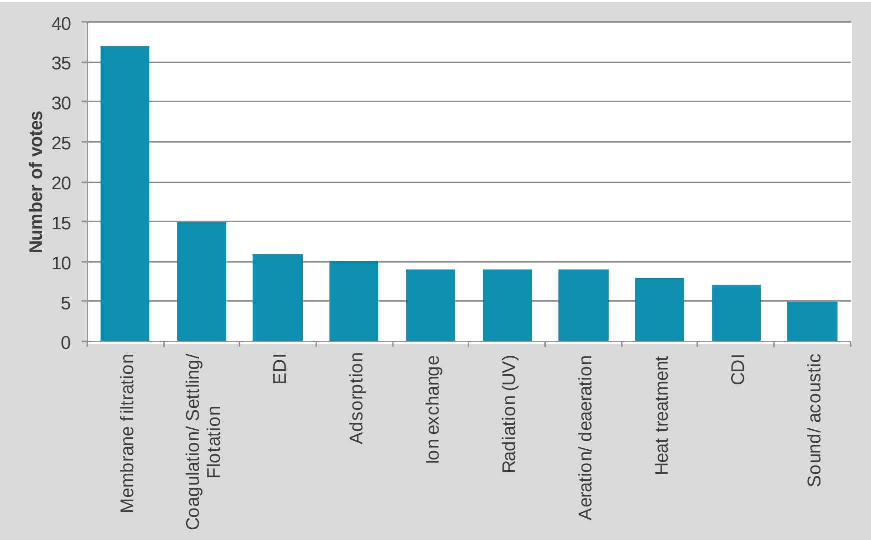


Figure 21: Technologies with the most potential for further R&D

Respondents were also asked to identify areas where there should be further R&D focus (in whatever technology is most appropriate). The fields identified by the respondents were:

- Cost reduction
- Energy savings/lower pressure requirements
- More robust membranes (especially with resistance to fouling)
- Improved materials (such as chemicals for nano-polymers)
- Better chemicals for treatment of membranes
- Automated water intake quality detection

The responses also identified different technology types in which innovation may be focusing, including support control systems and more novel/less widely adopted water treatment technologies (summarised in Error! Reference source not found. with example companies in each).

Table 19: Technology spaces of further innovation

Category	Technology notes	Example companies
Control systems	This allows systems to respond to changing conditions such as changes in the water intake quality or pressure changes in the systems. Areas of innovation include: • Control software • Sensors • Smart metering	Takadu Derceto
Waste Recovery	Example technologies • Re-use of brine solution in desalination • Chemical waste from the water treatment process	Desah BCR environment
Efficiency	Energy Recovery	ERI
Other water treatment technologies	Photonics Low temperature distillation Advanced oxidation technology	Engenuity Ocean Thermal Technologies corp.

5.2 Market structure and example company case studies

Traditionally water treatment technology has been dominated by large equipment and chemicals suppliers. This is reflected in the large number of legacy patents by some of the larger industrial conglomerates globally. However, increased innovation in the water treatment industry globally has seen the entry of a number of exciting new players, as well as the lateral migration of consumer goods companies into this space. Survey respondents were asked to identify companies that they thought were at the cutting edge of innovation. While the survey results indicate that big players such as GE and Siemens were involved in a lot of innovative R&D, and that there are a number of smaller players who are also developing innovative technologies. It was interesting that a number of engineering integrator and services companies were also identified as innovative. Membrane developers that were cited as particularly innovative included large membrane suppliers, including Dow, Toray and Kuboto as well as a number of smaller companies, such as NanoH2O.

The case studies below show the diversity of players in the membrane and UV technology fields, including major multinationals (Philips, LG), universities (MIT) and a geographic cross section of other corporations – Amiad (Israel), TrojanUV (Canada) and Metawater (Japan)[36].

5.2.1 Philips - UV Technology

Philips is a Dutch multinational, headquartered in Amsterdam. Founded as a light bulb manufacturer in Eindhoven in 1891 by Gerard Philips, it currently employs around 114,500 people in over 60 countries with revenue of €25.42 billion in 2010. They are organised into three divisions:

- Philips Consumer Lifestyle (Philips Consumer Electronics, Philips Domestic Appliances and Personal Care)
- Philips Healthcare (formerly Philips Medical Systems)
- Philips Lighting (the traditional powerhouse of the company)

Philips has supplied UV lamps for water treatment systems in the past. Recently they have moved into producing their own water treatment systems, such as the release of the Philips Intelligent Water Purifier in 2007. This is designed for household use and can be used as part of an existing tap or wall mounted. It has been initially rolled out in India, with likely focus elsewhere in emerging markets or peripheral areas without access to centralised potable water. The water purifier uses UV water treatment, but also contains a filter to remove particles. In addition to this Philips manufacturers water filters for other domestic appliances such as fridges and kettles.

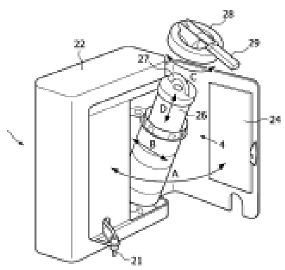
Product (external)	Filter cartridge	Patent WO2008056311: Water purification device and filter unit
		

Figure 22: Philips Intelligent Water Purifier product and patent drawing comparison.

The applicant-inventor network diagram of Philips does not show any collaboration with corporate or university partners for this technology.

[36] Needless to say, these case studies are meant to serve as examples, and are not exhaustive of all relevant participants or technologies. These are not to be taken in any way as recommendations for specific technologies.

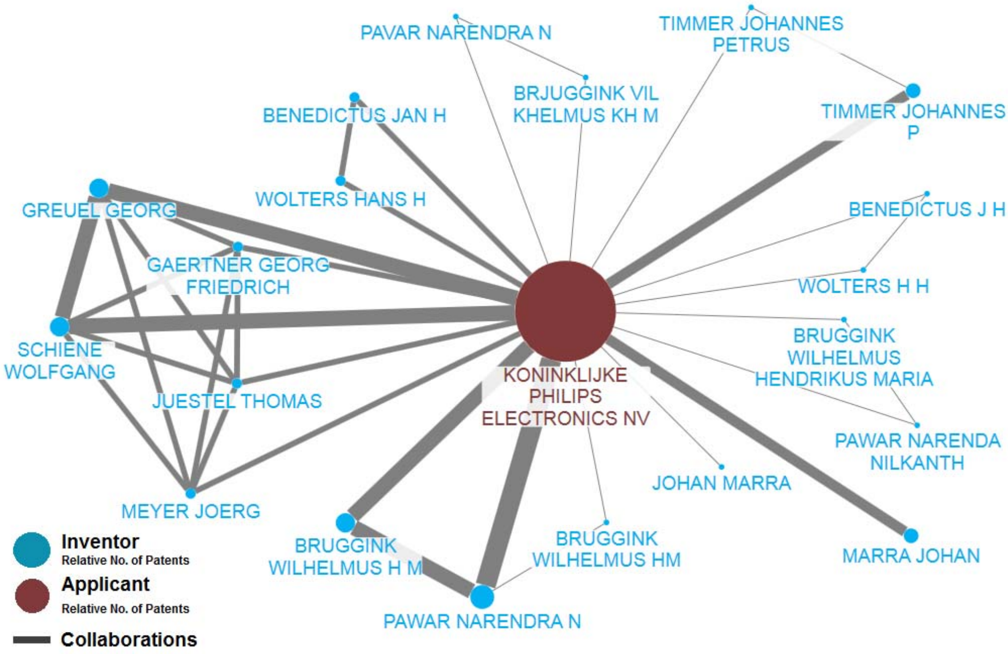


Figure 23: Philips applicant-inventor network diagram

5.2.2 Trojan Technologies Inc

Trojan Technologies Inc (trading as 'Trojan UV') is a Canadian water treatment company with a wide range of UV water treatment products for many different sectors. They were founded in 1976 in London, Ontario and their current revenue is over $100 million. The company's focus areas include municipal, marine, industrial and domestic water treatment. Its subsidiaries, Viqua and Aquafine, sell a diverse range of residential and industrial UV water treatment products. They also sell ballast water treatment systems for ships under the brand name Trojan Marinex. An example product from Viqua is their Sterilight range of UV water treatment system, which connects a UV lamp directly to the residential water supply, disinfecting water as it enters the residence. There are various product sizes and specifications so that users are able to select the product which fits their specific residential need. Some of these products also include monitoring systems which track the quality of water entering/leaving the system and adapts the treatment accordingly. The UV lamps are replaceable.

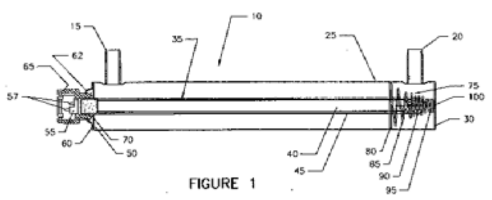
Trojan's SteriLight SP600-HO	Patent WO9519188A1: UV Disinfection unit
	

Figure 24: Example of Trojan SteriLight product range and patent drawing comparison

The applicant-inventor network diagram of Trojan Technologies does not show any collaboration with corporate partners. This does not necessarily mean that they are not involved in any joint developments, but simply that they are keeping their IP separate from such ventures, should they exist.

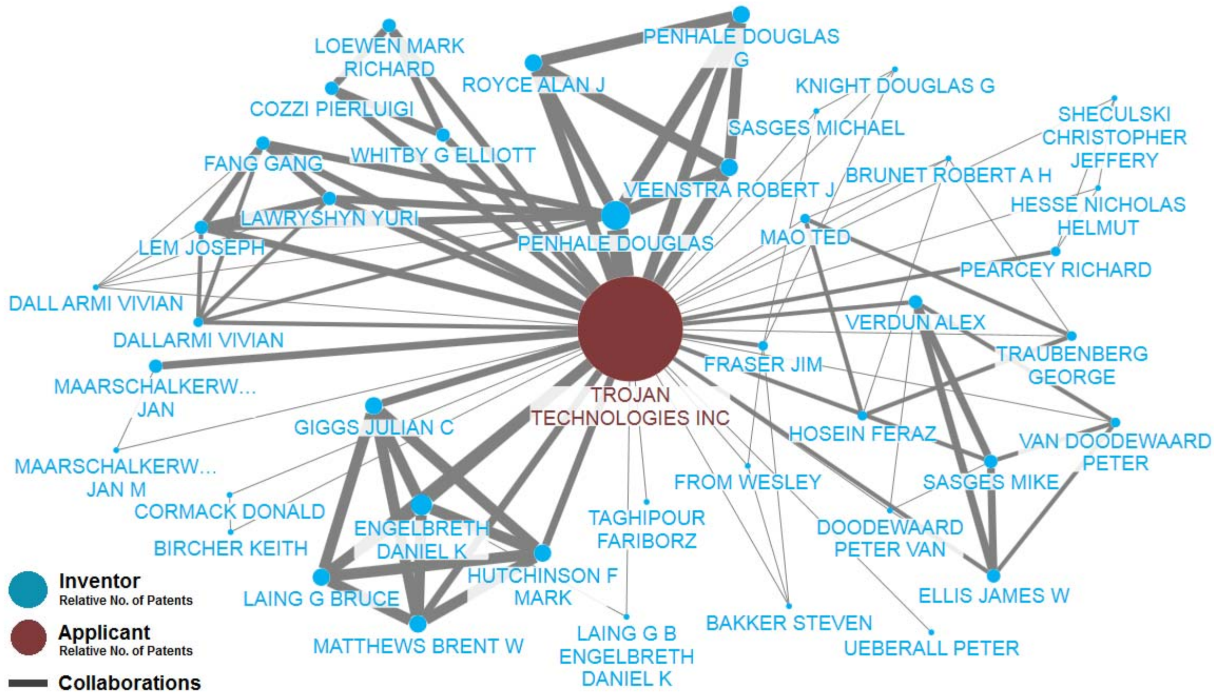


Figure 25: Trojan Technologies applicant- inventor network diagram.

5.2.3 LG Group

Founded in 1947, the LG Group is one of South Korea's largest multinational companies. LG electronics is a subsidiary of LG group, employs 91,254 people and in 2011 announced revenue of $48.97 billion. It is active in a broad range of consumer electronics sectors including mobile communications, home entertainment and domestic appliances.

The LG consumer water purifier range was released in India in 2011[37]. It consists of a four stage filtration system[38]:

- a sediment filter removing suspended solids,
- a pre-carbon filter removing chlorine and volatile organic compounds,
- a reverse osmosis membrane removing heavy metals, ionised compounds and microorganisms,
- a post carbon filter improves the smell and taste of the water.

Various safety and hygiene features were also considered during the design of the product casing, such as the heating method and water storage method.

[37] http://www.business-standard.com/india/news/lg-enters-water-purifier-mktrs-40k-product/131805/on

[38] http://www.lg.com/in/home-appliances/water-purifier/LG-WCD74GJ1P.jsp

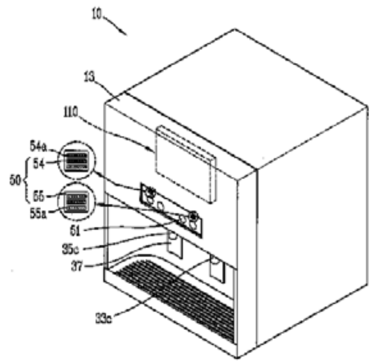
LG WCD74GJ1P Water Purifier	Patent EP2393570A1: Water purifying apparatus
	

Figure 26: LG water treatment device and patent drawing comparison

There has been information transfer between LG electronics and two other Korean companies in this field (Woongjin and SK Chemicals). The patent links are not direct, but through inventors from both companies who have appeared on patents together. It is unlikely that a direct collaboration between Woongjin and LG has occurred if we consider the tension between the two companies in the Korean press[39]. It could however be a strong indication that employees have moved between the companies.

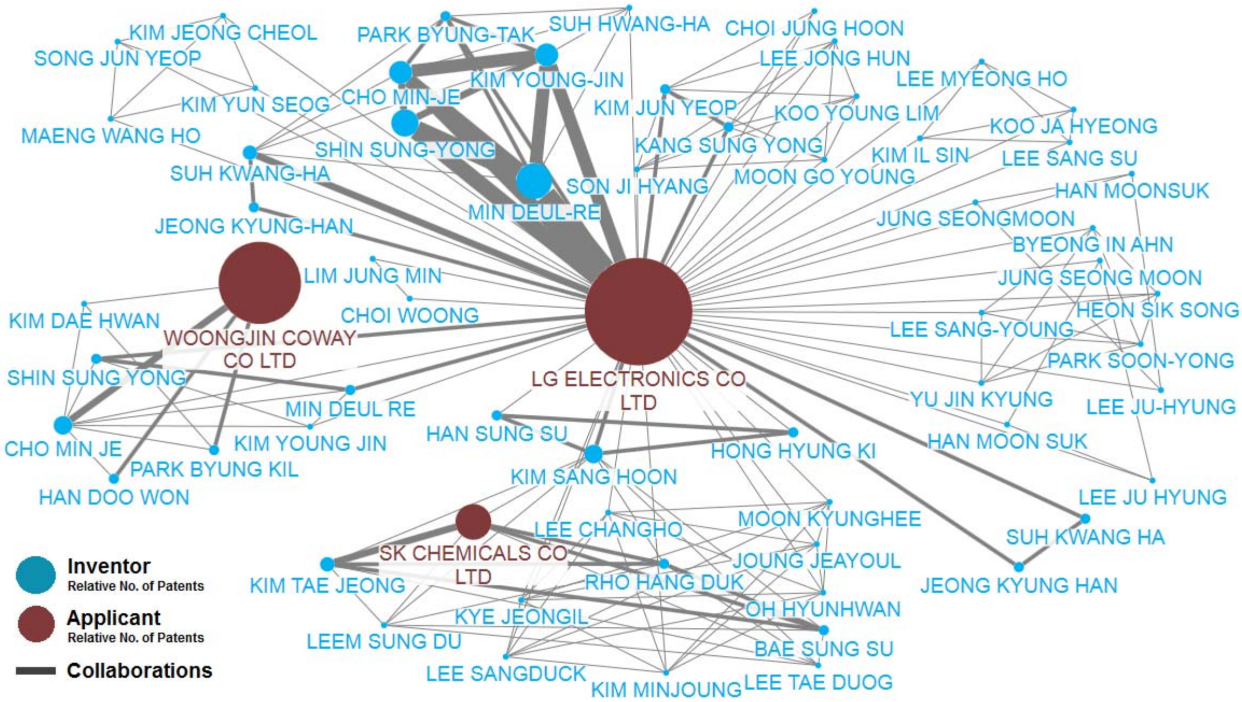


Figure 27: LG Electronics applicant-inventor network diagram

[39] http://www.koreaherald.com/business/Detail.jsp?newsMLId=20111201000701,

http://www.brightwire.com/news/156072-woongjin-coway-wins-trademark-lawsuit-against-lg-household-health-care

5.2.4 Massachusetts Institute of Technology

MIT is a one of the few American universities found to be active in this field. It is interesting that Jonathan F. Hester has patented both with MIT and 3M. Upon further investigation it appears that he was placed at MIT for the 3M Company Fellowship in 1999 in the Material Science and Engineering department.[40] The patents filed based on this research date from 2001. Further patents from MIT in our dataset were filed by different groups in 2010 and 2011 and do not seem to be related to this earlier work.

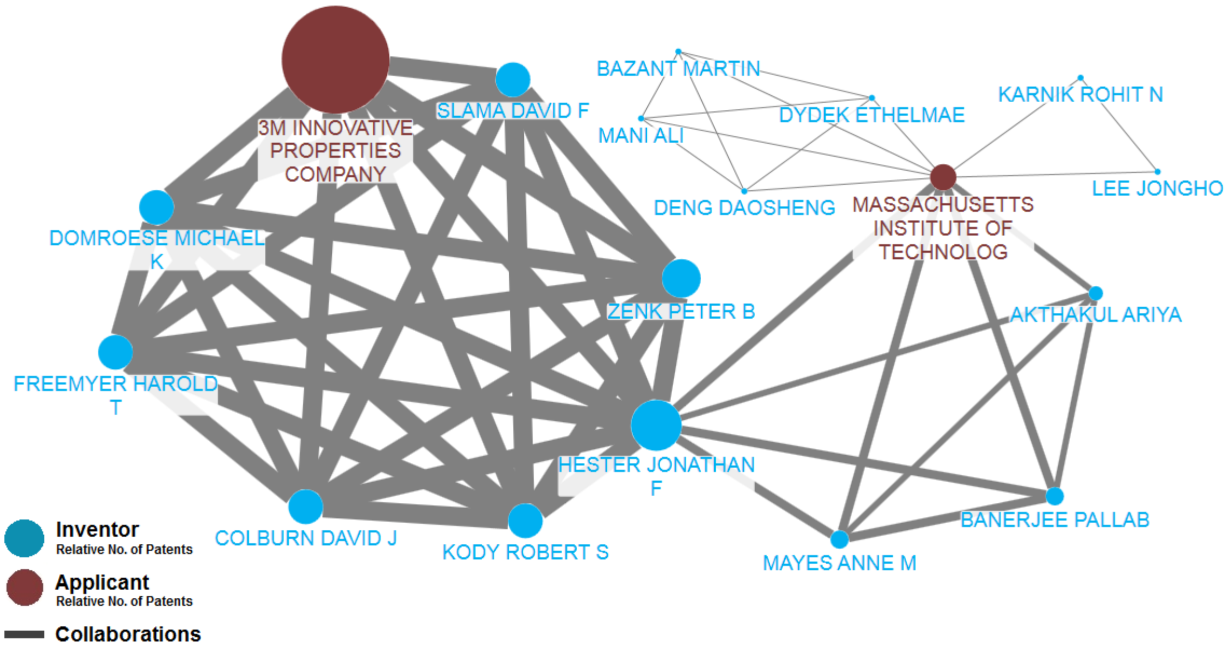


Figure 28: MIT applicant and inventor network diagram.

5.2.5 Amiad

While Amiad did not appear in the patent dataset, the company has been as a case study as they are a well-known, active supplier in the membrane water treatment field. Upon a further investigation of their patent portfolio, we concluded that the reason for their exclusion was due to the nature of their international patent filings. This report has focussed on membrane filtration specifically for municipal, residential and agricultural water treatment. However, due to the diverse applications of their membrane technologies their patents tend to be of a similarly broad nature and do not mention water explicitly, but refer more generally to the treatment of fluids.[41]

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[40] http://web.mit.edu/annualreports/pres99/11.05.html

[41] http://worldwide.espacenet.com/publicationDetails/inpadocPatentFamily?CC=WO&NR=2011107986A2&KC=A2&FT=D&ND=5&date=20110909&DB=EPODOC&locale=en_EP

http://worldwide.espacenet.com/publicationDetails/inpadocPatentFamily?CC=US&NR=2008047885A1&KC=A1&FT=D&ND=4&date=20080228&DB=EPODOC&locale=en_EP

Background

Founded in 1962, Amiad Filtration Systems Limited has developed a range of compact, automatic, self-cleaning filters incorporating innovative technology. This provides users from the water treatment and other industries a fast, efficient self-cleaning technology for continuous flow of filtered water. Suction-scanning technology combines focused flush with automation to provide 100% cleaning of the screen area. The company revenues in 2010 were $89.4million[42].

In addition to desalination, the technology is used in a range of industries including waste water treatment, ballast water, oil & gas and other fields.

Technology's application to desalination

Amiad's water filtration technology is used in desalination pre-filtration systems. Application can be large scale (as in the Chennai case) or modular (as in the Antarctica installation).

Large scale application examples:

- Pre-filtration system, based on Arkal disc technology at a desalination plant in Adelaide, Australia. Desalination plant capacity is using RO desalination technology
- Pre-filtration system for desalination plant in Chennai, India. Using 8,600 reverse osmosis membranes, the facility is one of the largest desalination plants in Asia, will process water from the Bay of Bengal to supply 100 million litres a day of purified water to the city of Chennai[43].

Pre-treatment of the raw sea water, containing up to 6.4ppm aluminium and about 50NTU of turbidity, includes coagulation-flocculation, gravity and pressure filtration.

Modular/small-scale example:

The ultra-compact skid mounted system is only 6m long,1.5m wide and 2m high and includes all the equipment needed for the desalination process:

- Screen pre-filter, for removal of coarse particles.
- Ultra-filtration membranes for complete clarification of the water and removal of algae and bacteria.
- Reverse osmosis membranes for desalination - as well as pumps, controls and piping.[44]

5.2.6 Metawater

Metawater is a Japanese environmental water treatment company based in Tokyo, Japan. They were established in 2008 following the merger of NGK Water Environment Systems Ltd and Fuji Electric Water Environmental Systems Co., Ltd.

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[42] Amiad Water Systems, Interim Results June 2011 http://www.amiad.com/files/Amiad_Interim_Results_2011_15-09-11_(2).pdf

[43] http://www.water-technology.net/projects/minjurdesalination/

[44] http://www.amiad.com.au/files/newsletter_0507.pdf

Metawater produces a range of water treatment products including a ceramic membrane filtration system. It is the largest Japanese supplier of such systems.

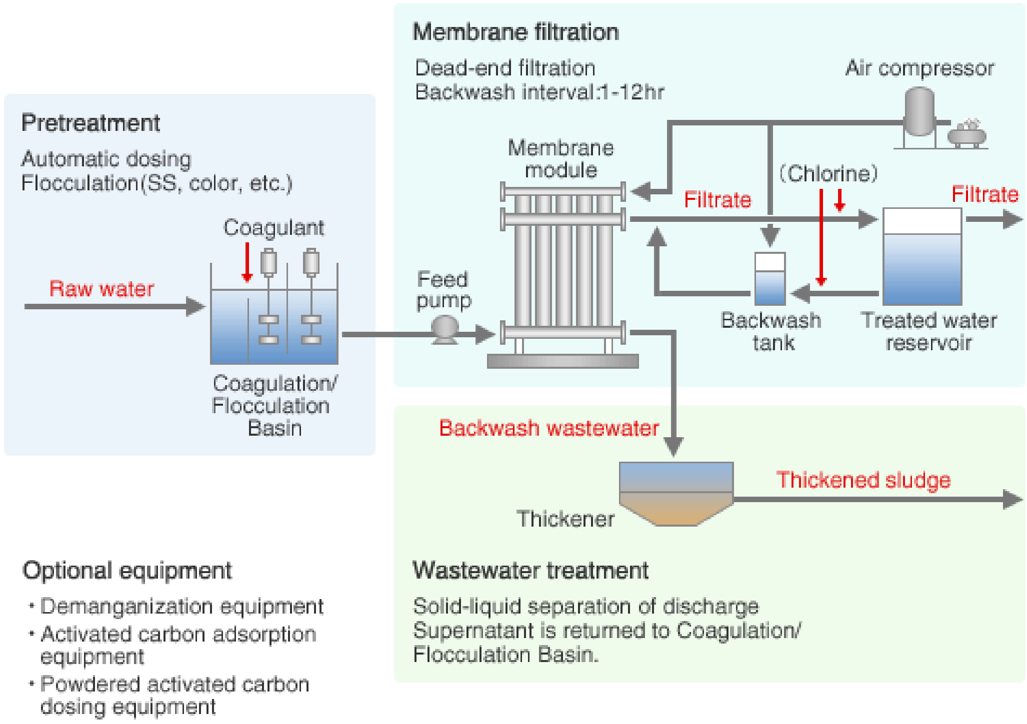

Figure 29: An example schematic of Metawater's membrane filtration system[45]

From their inventor-applicant network diagram, there is no clear indication of any external collaboration in their membrane development.

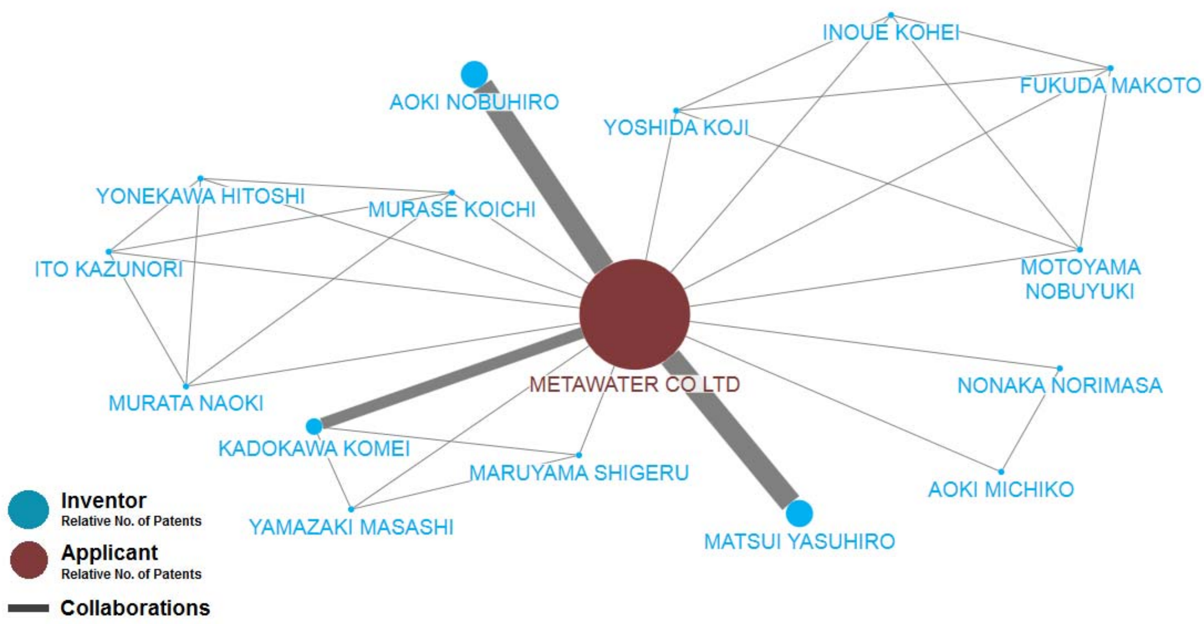

Figure 30: Metawater applicant and inventor network diagram

[45] http://www.metawater.co.jp/eng/product/drinking/membrane_clarify/flow.html

In addition to their work in the membrane industry, they are also involved in larger water projects. Metawater is the largest shareholder in Water Next Yokohama Co, which deals with the design, construction, operation and maintenance of water treatment systems.

Example project: Kawai Water Purification Plant Redevelopment Project, Yokohama Waterworks Bureau[46]

Water Next Yokohama Co is currently working on the "Kawai Water Purification Plant Redevelopment Project" with Yokohama Waterworks. Metawater will play a large role in the project including the manufacture and maintenance of the membrane filtration facility. The Kawai Water Purification Plant will be the largest-scale membrane filtration plant in Japan. The project aims to be environmentally friendly through the use of solar power and the recycling of waste.

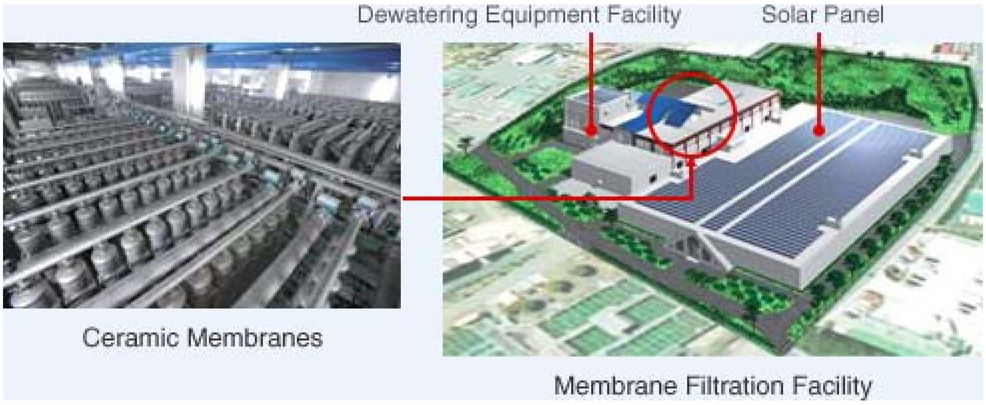

Figure 31: Envisaged Kawai Water Purification Plant under development by water next Yokohama Co.

5.3 Policy options in the water industry

Regulatory and competition related issues

Large companies dominate the market and so smaller innovative companies can struggle to get market recognition. Ideally, the large players could licence from or acquire smaller technology companies, which would allow new technologies to be delivered to the market through existing supply chains. However in practice the water industry is very conservative while in some instances acts as a regulated monopoly. Reasons for the conservatism is water utilities' aversion to risk as well as a lack of awareness by senior executives and decisions makers on the latest technological developments in the industry. The high cost of adding new technologies to existing systems and the stringent regulation governing the industry adds to this conservatism.

A number of the large companies undertake activities aimed at the growth of innovative technologies. They support technologies which they believe will improve efficiency and can lead to a decrease in operating cost in the medium term, or that the technology could be one of the longer term winners and they would like to be at the head of the industry by becoming early adopters. The large companies have two ways of focussing on innovation. In some instances they undertake their own R&D with funding far superior

[46] http://www.metawater.co.jp/eng/product/drinking/membrane_clarify/location.html

to the small new entrants, which can be viewed as a barrier to innovation from the smaller companies. In other instances large companies have VC-type incubators for seed funding into novel technological solutions, e.g. Veolia and GE. This source of funding means that the corporations can also act as a catalyst to innovation.

In some instances it is possible for larger players to hold back innovation in the field to fit with their research and development timeline as they cannot innovate as efficiently as the smaller entrants. This however creates the risk that one of their competitors implements this technology gaining a lead in the market.

Governments also play an important role. Many participants felt that government funding in the water industry allow the big players to continue promoting and operating less efficient technologies, even though they may not be profitable. This could starve smaller innovative companies out of the market. Corruption can also be a barrier for entry of new technologies into the market, especially in the developing world.

However, it all comes down to cost. If a new technology is proven to save reduce the systems cost money the big players would be willing to listen.

The emergence of electronics companies in this field, focussing on creating user devices, appears to be further catalysing innovation in this technology area.

Suggested policy actions to increase innovation in the water industry

A number of policy actions were suggested by the participants. Those most often mentioned were

- Tax incentives for investors and enhanced collaboration between universities and private companies.
- Seed funding and incubators
- Greater awareness by regulators of latest technologies
- Streamlining of testing and performance standards within and between countries
- Shorter timeframes for implementation
- Involvement of national health services for setting up of health standards – possibly allowing relaxation of standards that may be unnecessarily stringent

5.4 The role of intellectual property in the water industry

More than half of the industry respondents were found to use patent landscapes to inform their R&D and business strategy decisions (Figure 32).

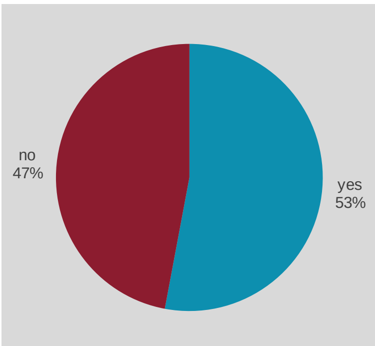

Figure 32: Proportion of survey participants using patent landscaping to inform the R&D and strategy decisions.

The main role for intellectual property in the water industry was found to be protection of the invention, especially during the growth phase. However in practice this applies only in countries where intellectual property is readily enforceable.

A secondary role of intellectual property relates to funding. Intellectual property is useful to be leveraged in licensing and earning money from your invention in that way. Intellectual property is also important in securing VC funding. In fact, one CEO of a funding organisation said that they would not invest in a company if it did not have any intellectual property right around its technology. Even if intellectual property does not cover disruptive or a “game-changing” technology, as long as there is some level of protection already in place.

The way in which licensing agreements are structured can have an important impact on the adoption of the invention. In some instances clients would prefer a choice of suppliers; therefore it may help the adoption of the technology to licence to a number of suppliers. It is important to bear in mind that the type of agreement should be assessed carefully on a case-by-case basis.

Participants rated the importance of 5 different types of intellectual property in the water industry, as displayed in Figure 33. Industrial design and trade secrets and patents were viewed as the most important form of intellectual property. Copyright and trademark were viewed as less important.

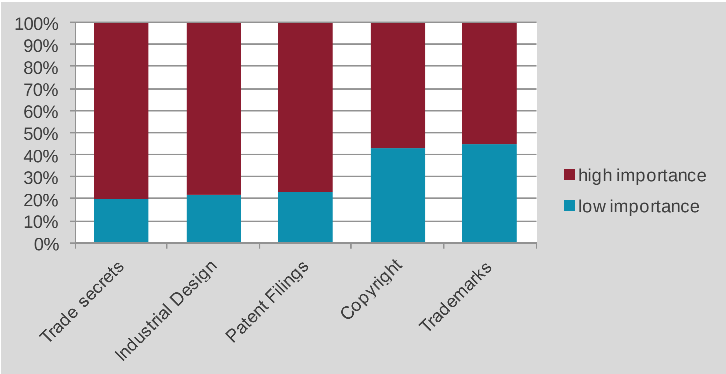

Figure 33: Respondent views on the importance of IP in the water industry

6 Key findings and implications

Patent landscape results - water treatment technology innovation hotspots

The patent landscape showed that there has been considerable level of innovation in the membrane-based water treatment field, with 4,773 patent families, of which 24% were filed in the last 5 years. A significant part of the innovation has been around adaptation of membranes for feed source treatment for desalination systems, which represented 571 patent families. In recent years there has been an acceleration of the rate of innovation, with 30% and 24% in the two categories filed in the last 5 years. The UV water treatment technology space is considerably smaller, at 1,829 patent families - of which 36 are related to applications in desalination technology systems. This space too has seen a significant proportion of new technologies, with 26% and 36% of the patents in the datasets filed in the last 5 years. We also found a convergence between the technologies in the two fields, with 250 patent families representing a combination of membrane- and UV-based water treatment technologies. As shown in the case studies, much of that convergence has been seen in the emergence of modular units combining membrane water treatment with UV-based water disinfection.

The industry experts' survey identified other areas of water treatment technologies where significant levels of innovation may be developing, including coagulation/settling/flotation and EDI, as well as a focus on cost further reduction and efficiency improvements. Water treatment itself however is only one component value chain which delivers potable water and sanitation. Many other technology types can be considered to help improve delivery. Technologies identified were smart control/management/communication systems and waste recovery (from the brine solutions and chemicals used in water treatment).

Centralised vs. decentralised water systems - the role of technology innovation

Discussions with industry experts have identified the decentralised vs. centralised water systems debate as one of the most important areas to watch in the coming years, as large investment deployment takes place in refitting water systems in developed economies and constructing water systems often from scratch in emerging markets and developing economies. Traditional business models in the water industry globally are under pressure, with particular challenges around balancing the public sector need for a 'reasonable' (or capped) profit, and private sector incentives for the adoption and introduction of new technologies[47].

In some ways these tensions can be traced to what technologies have traditionally been adopted; and how investments in technology architectures lead to technology lock-in[48] into system designs that may be inappropriate or inefficient in the long-run, but are cheapest today. Most of the developed economies have followed the Victorian model of water systems, with a large pipe network and large centralised water treatment facilities. Yet advancements in communications technology, the distribution of populations in many developing countries, and the sheer scale of urban development in recent decades may make decentralised water systems more appropriate.

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[47] KPMG (2011) 'Delivering Water Infrastructure using Private Finance'

[48] Arthur, B. (1989) *Increasing Returns and Path Dependence in the Economy*, Ann Arbor, MI: University of Michigan Press

In this context, one of the exciting results of this project was the identification of a range of modular technologies that are aimed at, or facilitate decentralisation of water treatment. For instance all-in-one UV water treatment units that also include membranes for pre-treatment, or water feed treatment technologies that enable modularisation of desalination units are all products and technologies that can facilitate faster deployment of water treatment solutions in *both* rural *and* urban areas, as well as facilitating industrial development in a wider geography.

The role of Intellectual Property in accelerating innovation

Intellectual property (IP) clearly plays an important role in the water industry. However, the highly regulated and fragmented nature of the industry means that there are distinct boundaries between the usage of IP by technology companies, and awareness of the role of IP by final buyers of the technology. For most water utilities the primary focus is on meeting regulatory requirements around safety standards and continuity of supply. Consequently many of the technologies deployed are tried and tested, and frequently of fairly old design. Technology integrators - who may supply turnkey solutions to the utilities - are closer to novel technologies where IP is critical. However, they too may be constrained in the types of technologies they integrate in turnkey systems, due to cost- and traditional-system focused tender designs.

By contrast, where novel technologies are concerned, clearly IP is seen as one of the critical factors supporting commercial success. The survey results indicated that more than half of the respondents use some form of patent landscaping to support R&D and strategic decision making. In addition to patents, industrial design and trade secrets were seen as extremely important, with copyright and trade marks playing a smaller role in the companies' IP strategy.

To understand the role of IP here, we need to consider the market structure. Unlike for instance telecoms or consumer electronics, in the water industry the final user (i.e. utilities) market is highly segmented, even within countries. So even where a new technology is successfully tested by one utility, there are limits to the market where it can be readily diffused. Technology start-ups who have limited access to the sorts of capital expenditure needed for full technology diffusion typically seek to sell a technology or be acquired by one of the major equipment OEMs (original equipment manufacturers). In this context, the IP can be extremely important in providing the technology start-ups with some level of protection towards not only other small technology companies, but also toward the major OEMs and technology integrators who would be interested in acquiring a technology once it has been proven. Companies not only use IP to protect their inventions (possibly with exit objectives), but also to generate revenue through licensing agreements or as leverage to obtain funding from investors or later acquisition by corporates.

So the paradox about the use of IP in the water industry is that there is a fragmentation within the value chain. For new technology developers strong use of IP is a critical feature of their market entry strategies, yet somewhere in the value chain the importance of IP is 'lost', as regulatory considerations take primacy. It is worth considering what the impact would be on the role of IP further down the value chain as investment levels increase in coming years, and in particular if such new investments are focused on newer technologies. It is also possible that as novel water treatment technologies become deployed more widely into commercial industrial settings and in decentralised water supply systems that novel business models can emerge, where IP becomes more critical.

It is broadly accepted that patenting intensity can differ significantly between industries. Yet corporate patenting rates can differ significantly within the same industry between countries (e.g. Japanese and US corporations may have a higher propensity to patent than European corporations), or even within the same country, for similar product portfolios and levels of revenues. Such differences may be related to greater reliance on external networks (e.g. through licensing and open innovation programmes); or simply differences in broad vs. narrow patenting styles between corporations[49]. Consequently corporate patenting activity and portfolio data should be interpreted in the context of the broader market share, value chain and supplier structure.

Market structure

The patent landscape illustrated how technology ownership is dominated by a number of large corporations. While some of the dominance is based on legacy patents, corporations also enter the market through the licensing-in and outright company acquisition of interesting technologies. The high capital intensity of technology deployment in the water industry, complexity of navigating regulatory differences between countries and fragmented markets mean that large organisations with established distribution channels enjoy an advantage in deploying technologies. Major Japanese corporations dominate both membranes and UV water treatment technologies, with some US, EU and South Korean corporations entering the space in the last decade. It was interesting that many non-Japanese companies have expanded their presence in the area. In particular South Korea's LG Electric, Germany's Siemens, France's Degramont and the US's General Electric Corporation have filed the majority of their patents in this field in the last 5 years. In the last 5 years the companies to file the greatest number of UV water treatment patents were Toshiba, Hitachi and WoongJin[50]. However, these findings should not be seen as indicating a concentrating market structure, or a dominance of the patent landscape by the *same* type of companies. There are indications that the water treatment industry may be experiencing structural shifts, from the sources outlined below.

Innovation from smaller players: Many of the most exciting technologies we identified are being developed by smaller and independent companies. In some niche markets (such as desalination) independent players such as Amyad have developed IP-backed technology leadership and market positioning over many years that puts them on a par with the large OEMs in those particular markets. But for many other companies, the strategy appears to be to use a market-proven IP-backed technology to position the company for an acquisition by a large OEM.

Lateral migration of new major players: The patent landscape also demonstrated that major players from the electronics space (such as Philips, LG and Samsung) and FMCG (fast moving consumer goods) space (Unilever and P&G) are entering the water

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[49]See for instance Iliev *et al* (2011) on differences in corporate patenting styles in the medical devices and telehealth field; and Lee *et al* (2009) on such differences in the low-carbon energy space.

[50] This South Korean company began as a publishing company in 1980, but around the mid 90s started to acquire a large portfolio of subsidiaries, including Coway (water treatment) and Ginseng (Beverages)

treatment space. The Philips case study showed how Philips has used technology capabilities in one space to develop new classes of products - such as in the consumer level self-contained UV water purification units. These findings are consistent with an interpretation that sees an increased decentralisation of the water treatment systems, especially in emerging economies where investment into Victorian-style centralised systems is occurring slowly, or may be avoided altogether for a more decentralised system. Clearly further research is needed in this area to validate such findings across a broader range of technologies, and consider the implication for developing economies.

Increasing geographic variety in patent locations: China and South Korea have an increase as OFF and OSF in the last 5 years (South Korea has increased more as an OFF than as an OSF). However, South Korea has grown a lot as a location for applicants and inventors, whereas China has stayed reasonably constant. This indicates that much of China's growth could be from non-Chinese companies choosing it as a location for patent filing. At the same time we see increased activities from Korean companies such as Samsung and LG. We also found that PCT has become more common as a filing location bother OFF and OSF in the last 5 years compared to all time.

Australia and the South Pacific, as well as Canada and India have had a considerable number of filings in membrane field, both in recent years and over all time. They are also popular inventor and assignee locations. Israel is disproportionately active in the patent landscape, both as an area of patent filings, but also as a residence for applicants and inventors.

Countries in Africa and Southern Asia are not significant locations for patent filings in this technology field, despite the importance of water treatment technology to these regions. This indicates that they are not innovation hubs in this field. Only SA, morocco and Egypt feature at all. In other Asian countries with patenting activity in these technology fields are predominantly island states such as Hong Kong, Taiwan, Singapore. There is also some activity from Malaysia, the Philippines and Indonesia.

Policy implications

Reaching of the millennium development goal on safe drinking water is encouraging and underscores the progress that can be made though the deployment of simple and cheap technologies. At the same time, it can be expected that the challenges related to water systems will continue to increase, requiring further investment and technological innovation to meet global needs. In addition to the commercial activity in the water industry, policy makers can also help to boost innovation. The relative lack of focus around IP issues downstream in the water industry (in particular among utilities) may be seen as a symptom of a lower focus on innovation than in other industries in the Cleantech and Energy space. Yet some of the environmental pressures, such as increasing water shortages and growing consumption levels, may require an acceleration of deployment of novel technologies, and altogether novel classes of technology solutions. Should such developments take place, of necessity IP issues will become more important.

The water industry is a mature field as far as the technology solutions are concerned. It is a conservative market, but also an essential one. As water scarcity increases there is also an increasing focus on new technologies from all players in the industry. This means there are increasing opportunities for new entrants in the market. While both large corporate players and new small entrants are developing exciting new technologies, there appear to be significant barriers to deployment of novel technologies, partly attributable to the regulatory focus inherited in the water industry. Hence there may be a role for government policies to accelerate innovation in the water industry. Through our survey we identified a range of policy actions that may help accelerate the development and deployment of essential water technologies:

- Enhanced collaboration between universities and industry
- Seed funding and incubators for water technologies
- Greater awareness by regulators and utilities of latest technologies
- Streamlining of testing and performance standards within and between countries
- Shorter timeframes for implementation of new technologies
- Involvement of national health services for setting up of appropriate health standards – possibly allowing relaxation of current standards

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Appendix 1: Patents and business strategy

In practice, there are a number of ways in which companies use IPRs to shape their business strategy. This section summarises the most important aspects.

Licensing

Patent owners can licence their IP to a third party in return for a fee or some other arrangement between the relevant parties. A specific case is a cross-licensing agreement, where is pre-defined arrangement by which the partners can use one-another's IP. The licensee is then free to use the licensed IP for the time agreed. In some cases the agreement will only cover licensing for production, which means that the IP is licensed by the owner to only be used in a certain predefined way. In cases where a licensee oversteps the agreements of the licensing contract, or where someone is infringing on a patent owner's IP, they may seek enforcement licensing. This generally takes place out of court and targets companies that have already commercialised their technology.

Financing and investment

A company's patent portfolio can be an important consideration during fund-raising (such as through Venture Capital funding). In R&D_ intensive industries, a strong patent portfolio can be a strong signal of quality and market potential. In some industries strong patent protection may be seen as *the* critical factor in being able to commercialise a technology successfully.

Blocking market entry by other players

Patents can be used to block market entry and prevent the sale of products that infringe on the rights of the patent holder. Patent owners can decide whether or not to assert their rights through a patent lawsuit. This decision is based on strategic and economic considerations.

Technology standards bodies

These are industry associations administering key technology standards on behalf of the market. Cross licensing often forms part of these associations as many of the partners will contribute IP for mutual use through some pre-defined arrangement.

Technology transfer[51]

This is often associated by university-to-industry transfer, where universities license the use of their spin-off businesses or other industrial partners.

Risk pooling

Risk pooling involves consortia of major industry players seeking to pool their resources for highly capital intensive and risky ventures. IP is pooled of shared though a predefined arrangement.

[51] For further information see http://www.wipo.int/ip-development/en/strategies/technology.html

Strategic leadership

It may be beneficial for companies to licence their technology to partners and other market players at a less economic rate in order to influence the technology development path favouring the adoption and potential lock-in of their technology.

Patent banks/libraries

Some IP owners keep banks of patents which they do not enforce of use for manufacturing. These patent banks can be used in a number of ways , depending on the owner. Some of these are used as a reference library for smaller players to find IP protecting them against possible litigation by larger players or providing them a platform on which to develop their product. In an extreme case, the patents are accumulated by non-practicing, non-manufacturing entities which seek financial gain through enforcement licensing.

Appendix 2: Challenges addressed through water treatment

Suspended solids

Turbidity

Turbidity is defined by the US EPA as "a principal physical characteristic of water and an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample"[52]. It is a measure of clarity of water and used as an indicator of water quality. Typical sources of turbidity includes waste discharges, runoff water, algae or aquatic weeds in water reservoirs or lakes, erosion of rocks or mineral deposits and humic acids from decaying plants. Turbidity encourages the growth of pathogens in water, leading to waterborne disease outbreaks[53]. The first step in removing turbidity is by injecting coagulants aid or flocculants, allowing the suspended solids to lose the positive charges and 'floc' in larger clumps. It is then followed by filtration process to remove suspended solids from drinking water.

Dissolved solids

Hardness

Hard water is water that contains high amount of minerals such as calcium and magnesium. It causes scaling of heating elements in hot water systems, kettles, irons and other domestic appliances, resulting in shortened life and inefficient performance of the appliances. Hard water is often softened by water companies before putting it into supply, the most common method involves the use of ion exchange resin where Ca^{2+} ions are replaced by twice the number of monocations such as sodium or potassium ions. Lime softening is another method of water softening, utilising the addition of lime (calcium hydroxide) to remove calcium and magnesium ions by precipitation.

Alkalinity

Alkalinity measures the ability of water to neutralise acids and bases so as to maintain a fairly stable pH level. Alkalinity can be caused by the presence of ions such as hydroxides, carbonates and bicarbonates with bicarbonates being the most common sources of alkalinity. High alkaline water causes excessive drying of skin due to the removal of normal skin oils and strong alkaline water produces objectionable soda taste. High amounts of alkalinity can be reduced using RO filtration and demineralisation methods such as distillation and deionisation which also removes total dissolved solids. Lime softening can also be used to precipitate an equivalent amount of alkalinity. Anion resin regenerated with sodium chloride removes carbonates, bicarbonates, sulfates, as well as nitrates ions and replaces these anions with a chemically equivalent amount of chloride ions.

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[52] US EPA. "Chapter 7 Importance of Turbidity." EPA Guidance Manual, Turbidity Provisions (1999)

[53] US EPA. "Chapter 7 Importance of Turbidity." EPA Guidance Manual, Turbidity Provisions (1999)

Free mineral acids

Acidity in ground water is usually caused by free carbon dioxide in water. In some cases, water may contain free mineral acid such as hydrochloric acid, sulphuric acid or nitric acid. Acid water causes corrosion of metal parts in the water system. This can be treated by neutralising the acidity with the addition of alkalis.

Carbon dioxide

Carbon dioxide dissolves easily in water, resulting in carbonic acid. Carbonic acid increases acidity in water and if not neutralised, can cause corrosion of plumbing and distribution systems. Carbon dioxide in water can be removed via aeration or by adding alkalis such as lime or soda ash.

pH

pH is a measure of acidity or alkalinity of water. Water with a pH level lower than 6.5 could indicate acidic, soft, and corrosive water while water with a pH level greater than 8.5 could indicate hard water. Ideal pH of drinking water is between 6 to 8.5, water with low pH can be increase by adding alkalis and water with high pH can be decreased by adding acids.

Sulphate

Sulphate may leach from soil and can be found in most of the natural waters. Sulphate is generally non-toxic but water with high level of sulphate can cause intestinal discomfort, dehydration and diarrhoea. High concentration of sulphate in water also results in a offensive taste in drinking water. Sulphate can be removed via demineralisation using RO filtration and distillation.

Chloride

Chloride is one of the major anions found in water and are generally combined with calcium, magnesium, or sodium. Typical sources of chlorides in water include chloride-containing rocks, agricultural run-off, wastewater and road salting. Chlorides can affect the taste of food products and cause corrosion of metals. High concentration of chloride in water can be reduced using RO filtration, electrodialysis and demineralisation such as deionisation and distillation.

Nitrate

Nitrate, produced from the natural decay of vegetable material in soil and the use of nitrogenous fertilisers on arable farmland, can be found in all tap and bottled water. High concentrations of nitrate in water can cause methaemoglobinaemia (blue baby syndrome), a potentially fatal illness in very young children. Excessive concentration of nitrates in water can be reduced via RO filtration, electrodialysis, ion exchange and demineralisation using distillation.

Fluoride

Fluoride exists naturally in water sources and is derived from fluorine. Higher concentrations of fluoride are usually found in underground sources. Fluoride is well-known for its prevention in tooth decay. For this reason, water fluoridation where controlled amount of fluoride is added into the water supply is implemented in some countries such as the United States and the United Kingdom. However, there have also been claims of adverse effects of fluoride including cancer, birth defects and hypothyroidism. In this case, RO filtration is one effective system in removing fluoride in water.

Sodium

Sodium salts are highly soluble in water. Most drinking water supplies contain less than 20mg/litre of sodium; however this level may exceed 250mg/litre in some countries[54]. Concentration of sodium in water can be influenced by saline intrusion, mineral deposits, sewage effluents and salt used for de-icing roads. Water treatment chemicals such as sodium fluoride, sodium bicarbonate, and sodium hypochlorite can lead to sodium levels as high as 30mg/litre. Domestic water softeners can increase sodium levels to 300mg/litre. Accidental overdoses of sodium chloride have been reported to cause acute effects such as nausea, vomiting and muscular twitching and death[55]. Excessive sodium in drinking water can be reduced by RO filtration, electrodialysis, distillation and ion-exchange.

Silica

Silica (SiO_2) is an oxide of silicon, and can be found in most of the minerals. It is ecologically harmless and presents in surface and well water in the range of 1 to 100 mg/litre. Silica can be removed from water using demineralisation techniques, anion exchange and RO filtration. Silica is objectionable in cooling tower makeup and boiler feed water as silica evaporates in a boiler at high temperatures and then redeposits on the turbine blades. These deposits must be periodically removed or damage to the turbine will occur.

Iron or manganese

Manganese, although occurs naturally in many surface water and groundwater sources, soils and plants, its concentration in water is also affected by human activities. Several studies have linked excessive manganese exposure and neurological disorders in children. High concentrations of manganese have also been associated with toxicity of the nervous system. This can be treated with filtration, ion exchange and aeration.

Aluminium

Levels of aluminium in drinking water vary depending on the levels found in the source water and whether aluminium coagulants are used during water treatment. Aluminium based salts are used for effective treatment of surface water, acting especially as a barrier against pathogenic microorganisms. High concentration of aluminium in water has been linked to Alzheimer's disease. Aluminium chloride may corrode the skin, irritate the mucous membranes in the eyes, and cause perspiration, shortness of breath and coughing. Aluminium in water can be removed by means of ion exchange, coagulation and flocculation.

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[54] WHO. "Sodium in drinking water." Background document for development of WHO Guidelines for Drinking-water Quality (2003)

[55] WHO. "Sodium in drinking water." Background document for development of WHO Guidelines for Drinking-water Quality (2003)

Oxygen

Dissolved oxygen is present in all rainwater and surface supplies due to contact with the atmosphere. Oxygen adds to the taste of water. For this reason a small amount of it is desirable in drinking water. Oxygen causes corrosion. It normally has little corrosive effect in cold water but when the water is heated, the oxygen can cause serious corrosion problems. Sodium sulphite is the most widely used chemical for removing oxygen in water supply.

Hydrogen sulphide

Hydrogen sulphide is formed by sulphur bacteria that may occur naturally in water. Most of the hydrogen sulphide present in raw waters is derived from natural sources and industrial processes. Water containing hydrogen sulphide gives water a nuisance "rotten egg" smell and taste. High concentration of hydrogen sulphide in water in rare but its presence has been known to cause nausea, illness, and in extreme cases, death. It also promotes corrosion due to its activity as a weak acid. This can be treated by aeration, chlorination and carbon filter.

Ammonia

Ammonia in water (NH3) is a gas and is extremely soluble in tap water and water supplies. Ammonia may be present in drinking water as a result of disinfection with chloramines. The presence of ammonia at higher than geogenic levels is an important indicator of faecal pollution. Ammonia in water can be treated by means of chlorination and cation exchange resin.

Disinfection

Microorganisms

Microorganisms can be found commonly in nature in soils, food, water and air. Most microorganisms are harmless, however some microorganisms can cause disease and are harmful to people with low resistance to disease. Bacteria, virus and protozoa are the types of pathogenic microorganisms that can be found in drinking water. Water disinfection is therefore important in the removal of these microorganisms. The larger part of pathogenic microorganisms is removed by means of water treatment techniques, such as coagulation, flocculation, settling and filtration. Chlorine, ozone and UV radiation are few more methods that can be used to remove pathogens from water.

Desalination specific challenges

Particle and colloidal deposits

Deposits from particle and colloidal pollution can be defined as suspended and colloidal matter, affecting both membrane and thermal desalination systems. In the case of RO, solids plug the membrane, so that the water that needs treatment is no longer able to pass through. When the membrane is plugged more pressure is necessary to be able to perform the usual water treatment, leading to higher energy input requirements. The sources of this pollution in feed water can vary greatly, though they are often caused by bacteria, clay, and iron corrosion products.

Scaling

Scaling can also cause RO membranes to plug and is mainly a problem during nanofiltration and reverse osmosis processes. The membrane concentrate absorbs salts. Certain inorganic salts, such as calcium carbonate and barium sulphate can become over-saturated. This causes them to precipitate.

The surface blockage of the scale results in permeate flux decline, reducing the efficiency of the process and increasing operation costs. Scaling also causes a higher energy usage and a shorter life span of the membranes as they will need cleaning more often.

Biofouling

The types of microrganisms, their growth factors and concentration in a membrane system greatly depend on critical factors including temperature, the presence of sunlight, pH, dissolved oxygen concentrations and the presence of organic and inorganic nutrients. The microrganisms have damaging, often irreversible effects on the membrane systems.

Different types of biofouling can occur during desalination, related to both aerobic and anaerobic bacteria. Microrganisms can enter the system through water or air. Bio-fouling (biological contamination) occurs most often during nanofiltration and reverse processes because the membranes cannot be disinfected with chlorine.

Algae growth can occur during the pre-treatment of water within the membranes of reverse osmosis desalination systems. Membrane system parts that are exposed to sunlight or contain still water can provide favourable conditions for the growth of algae. Algae can feed aerobic bacteria by produce oxygen when alive, and by releasing organic nutrients when they die.

Bacteria may also attach to the inner walls of pipelines and form a biofilm, which can then spread through the system and grow on the membranes. This then encumbers the feed water flow and result in a higher pressure irreparable damage to the membranes.

Some membrane materials may be suitable environments for microrganisms to grow, contributing to a short life span of the membranes

Corrosion

Most desalination systems operate at high temperatures and are often troubled by depositions and corrosive effects in the system. The level of corrosion will depend on the type of the corrosive agent. This will also impact which type of material in the system is corroded.

Appendix 3: Search string description

Our search strategy included a combination of keywords and classification code searches. Keywords searches also allowed for stemming. The data searches were conducted in December 2011 and updated in January 2012. Note that these search strings formed an initial dataset which was designed purposefully to be inclusive rather than exclusive. The final datasets were the results of additional automated and semi-automated filtration steps, as described in the methodology section. Up to 50% of the patents in these initial datasets were removed. However, the search strings can be used by readers of the report to perform initial searches on which further analysis can be performed.

UV dataset

Classification codes and keywords were combined to create the search strings. This is because the water treatment classification codes relevant to UV not only included water treatment, but also the treatment of waste water and sewage, which was outside the scope of this project. To limit the search to water treatment only the following keyword search strings were added to the classification searches:

[water OR aqua OR H2O] in proximity to [treatment OR clean OR purify OR desalinate]

Table 20: Classification codes used for UV water treatment dataset creation

Type	Code	Description
IPC	C02F 1/32	Treatment of water, waste water, or sewage >> by irradiation >> with ultra-violet light
USPC	210/748.1	Treatment with ultraviolet radiation
ECLA	C02F 1/32	UV water treatment

Membrane dataset

Classification codes and keywords were combined to create the search strings. IPC codes used for this dataset related either to the water treatment or membrane filtration technologies or as such these were combined. A full list of classification codes used can be found in Table 21.

Search string with keywords only:

[[water OR aqua OR H2O] in proximity to [treatment OR clean OR purify OR desalinate]] AND [[water OR aqua OR H2O] in proximity to [treatment OR clean OR purify OR desalinate]]

Search strings with IPC codes:

(C02F 1) AND ([ultra OR nano OR micro] in proximity to [filtration OR filter OR membrane])

(B01D 61/02 OR B01D 61/04 OR B01D 61/08 OR B01D 61/14 OR B01D 61/16 OR B01D 61/18 OR B01D 63 OR B01D 67 OR B01D 69/04 OR B01D 69/06 OR B01D 69/08 OR B01D 69/10 OR B01D 69/12 OR B01D 71/00) AND C02F 1

(B01D 61/02 OR B01D 61/04 OR B01D 61/08 OR B01D 61/14 OR B01D 61/16 OR B01D 61/18 OR B01D 63 OR B01D 67 OR B01D 69/04 OR B01D 69/06 OR B01D 69/08 OR B01D 69/10 OR B01D 69/12 OR B01D 71/00) AND ([water OR aqua OR H2O] in proximity to [treatment OR clean OR purify OR desalinate])

Search strings with USPC:

(210/650 OR 210/651) AND ([water OR aqua OR H2O] in proximity to [treatment OR clean OR purify OR desalinate])

Search strings with ECLA:

(B01D 61/02* OR B01D 61/14* OR B01D 61/58 OR C02F 1/00D OR C02F 9/00B OR C02F 1/44C OR C02F 1/44D) AND ([water OR aqua OR H2O] in proximity to [treatment OR clean OR purify OR desalinate])

Table 21: Classification codes used in the water treatment patent search

Type	Code	Description
IPC	B01D 61/02	Reverse osmosis; Hyper filtration
IPC	B01D 61/04	Reverse osmosis; Hyper filtration feed water pre-treatment
IPC	B01D 61/08	Reverse osmosis; Hyper filtration apparatus
IPC	B01D 61/14	Ultrafiltration; Microfiltration
IPC	B01D 61/16	Ultrafiltration; Microfiltration feed water pre-treatment
IPC	B01D 61/18	Ultrafiltration; Microfiltration apparatus
IPC	B01D 63[56]	Apparatus in general for separation processes using semi-permeable membranes
IPC	B01D 67	Processes specially adapted for manufacturing semi-permeable membranes for separation processes or apparatus
IPC	B01D 69/04	Tubular membranes
IPC	B01D 69/06	Flat membranes
IPC	B01D 69/08	Hollow fibre membranes
IPC	B01D 69/10	Supported membranes
IPC	B01D 6912	Composite membranes
IPC	B01D 71/00	Semi-permeable membranes for separation processes or apparatus characterised by the material; Manufacturing processes specially adapted therefore
IPC	C02F 1	Treatment of water, waste water, or sewage
USPC	210/650	Filtering through membrane (e.g., ultrafiltration)
USPC	210/651	Membrane filtration >> Removing specified material
ECLA	B01D 61/02*	Reverse osmosis and nanofiltration
ECLA	B01D 61/14*	Ultra and microfiltration
ECLA	B01D 61/58	Multistep membrane filtration
ECLA	C02F 1/00D	Filtration water treatment systems
ECLA	C02F 9/00B	Multistage filtration for water treatment
ECLA	C02F 1/44C	Nanofiltration water treatment systems
ECLA	C02F 1/44D	Ultra and microfiltration water treatment

[56] Where the IPC code appears incomplete, it indicates that all IPC subgroups were searched

Appendix 4: Patent terminology

Patent applications vs. granted patents

Patent landscaping is based on the development of a patent dataset specific to a particular technology field, application area or problem focus. This dataset can be made up of granted patents and patent applications, as well as patent families, as explained below. Patent applications may be published even though a patent has not been granted yet, which provides early information about innovative activity. Differences in the rates between granted and non-granted patent applications can also provide proxies for the level of genuine inventiveness in a technology field, or provide an insight into industry players' patenting strategy.

Patent families

Patent documents are geographically specific, while technologies can flow across countries. Consequently an inventor seeking patent protection over the same technology in more than one country will end up having multiple patents protecting the same technology or invention. This is broadly referred to in the patent literature as 'patent families'[57].

Patent families can therefore be viewed as a proxy for a number of innovations around a technology field. In addition, analysis of the size and composition of individual patent family can help to understand better companies' patenting strategies. One patent family can include more than one patent in a single country, each protecting a different aspect of the invention.

Technology classification codes

Patents are tagged by various classification codes by the patent examiners dealing with their application, such as IPC (international patent classification) codes, ECLA (European classification), US classification codes. By looking at the various trends we can see how the research focus in a field has changed from one aspect to another. IPC codes are most frequently used, as it is associated with the most patents.

Office of first filing (OFF)

The country where the first application was filed – this is taken to be the earlier priority country.

Office of second filing (OSF)

This is the jurisdictions where subsequent family members of a patent were filed. Here each application/patenting country in a family of counted only once, even when more than one patent from that family is filed in the country. The office of first filing is also not included here.

57 For more on the different types of patent family definitions you can refer here: http://www.epo.org/searching/essentials/patent-families/definitions.html and http://www.intellogist.com/wiki/Patent_Families

Appendix 5: Focus dataset

Refer to accompanying dataset in Excel spreadsheet.

Appendix 6: LDCs investigated

A list of the least developed countries investigated in the geography analysis. No patents, offices of first or second filings were identified in these countries. Except for Malawi and Zambia, our databases do not contain filings for these countries.

Table 22: Least developed countries investigated

Least developed countries	
Afghanistan	Lesotho
Angola	Liberia
Bangladesh	Madagascar
Benin	Malawi
Bhutan	Mali
Burkina Faso	Mauritania
Burundi	Mozambique
Cambodia	Myanmar
Central African Republic	Nepal
Chad	Niger
Comoros	Rwanda
Democratic Republic of the Congo	Samoa
Djibouti	São Tomé and Príncipe
East Timor	Senegal
Equatorial Guinea	Sierra Leone
Eritrea	Solomon Islands
Ethiopia	Somalia
Gambia	Sudan
Guinea	Tanzania
Guinea-Bissau	Togo
Haiti	Tuvalu
Kiribati	Uganda
Laos	Vanuatu
	Yemen

Appendix 7: Detailed patent coverage

Table 23: Detailed patent data coverage

Patent dataset	Date
INPADOC	1900 - present[58]
US (Granted)	1971 - present
US (Applications)	2001 - present
Europe (Granted)	1980 - present
European (Applications)	1979 - present
PCT publications	1978 - present
Japan (Title, Abstracts)	1976 - present
German (Granted)	1968 - present
German (Applications)	1968 - present

[58] For more detailed information about exact INPADOC coverage, refer to http://www.epo.org/searching/essentials/data/tables.html

For more information contact WIPO at www.wipo.int

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