



Reverse Osmosis Desalination

Our global expertise to address water scarcity

WATER TECHNOLOGIES

Desalination:

an alternative solution to increase available water resources

By 2030, nearly half of the world's population¹ will live in a situation of water stress due to population growth, resulting in the skyrocketing of water needs for human consumption, agriculture and industry, thereby exacerbating usage conflicts. It is estimated that total water demand will more than double by 2050.

While 72% of the earth's surface is covered with water, 97% of this water is salty or brackish. The distribution of the remaining 3% (freshwater) is very uneven. For countries facing chronic shortages, the only available water resources will be treated wastewater or saltwater.

At present, only 0.7% of the drinking water produced stems from saltwater.

As nearly 60% of the world's population live less than 100 km away from a maritime coast², **desalination has become an undeniable alternative resource for the present and the upcoming decades.**

Up until recently, the demand for desalinated water mainly came from public authorities. Now, the industrial sector is increasingly opting for this solution to cover its needs of water for its production.

Among the various processes, membrane desalination via reverse osmosis (RO) has become the most widely used solution, as it is generally the least costly. It is particularly suited in countries under water stress and with limited energy resources.

Over the years, Veolia Water Technologies (VWT) has gained unrivaled expertise – and moved into the leading position – in the use of this technology, with 6.75 million cubic meters of desalinated water produced per day.

¹Source FAO

²Source Cluster Maritime 2009



97 %

of the world's water reserves consist of seawater

10 %

a year: the growth rate of the water and brackish water desalination market over the past 5 years

6,75

million cubic meters
of desalinated water produced per day worldwide through Veolia Water Technologies' membrane desalination process

What is desalinated water used for?

The desalinated water produced is used for the production of drinking water for human consumption and utilities such as irrigation of green areas, urban cleaning, agriculture (55%) and to cover water needs in most industrial processes (42%).

Source GWI-DesalData 2015

The Veolia Water Technologies solution

40 years of expertise in membrane desalination

With very numerous membrane desalination references – ranging from modular equipment to large turnkey projects producing up to 392,000 m³ of drinking water per day – Veolia Water Technologies is the world's undisputed industry leader.

Ever since the first RO seawater desalination plant in the late 1970s, the company has played a major role in the development of technologies and their improved cost-effectiveness through the experience gained on the projects and its Research & Innovation teams.

« More than 1,950 reverse osmosis plants and compact systems operating across the world, Veolia is a key market player »

The developments have made it possible to reduce the plants' energy consumption by a factor of 4, lower operating costs and environmental impacts, optimize the pre-treatment of raw water (indispensable to avoid damaging the membranes), improve production costs and the efficiency of the membranes.

As it became more attractive, membrane desalination surpassed thermal desalination back in 2001. It now accounts for an annual market share of 85 % of the plants contracted.

As a major player in that market, Veolia Water Technologies relies on its global network of specialized entities to guarantee the most appropriate solutions to its municipal and industrial customers.

KEY DATES

1977

First brackish water RO plant in Saudi Arabia (BWRO)

1988

First seawater desalination plant in Spain (SWRO)

2001

RO technologies surpass distillation technologies

2000 - 2011

Veolia has built 14% of the world's installed desalination capacity*

2010

Exclusive Veolia achievement: the first hybrid desalination plant combining MED** and RO

2014

Partnership between Masdar and Veolia within the framework of a water desalination program using renewable energy sources

2016

Veolia Water Technologies is launching its Spidflow™ Filter on the market

**source : Desaldata, GWI*

*** Multiple Effect Distillation*

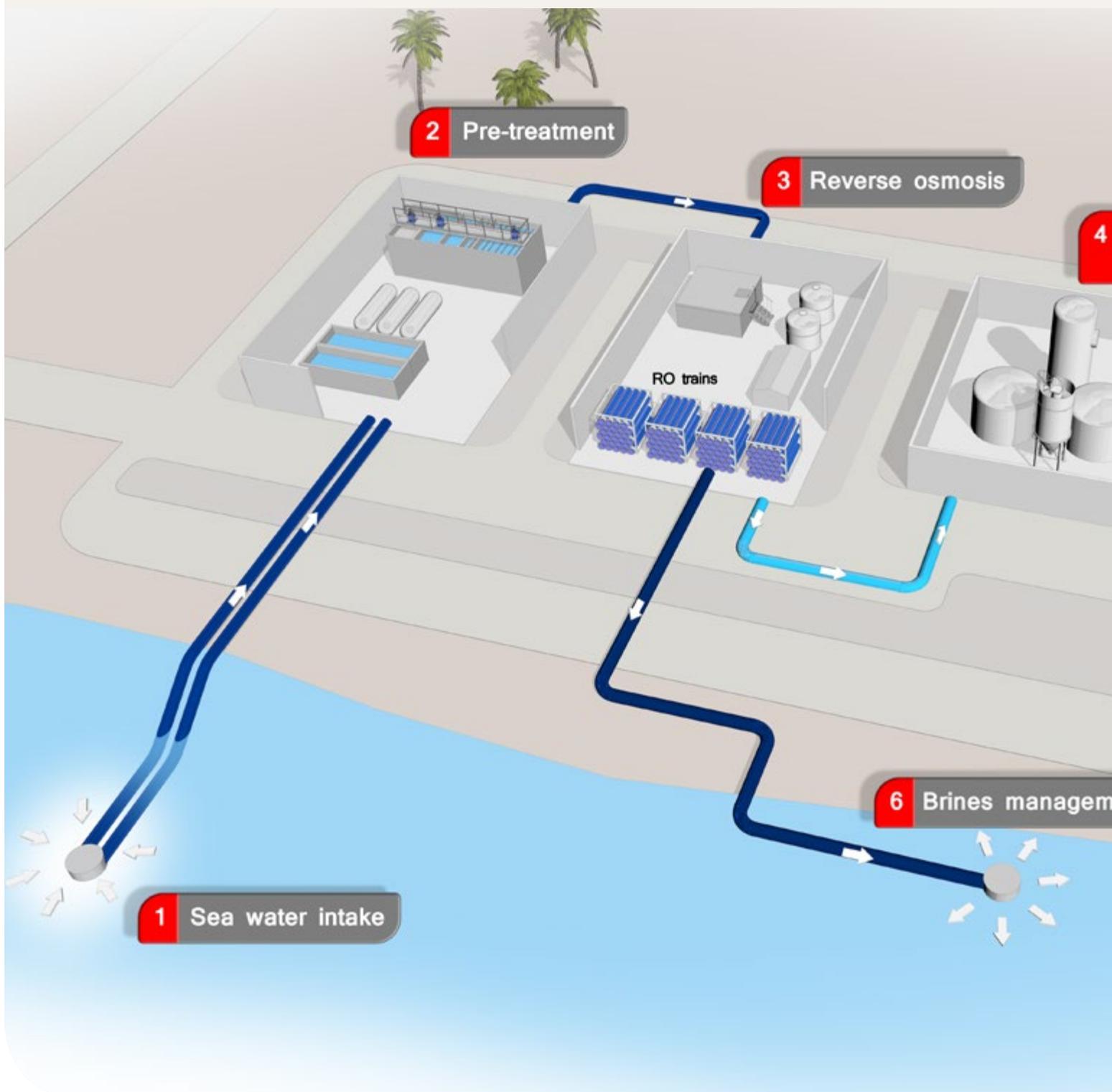
Membrane desalination is based on the principle of reverse osmosis. It consists in pushing water under high pressure through semi-permeable membranes, in order to obtain osmotic equilibrium. The salts and other impurities are retained on the side of the saltwater supply. RO is efficient for low or high concentrations of salts and can thus be used to treat brackish water as well as seawater. The saline solution to be treated is separated into two phases: the permeate (freshwater free of salts and impurities) and the concentrate stream (brine enriched with the dissolved salts retained).



Comprehensive know-how

and technological solutions for each stage of RO desalination

As the world leader in reverse osmosis desalination, Veolia Water Technologies (VWT) has a unique portfolio of proprietary technologies backed by a continuous innovation capability. With their proven expertise, our teams deal with each project in a sustainable, comprehensive way, ensuring optimal integration of the reverse osmosis technology across the entire process, from design to operation.



1 Seawater intake

VWT takes account of local natural constraints (geological environment, water quality) to adapt the type of intake to the specific needs. As the quality of the raw water varies, depending on whether it was pumped directly from the sea or from beachwells*, the subsequent treatments and equipment used will vary accordingly.

***Beachwells**: coastal wells wherein the natural sand layer acts as a pre-treatment and filters the pumped seawater, providing water with more stable characteristics (constant salinity, little temperature variation, low pH).

2 Pre-treatment

RO membranes are highly sensitive to variations in water quality, temperatures, the presence of algae, etc. A raw water pre-treatment system is thus indispensable and its choice is a key factor in the design of a sustainable RO desalination plant.

VWT offers a range of solutions suited to its customers' quality targets.

- **Actiflo**[®]: a compact high-speed lamellar clarification process, particularly efficient on turbidity, organic compounds, color and algae
- **Spidflow**[™]: Rapid and compact dissolved air flotation system for the treatment of water containing low-density particles, algae or humic matter
- **Filtraflo**[™] TGV: high-speed gravity filtration through a granular medium, particularly efficient in eliminating turbidity
- **Spidflow**[™] Filter: a compact bundle involving both rapid DAF and high-speed gravity filtration through a granular media.

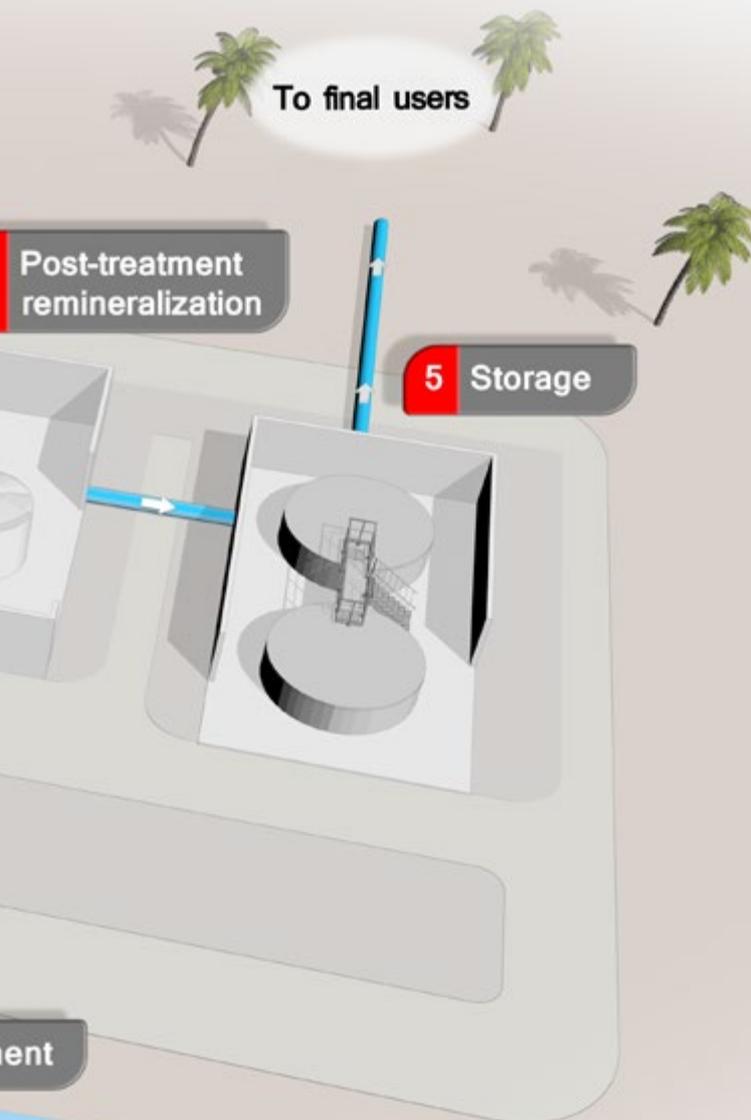
3 Reverse osmosis

For a selection of RO membranes suited to the applications requested by customers, VWT relies on a dedicated center of expertise called **ARAMIS**. Independently from manufacturers, this entity assesses the equipment available on the market, defines ideal operating conditions according to situations, and tests the equipment over the long term to optimize the processes (see p 12).

4 Post-treatment - remineralization

The freshwater extracted via the RO process must be treated in accordance with the type of end-use and legal requirements. VWT has a unique range of technologies to choose from, depending on needs:

- Injection of CO₂ to remineralize the water
- Calcite filter to neutralize the pH of the water produced and minimize its corrosiveness
- Multiflo[™] clarification for the production of limewater



Veolia Water Technologies also offers a comprehensive range of standardized RO solutions, and a dedicated **SIRION**[™] range of chemicals experts - **Hydrex**.

Proven adaptability

with a wide variety of contract models

Veolia Water Technologies (VWT) has built up its desalination experience through the installation of 1,950 reverse osmosis facilities within the scope of projects of all sizes and all complexity levels.

Beyond the technological aspect, the company provides engineering to its customers, adapting its level of response and intervention to their financial constraints, governance choice, economic/social/environmental situations, the number of project partners, etc. For customers, this widely recognized adaptability is an additional asset.

An ideal partner for IWP/IWPP (independent water projects and independent water & power projects)

High-growth countries, such as the Persian Gulf countries, have launched into major programs to expand their water and/or power production capacities. These projects are divided into two categories – IWP (independent water projects) and IWPP (independent water and power projects) to attract investors and benefit from top private-sector expertise. Taking part in this type of complex projects which involve numerous players is a challenge which requires total coordination and comprehension among all parties involved, i.e. skills that VWT has developed over the years. Recognized for its contract management expertise, our company stands out as a subcontracting partner, supplier of EPC equipment, or provider of wider expertise in a growing number of these unconventional installations.



The Fujairah 2 hybrid desalination project in the United Arab Emirates was the world's second biggest IWPP when its construction was completed in 2010. It was entrusted to a consortium made up of the Abu Dhabi Water and Electricity Authority (60%), International Power (20%) and Marubeni (20%), who chose VWT for its engineering and construction and for the supply of equipment for all MED and RO desalination aspects. The operation and maintenance of the RO facility was entrusted to Veolia Water under another specific contract.

Operation and Maintenance (O&M): the global leader in water services

With over 8,500 contracts for the operation of drinking water or wastewater plants, Veolia, who signed the very first O&M partnership in 1853, is the world's most experienced private operator. From the sustainable maintenance of installations to maintenance programs, from equipment optimization to the total control of the quality of the water produced and environmental impacts, the Group and its subsidiaries are committed to results, in keeping with the performance indicators defined with the customers.

At Sadara in Saudi Arabia, the VWT subsidiary SIDEM, after completing the D&B phase, will handle the operation and maintenance of the country's biggest ultrafiltration/RO desalination plant for a period of 10 years.

An expert in integrated Design-Build-Operate solutions

For municipal authorities and industrial players who wish to benefit from the expertise of a global leader in desalination, while preserving their capital and control over their water strategies, VWT sets up **DBO (Design Build and Operate)** or **BOT (Build Operate and Transfer)** contracts. By defining the plant's operating methods in its design phase, Veolia guarantees the high performance and reliability of the facilities over the long term, the management of risks, and the control of operating costs. Handling the design/operation of the facility all the way to its transfer to the customer (under a BOT project), Veolia works with reliable partners for the projects' funding requirements and legal framework.

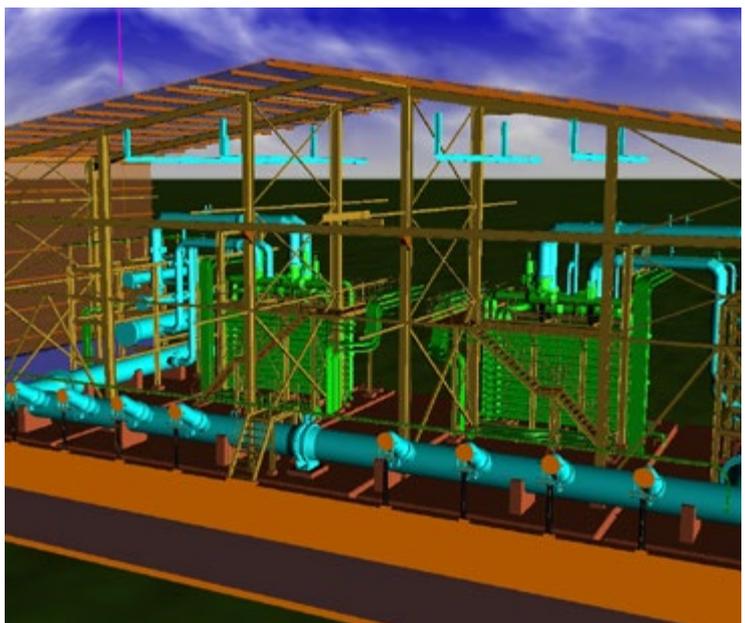


*In 2007, in New South Wales, the Government entrusted Veolia with a contract to design, build and operate (for a period of 20 years) **the Kurnell desalination plant in Sydney**, under a Veolia-John Holland joint venture. Veolia Water Technologies, played a prominent role in the plant's design/construction and its commissioning in 2010.*

Equipment and Services: supplier of equipment and services

The company also offers a wide range of packaged modular units: standard desalination units mounted on skids adaptable to all types of applications (drinking water, irrigation, industrial processes), the **SIRION™** reverse osmosis skids, photovoltaic equipment (as an option), etc. These compact, versatile units optimize the time taken for transportation, installation and commissioning.

To ensure the long-term success of a project and anticipate future needs, VWT also offers a wide range of associated services: Hydrogeological modeling, pilot plants, management software, maintenance services, technical assistance (operation, membrane autopsies, etc.), emergency service using mobile units (Spidflow™, UF, BWRO, SWRO), etc.



At Basrah, Iraq, the Hitachi-Veolia consortium was entrusted with the engineering and supply of equipment for a membrane desalination plant in 2014, as well as its operation and maintenance for a 5 years period.

References

The pioneer in Hybrid desalination



FUJAIRAH 2, the world's biggest hybrid desalination plant

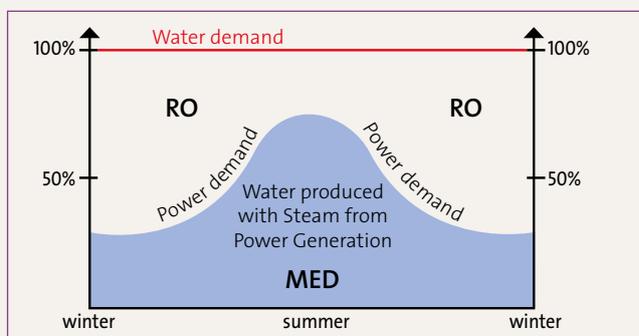
Located in Qidfa, United Arab Emirates, the Fujairah 2 desalination plant built by Veolia Water Technologies via its subsidiaries SIDEM and OTV produces 591,000 m³/day of desalinated water to meet the population's growing water needs and boost the region's development potential.

Combined with a 2,000 MW power plant built by Alstom, this desalination plant is the first to combine RO and multiple effect distillation (MED) technologies. This hybrid solution exclusively developed by VWT optimizes the use of the electricity produced by the power plant, particularly in the winter. Indeed, in the summer, peak consumption is linked to air-conditioning needs during very hot weather. The thermal power plant then operates at full capacity, providing a maximum amount of vapor which is used to distill seawater. In the winter, RO desalination is favored as it only consumes electrical energy, which is readily available at that time of year.

“ *Hybrid desalination guarantees flexibility through optimized joint use of two desalination techniques – MED and RO* ”

Spidflow™ expertise

As a showcase of VWT know-how, Fujairah 2 also boasts rapid flotation pre-treatment via Spidflow DAF – the most extensive such facility yet to be installed anywhere in the UAE – to remove the red algae which regularly and randomly pollutes the region's coastal waters.



A world-unique R&D platform

The operation and maintenance of the reverse osmosis desalination facilities were also entrusted to Veolia for a period of 12 years. They will be backed by a world-unique R&D platform dedicated to the continuous optimization of operating practices and processes (see R&I pages).

Municipal references

The partner of local authorities

Az Zour South, No.1 reference for RO desalination in Kuwait

Capacity: 136,450 m³/day
Main technologies: Filtraflo™ TGV, Sea Water RO
Contract: DBO
Year: 2014
Customer: Ministry of Electricity and Water



“Water & Energy Exchange (WEX) Desalination Award” 2014



Sydney Kurnell, Australia Desalination Project of the Year in 2011*

Capacity : 250,000 m³/day
Main technology: Sea Water RO
Contract: DB
Year: 2010
Customer: Sydney Water corporation
** Global Water Intelligence*



“Project of the Year” at the “Australian National Infrastructure Awards” 2010 “National Project Management Achievement Awards”, “Sydney Engineering Excellence Awards” 2010



Campo de Dalías (Almeria), Spain’s 5th biggest desalination plant,

Capacity: 97,200 m³/day
Main technologies: PDMF, Sea Water RO
Contract: DBO / 15 years of operation
Year: 2015
Customer: ACUAMED (on behalf of the Ministry of the Environment)



Sur, First independent desalination project in Oman

Capacity: 131,800 m³/day
Main technologies: 28 beachwells, Spidflow™, PDMF, Sea Water RO
Contract: BOT/22 years of operation
Year: 2009/extension in 2016
Customer: Ministry of National Economy

World’s largest beachwell desalination pre-treatment facility



Municipal references

Showcase facilities for local authorities

Gold Coast,
Desalination as a water resource not dependent
on rainfall (Australia)

Capacity: 125,000 m³/day

Main technologies: GDMF, Sea Water RO

Contract: DB/10 years of operation

Year: 2010

Customer: JV Queensland and Gold Coast City
Council



*2009 Membrane Desalination Plant of the Year
(Global Water Intelligence), 2007 Engineering
Excellence Award*



Aruba,
Desalination to counter water stress
(Caribbean islands)

Capacity: 24,000 m³/day

Main technologies: Beachwells, Sea Water RO

Contract: DB

Year: 2012

Customer: Water en EnergieBedrijf Aruba N.V



Mossel Bay,
South Africa's biggest RO desalination plant
(South Africa)

Capacity: 15,000 m³/day (10 000 m³/day in
drinking water – 5,000 m³/day in reuse)

Main technologies: PDMF, Sea Water RO

Contract: DBOM

Year: 2010

Customer: Mossel Bay Municipality
and Petro SA



Laayoune,
Membrane desalination to support Morocco's
growing water needs

Capacity: 26,000 m³/day

Main technologies: PDMF, Sea Water RO

Contract: DB

Year: 2010

Customer: National Office of Drinking Water



Industrial references

Supporting industrial projects

Sadara Marafiq, Production of desalinated water for a petrochemical complex (Saudi Arabia)

Capacity: 178,650 m³/day

Main technologies: Spidflow™, Ultrafiltration,
Sea Water RO

Contract: DBO (10 years of operation)

Year: 2016

Customer: Marafiq for Saudi Aramco

First Spidflow reference in Saudi Arabia



Coal-fired power plant, Use of desalinated water as ultra-pure process water (The Netherlands)

Capacity: 15,840 m³/day

Main technologies: Multiflo™, Spidflow™,
Microfiltration, Brackish Water RO,
Mixed-Bed Ion Exchange

Contract: Turnkey

Year: 2013

Customer: confidential



Power Plant Desalination of river water for the production of power plant cooling water (CTMU), USA

Capacity: 36,000 m³/day (6,600 gpm)

Main technologies: Actiflo®, MMF, BWRO

Contract: DBOM

Year of commissioning: 2010

Customer: Confidential



Mining effluent A Zero Liquid Waste solution for the treatment of mine effluents, USA

Capacity: 19,000 m³/day (3,500 gallons /minute)

Main technologies: Turbomix® chemical
softening, Brackish Water RO, Veolia HPD
evaporation and crystallization technology

Contract: DB and 10 years of operation

Year of commissioning: 2013

Customer: Confidential



Research excellence,

continuous innovation, and commitment to responsible desalination for the years to come

In close contact with customers, Veolia Water Technologies' multi-local network of desalination experts and the Group's R&D center (Veolia Research & Innovation) make every effort to further optimize treatment facilities and their energy efficiency while keeping down costs and environmental impacts. In anticipation of tomorrow's desalination requirements, they accelerate the marketing of innovative solutions, reinforcing Veolia's position as world leader in this sector.

A continuous improvement strategy

For the past 35 years, VWT has been developing unique technological know-how in membrane desalination. Through the feedback received and the support of Veolia R&I, it constantly strives to improve and enrich this valuable expertise to provide increasingly reliable and efficient solutions for the greatest number of people. In this regard, numerous programs focused on research and the validation of processes and new equipment are set up, usually in collaboration with customers or partners.

Dedicated experimentation platforms

Because the ability to demonstrate the reliability of its technological solutions to its customers is primordial, Veolia sets up test platforms to identify the most efficient and economical solutions under real conditions.

Thus, the Fujairah 2 platform, built next to the Fujairah 2 plant operated by Veolia in the United Arab Emirates (see p 8) is dedicated to seawater pre-treatment requirements upstream from the RO units. This phase is indispensable as it prevents the risk of membrane clogging. Thanks to the various tests conducted on this platform, VWT can now offer its customers optimized, reliable pre-treatment solutions for the most difficult-to-treat waters.

850 experts across the Group

220 international partners

over **2,000** registered patents

6 research centers

3 test platforms

278 research pilots

Veolia Global R&D and Innovation capabilities

ARAMIS, an analysis center dedicated to membrane technologies and their applications.

- assessment of membrane performance (retention, hydraulic and mechanical properties, etc.) to enable us to choose the right suppliers
- autopsies of membranes under operation: retention, hydraulic properties, identification of the type of clogging (electronic microscopy)
- help with the optimization of operating conditions, washing efficiency, etc.



A cutting-edge designer/ builder

Beyond the improvement of existing equipment and processes, our teams are also tasked with assessing new equipment and the conditions for their optimal integration in the solutions offered to customers. In close contact with manufacturers, such as membrane producers, the world leader in water treatment makes the most of its design/build expertise to offer new, cost-effective facilities which consume less energy. Here again, their robustness and durability are tested on industrial-scale pilot units.

The “energy efficiency” partner

One of the main focuses of Veolia’s research concerns the development of processes which consume the least amount of energy. Despite the fact that innovations have made it possible to reduce the energy consumption of processes by a factor of 4 since the beginning of membrane desalination, Veolia is constantly striving to do better and is currently at the cutting edge of research on seawater desalination using renewable energy sources.

In 2014, **Masdar**, also known as the (Abu Dhabi’s energy operator), chose Veolia – via **SIDEM**, its subsidiary specialized in desalination – as its industrial partner for an ambitious water desalination program using renewable energy sources.



Hiprode, a totally new design in RO seawater desalination units. It allows optimum use of the greater permeability of the new membranes available on the market, thereby improving efficiency and reducing the size of the facility and its cost. The prototype tests conducted on this new configuration in a desalination plant operated by Veolia in Gibraltar were completed with success at the end of 2014, allowing the integration of this technological improvement in VWT’s offering.

Environmental responsibility commitment

Brine disposal and impact studies

Desalination processes, whether thermal or RO based, result in the production of brine. VWT is committed to sustainable development by ensuring the implementation of efficient solutions that minimize the discharge of concentrates into the environment. To this effect, projects include environmental impact studies, like in Sydney (photo below).

Treatment of concentrates / brines

VWT already uses a wide array of technological solutions to treat brines. These include injection into deep wells, natural or forced evaporation in confined ponds, and more compact evapo-concentration.

Anticipating future needs, VWT also has «Zero Liquid Discharge» solutions:

- **OPUS 2**, which uses salt desaturation /precipitation technology followed by filtration through **Ceramem** ceramic membranes,
- Evaporation and crystallisation systems developed by **HPD** and **VWT Italia**.

World leader

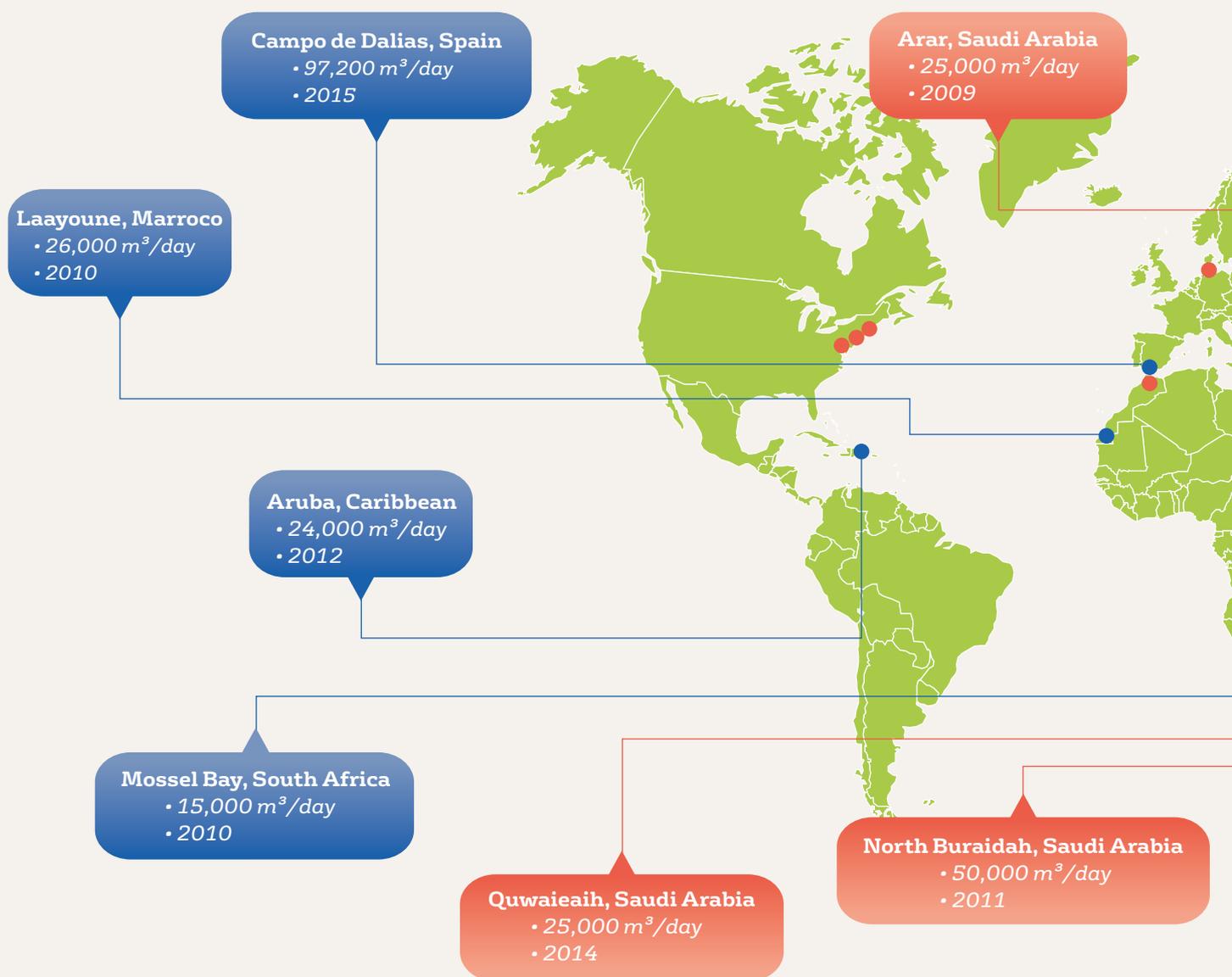
A network of experts and recognized know-how

At Veolia Water Technologies, desalination involves multi-local centers of expertise where dedicated teams have been working for decades in close keeping with the specific requirements and situations of municipal and industrial customers.

Veolia's strength also lies in its ability to mobilize the resources of this international network and pool feedback in order to improve the fundamental skills of the whole.

This global dimension enables Veolia to identify future challenges for desalination players, anticipate changing needs, and prepare tomorrow's solutions to adapt them to local requirements.

Some of our RO desalination



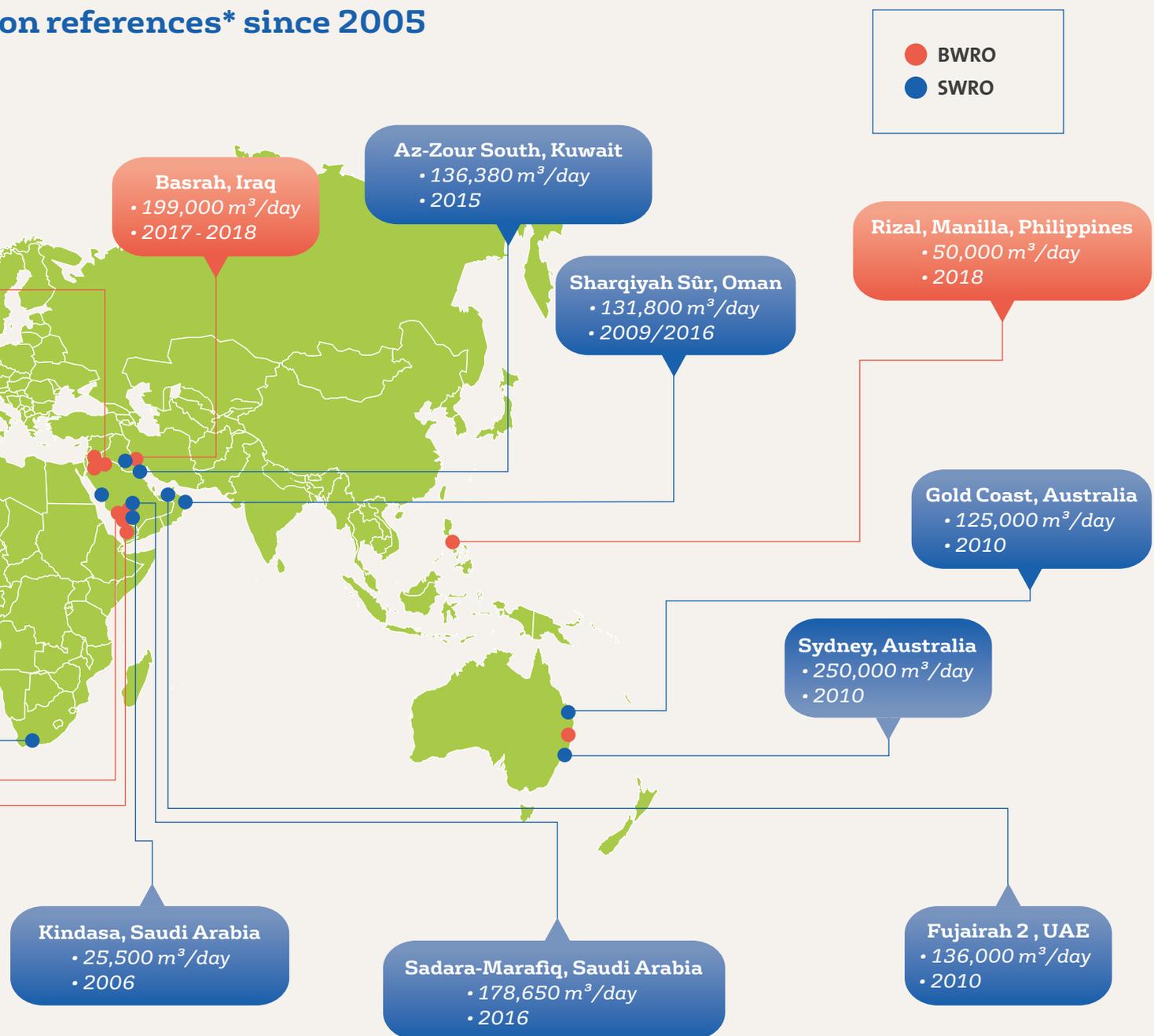
* > 15 MLD



Through its expertise in engineering standards, complex contract relations and international regulations on desalination, Veolia Water Technologies provides its customers with reliable, cost-effective facilities which are people and environmentally friendly.

Our solutions are designed to address the priorities and concerns of cities, by minimizing costs and maximizing performance and service levels.

on references* since 2005



Resourcing the world

Veolia Water Technologies

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