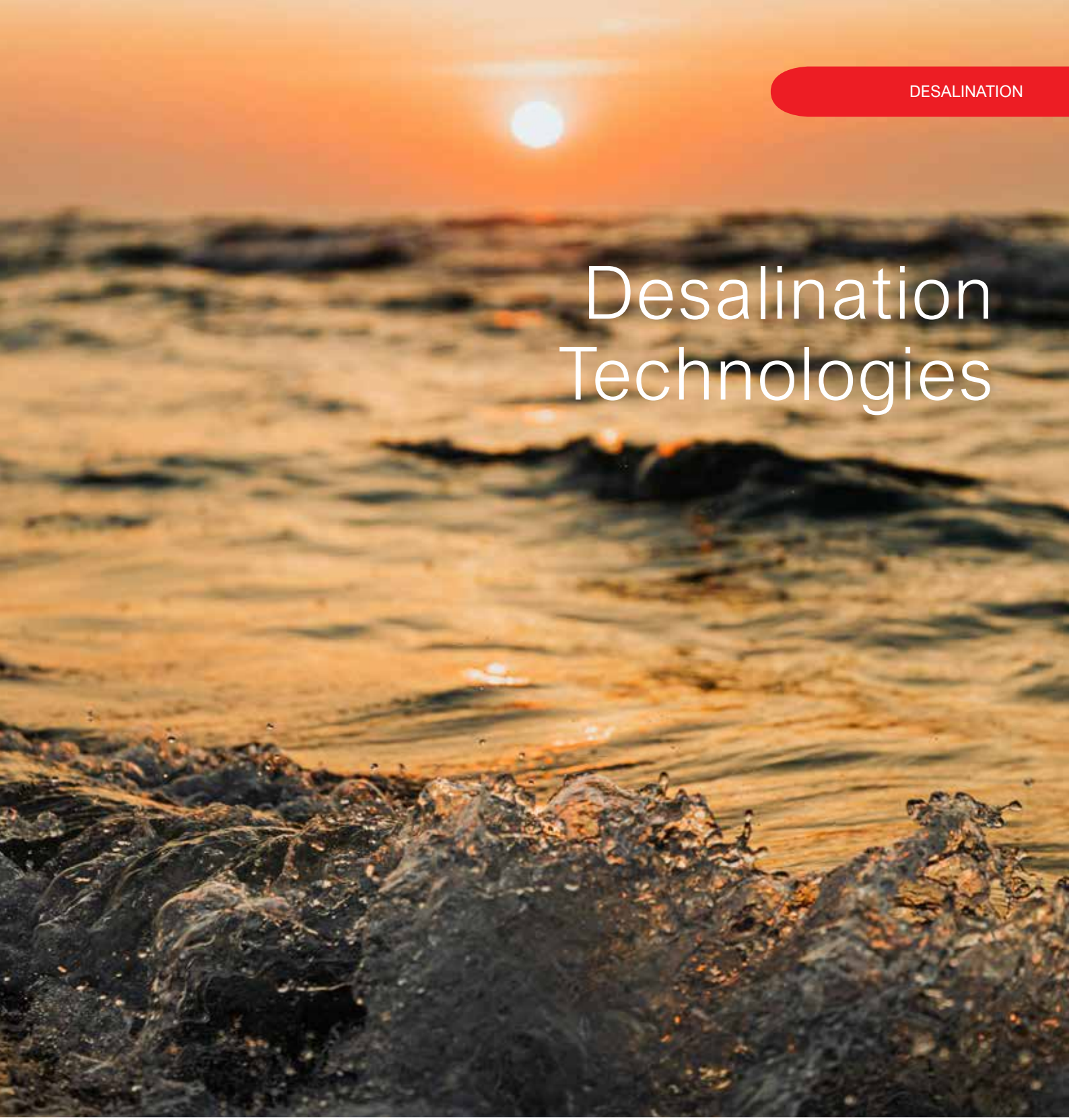


Desalination Technologies

Reverse Osmosis & Thermal Desalination
for Drinking water, Industrial water & Water recycling

WABAG

sustainable solutions. for a better life.

WABAG - for over 100 years a synonym for innovative and successful water engineering solutions.

At present, the widely preferred technologies for the desalination of sea and brackish water are

- Membrane technology - Reverse Osmosis (RO)
- Thermal desalination - Multi-Effect- Distillation (MED).

These technologies are applied in the production of both potable water and industrial process water, forming the foundation for optimised and fully customised solutions.

Desalination technologies are also gaining importance in WATER RECYCLING and DEMINERALISATION systems. The use of advanced membrane technologies, such as reverse osmosis, enables the reuse of industrial effluents as highly purified process water, for example as boiler feed water.

WABAG is a global leader in advanced water and wastewater treatment solutions, serving both municipal and industrial clients worldwide. Driven by innovation and engineering excellence, WABAG stands among the very few companies capable of delivering a full spectrum of desalination technologies for both seawater and brackish water applications.

- Reverse osmosis
- Thermal desalination (MED, TVC, MVC, MSF)
- Electrodialysis (ED)
- Ion exchange (IX)

We have successfully designed, commissioned, and delivered over 100 desalination plants.

What makes WABAG a preferred partner?

- A comprehensive desalination technology portfolio
- Proven experience in mega-scale desalination for cities and industries.
- Proven process know-how and expertise as well as an understanding of entire systems
- 125+ IP Rights. In-house R&D centres in Austria and India, which guarantee the optimisation and further development of desalination technologies
- The provision of complete solutions: EP, EPC, DBO, BOOT
- Experience as a desalination plant operator
- A multinational presence and long-term experience
- The integration of desalination plants with water reclamation systems
- Freedom of choice on the most suitable membrane systems

Desalination is the Answer To:

- Rising global freshwater scarcity
- Increasing climate variability
- Growing urban, industrial & energy-sector demand
- Limited conventional water sources in coastal and arid regions

Resulting In Key Benefits:

- Continuous, predictable water supply
- Reduced pressure on rivers, lakes & aquifers
- Stronger urban and industrial resilience
- Scalable solutions for current and future demand
- Integration with renewable energy (solar, wind)

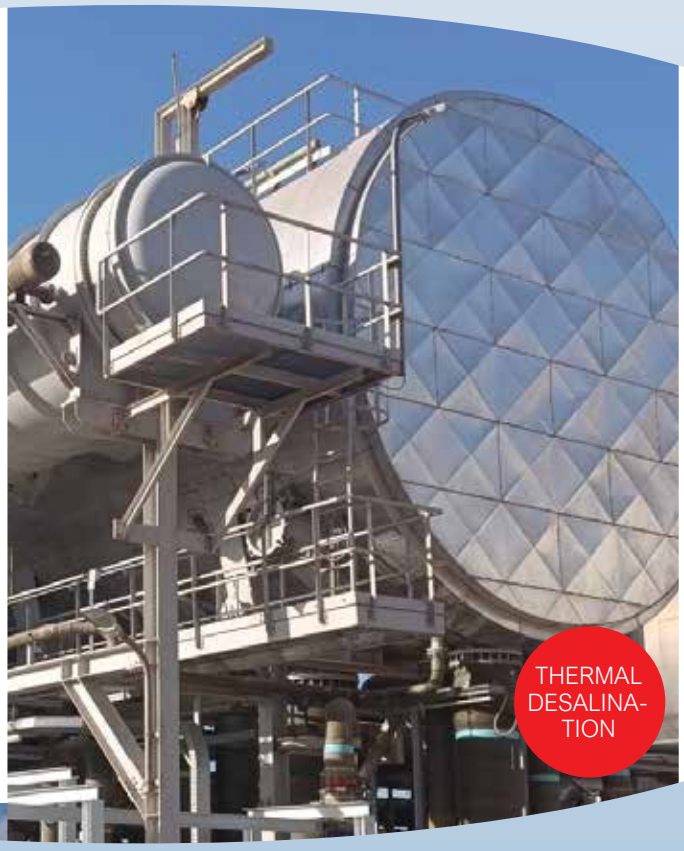
Reverse Osmosis or Thermal Desalination

The larger the salt content of the untreated water and the greater the required degree of purity at the desalination output, the higher the energy costs.

In the past, Reverse Osmosis installations required sizeable amounts of electrical power. However, owing to increased energy optimisation, these processes have now become far more cost-efficient. In today's world, RO is indispensable for the supply of potable water in countries lacking adequate ground or surface water resources. It has emerged as the most economic solution where residual steam is unavailable as an energy source.

By contrast, Thermal Seawater Desalination using residual steam as an energy source is the most appropriate solution in power plants and offers major O&M savings. Thermal MED installations, for example, are operated with low pressure exhaust steam or with output steam from steam turbines. For steam pressures above 2 bar, thermal MSF would then be appropiate. When such energy is available this process is most suitable.

WABAG is one among the very few companies in the world to offer both technologies on standalone or hybrid basis. is



PERUR 400 MLD SWRO, Chennai, India, Seawater Intake sinking

Reverse Osmosis Desalination

RO – the advantages:

- Proven and time-tested technology
- Relatively low investment costs as compared to thermal methods
- Application flexibility - from very small (< 100 m^3/d) to large installations (> 100,000 m^3/d)
- No cooling water requirement
- Less energy consumption than with an MED system

RO is a pressure-driven process. Saline water is forced through semi-permeable membranes under pressure, thereby separating the saltwater into a freshwater stream (known as permeate) and a brine stream (concentrate).

Typical process steps in an RO system:

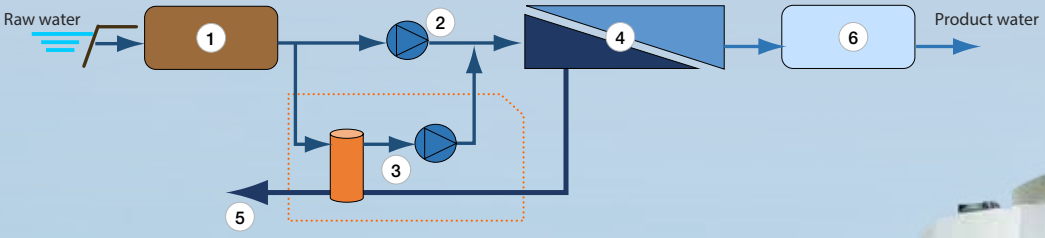
1 Pre-treatment (protecting the RO membranes)
2 High Pressure Pumps
3 Energy Recovery system
4 RO Membrane Modules
5 Concentrate discharge
6 Post-treatment (remineralisation, disinfection)

The recovery percentage of purified water depends upon various factors that include membrane size and internal structure, temperature, operating pressure and membrane surface area.

◂ ▴ Al Wasia, Saudi Arabia
Brackish water RO, 200,000 m^3/d ,

Due consideration given to the economic factors such as:

- Energy recovery
- Membrane durability
- Chemical consumption
- Process automation



Nemmeli, India
Seawater RO, 100,000 m^3/d

Complete and Exclusive: Customized Solutions.

WABAG supplies RO plants for various types of raw water such as seawater, brackish water and industrial effluents. As a provider of end to end solutions, WABAG delivers the entire process from the raw water onwards, including deep seawater intake and outflow structures to the post-treatment of product water and product water pumping stations.

On the strength of its experience in design, construction and operation of plants of varying sizes, WABAG offers economically advantageous and technically proven solutions for every application.

Highly effective pre-treatment systems are extremely important

As a comprehensive systems supplier, we provide not only the necessary inflow and outflow structures, including subsea pipelines, but also prioritize efficient pre-treatment processes.

The success of a desalination plant relies heavily on its pre-treatment system. Our pre-treatment solutions go beyond conventional filtration technologies, addressing specific concerns such as red tide, oil in seawater, and high total suspended solids.

We utilize advanced techniques such as Dissolved Air Floatation (DAF), lamella clarifiers (OPUR-SK™), and highly effective Micro and Ultrafiltration systems, ensuring superior pre-treated water quality and enhancing the overall efficiency of the RO treatment process.

Saving energy & costs. Innovative Layouts and Energy Efficiency.

WABAG's innovative layouts, including compact Inline systems, optimize space utilization with a smaller footprint while reducing specific power consumption in the RO system.

We provide energy-efficient two-pass Reverse Osmosis (RO) systems equipped with the latest energy recovery devices, minimizing energy consumption and producing high-quality permeate for various industrial applications. To meet potable water standards, we incorporate post-treatment remineralization systems using methods such as lime and CO_2.

▲ ZARAT SWRO, Tunisia, 50,000 / 100,000 m³/d, RO system with Energy Recovery

ZARAT SWRO, Tunisia,
Sandfiltration for pre-treatment

Al Ghubrah SWRO, Oman

Supply of potable water to the Muscat region - **191,000 m³/d for 1,200,000 people**

Best practice references

Compact design featuring an inline system.

An integrated solution.

Client:	Muscat City Desalination Company SAOG (MCDC)
Contract type:	EPC
Commissioning:	20116
Raw water:	seawater
Product:	potable water
Capacity:	191,000 m³/d
Process:	reverse osmosis with self-cleaning filters and membrane pre-treatment

Reducing CAPEX, OPEX and footprint.

Main parameter:	45,000 mg/l TDS, Temp.: 35 °C
Product recovery:	38%
Potable water quality:	TDS < 200 mg/l
Plant availability:	100 %

The SWRO plant was completed as an EPC project by the "International Water Treatment LLC" (IWT) joint venture partners WABAG, Cadagua and Galfar, and apart from rapid realisation, demanding site conditions had to be met:

- Limited spare available – built on 9.7 acre,
- Located near the centre of Muscat
- Surrounded by a neigh-bouring desalination and power plant.

Objectives

- Ensuring reliable operation even during difficult raw water intake conditions such as red seawater tides
- Continuous RO water production
- Low life cycle costs

SEAWATER INTAKE SYSTEM

Screened sea water received from a depth of 10 mtrs and distance of 1.65 km offshore through subsea pipe.
Installed solely for the use of this plant. Construction required careful planning as significant dredging was required for the installation of new intake, including around an existing an operational brine outfall and conveyance pipeline from the neighbouring desalination plant.

PRE-TREATMENT

Dissolved Air Floatation (DAF), Dual Media Pressure Sand Filter
A combination of DAF and DMF for treating Red Tide, O&G, suspended solids and organic remains.

INLINE CONNECTION

from pre-treatment to cartridge filters and SWRO.

DESALINATION

- Two pass RO
- Operating pressure: 56-72 bar
- Trains: 8 (7 primary, 1 spare), each skid: 27,300 m^3/d, 2,240 membranes

Split partial first pass SWRO for optimal energy consumption. Second pass BWRO skids to achieve the boron limit in the outlet.

ENERGY CONSUMPTION

3.2 to 4 kWh/m^3

ENERGY RECOVERY SYSTEM

Pressure exchanger in the first pass of SWRO with latest Q-series from ERI system.

POST-TREATMENT

Re-mineralization with lime & CO_2 for post-treatment to potable water standards

AL GHUBRAH SWRO - FEATURES

- Subsea intake pipeline for best water quality
- Red tide insurance using DAF – DMF as pre-treatment
- Innovative layout for compact foot print (Inline system, Arrow head DMF layout)
- Two pass RO system with latest Q-series from ERI system
- Standby RO skid for high plant availability

FURTHER REFERENCE EXAMPLES

SEAWATER - SWRO FOR POTABLE WATER PRODUCTION:

PERUR, Chennai, India
400,000 m^3/d, potable water, DBO, start-up: 2026

ZARAT SWRO, Tunisia
50,000 / 100,000 m^3/d
Potable water, EPC, start up: 2024

Jazan SWRO, KSA
60,000 m^3/d, Potable water, EP, start up: 2022

SWRO - Desalination plant for Refinery at Mangalore, India

Reverse osmosis to ensure industrial water supply.

Best practice references

Lamella clarifiers – the WABAG OPUR-SK™ technology for highly effective pre-treatment

Turnkey realization of 30 MLD SWR, expandable to 70 MLD.

Design, build, operate.

Client:	Mangalore Refinery and Petrochemicals Limited (MRPL)
Contract type:	DBO - Design-Build-Operate
Start-up:	2021
O&M period:	2022-2032
Raw water:	seawater
Product:	industrial water
Capacity:	30,000 m^3/d, expandable to 70,000 m^3/d
Main parameter:	TDS: 40,000 mg/l, Turbidity: 400 NTU
Product recovery:	45.4%
Potable water quality:	TDS: < 500 mg/l, LSI +ve

MINIMIZING DEPENDENCY ON FRESH WATER RESOURCES

WABAG delivered a turnkey 30 MLD SWRO plant - expandable to 70 MLD - in Mangaluru, Karnataka, for MRPL, reducing the refinery's dependence on freshwater sources. The plant features advanced pretreatment with electrochlorination, lamella clarifiers, and ultrafiltration, followed by a two-stage RO system with three 10-MLD trains. The scope also included an 11-km cross-country pipeline to supply water to the MRPL refinery. Since 2022, WABAG has been responsible for operation and maintenance under a 10-year O&M contracct.

MAIN PROCESS STEPS/COMPONENTS

- Seawater caisson and intake pipe
- Air bursting and shock chlorination
- Bar screens and traveling band screens
- Seawater intake chamber
- Electrochlorination
- Maritime intake filter
- Intake chamber (upflow filter and sedimentation tank)

MRPL SWRO - FEATURES

- Turnkey realization of 30 MLD SWRO, expandable to 70 MLD
- Comprehensive pre-treatment and 2-stage RO system.
- Energy-efficient plant (3.74 KW/m^3)
- Design, Build and Operate (10 years operational period)

Located right at the bank the of Arabian Sea and very next to the Mangalore Port, the new SWRO plant is a reliable an sustainable source of water, playing an important role in uninterrupted operations of the refinery.

Objectives

- Ensuring a reliable supply for uninterrupted operations
- Minimizing dependency on freshwater resources
- Low energy demand
- Future-proof against erratic climatic conditions

PRE-TREATMENT

- Distribution chamber
- Ferric chloride and Poly electrolyte dosing
- Flashmixer & Flocculators
- Lamella clarifiers
- Clarified water tank
- Selfcleaning filters
- Ultrafiltration
- UF-product water tank
- Micro cartridge filter
- SMBS and antiscalant dosing

DESALINATION BY RO

- 2 Pass Reverse Osmosis System:
- SWRO – TDS: < 350 mg/l, Recovery: 45%
- Intermediate RO Permeate Tank
- Cartridge Filter
- Brackish Water RO – TDS: < 20 mg/l
- Energy recovery by pressure exchanger (achieving overall energy recovery of 47%)
- Product water storage tank
- Outfall water tank
- Outfall with diffuser

POWER SAVINGS

- Specific power consumption of 3.74 kWh/m^3
- 97% of waste pressure from reject stream are recovered and transferred to feed stream using pressure exchanger based energy recovery device.

WABAG SCOPE

WABAG has executed the project on turnkey basis, being responsible for design and engineering, construction, equipment supply, installation, testing and commissioning as well as 10 years O&M.

INTAKE HDPE PIPELINE TOWING & SINKING

- Pipeline details
  1,600 mm DIA HDPE PIPE-PN 6-SDR 26
- Total length:
  910 m along with 4 inspection manholes

FURTHER REFERENCE EXAMPLES

SWRO FOR INDUSTRIAL APPLICATIONS:

Solar PV Manufacturing, INDOSOL:
100,000 m^3/d, EP & 15 years O&M
Start-up: 2027

Jamnagar Refinery, RIL:
53,000 m^3/d, EPC, Start-up: 2026

Punj Lloyd, Ltd, Doha, Qatar
Solar Technologies, Ultrapure water for Polysilicon Project,
12,480 m^3/d, EPC
Start-up: 2016

MRPL Refinery - Ultrafiltration for pre-treatment

DESIGN, BUILD, OPERATE.

Closing the Water Cycle: Reverse Osmosis & Evaporation for Water Recycling and Zero Liquid Discharge (ZLD)

Best practice references

Water Recycling - Reference Examples:

Dangote Petrochemical Complex, Nigeria: 26,400 m³/d,
Ras Tanura Refinery, KSA: 20,000 m³/d
RIL, Dahej Refinera, India: 36,000 m³/d
Paradip Refinery, India: 54,000 m³/d,
Tertiary Treatment Plants at Ghazibad (40,000 m³/d) & Koyambedu, Chennai 45,000 m³/d

NMDC Ltd. - Water Recycling and ZLD plant for new steel works ag Jagdalpur, India.

Design, build, operate.

Client:	NMDC Steel Limited, India
Contract type:	DBO - Design-Build-Operate
Start-up:	2023
O&M period:	2023-2028
Raw water:	various effluents from steel production
Product:	make-up water for cooling tower
Capacity:	4,320 m³/d, Evaporator: 29,925 kg/h

The Largest Centralised Zero Liquid Discharge Plant of Steel Industry in India.

WABAG has successfully completed the construction and commissioning of a centralized Zero Liquid Discharge (ZLD) plant for NMDC Steel Ltd. at its integrated steel plant in Nagarnar. The project covered the design, construction, commissioning, and operation of a ZLD facility with a capacity of 180 m³/h, supporting a steel production capacity of 3 MTPA.

MAIN PROCESS STEPS/COMPONENTS

- Pre-treatment: High-Rate Solid Contact Clarifier (HRSCC)
- Multi Grade Filter (MGF)
- Activated Carbon Filter (ACF)
- UV Disinfection System
- Basket Strainers
- Ultrafiltration System
- MIcron Cartridge Filter
- 2-stage Reverse Osmosis
- Multiple Effect Evaporator (MEE)
- Sludge treatment

- **MAXIMIZING SUSTAINABILITY**
- **MINIMIZING ENVIRONMENTAL IMPACT**
- **MINIMIZING DEPENDENCY ON FRESHWATER RESOURCES**

Innovation-Driven Research for Next-Generation Desalination

Membrane Crystallization - Introducing our new patented process,ZEROPUR®

In-house R&D

On the foundation of our extensive desalination experience, our current focus is on the development of the membrane crystallization process (ZEROPUR®), a technology for zero liquid discharge (ZLD) or minimum liquid discharge (MLD).

This patented innovation incorporates a combination of vacuum membrane distillation with crystallization, which provides scaling-free operation and subsequently high desalination performance. It covers a very elegant solution for liquid or brine concentration with continuous crystal removal/discharge and can also be utilized for the recovery of valuable resources through the selective separation of salts (lithium chloride, etc.).

The main features are the modular system design and the non-metallic material of construction, which prevents corrosion problems. This technology has the potential of a game changer and for example offers great potential for landlocked Indian industry, which is legally obliged to employ ZLD.

Biomimetic RO Membranes for low-energy Brackish Water Desalination

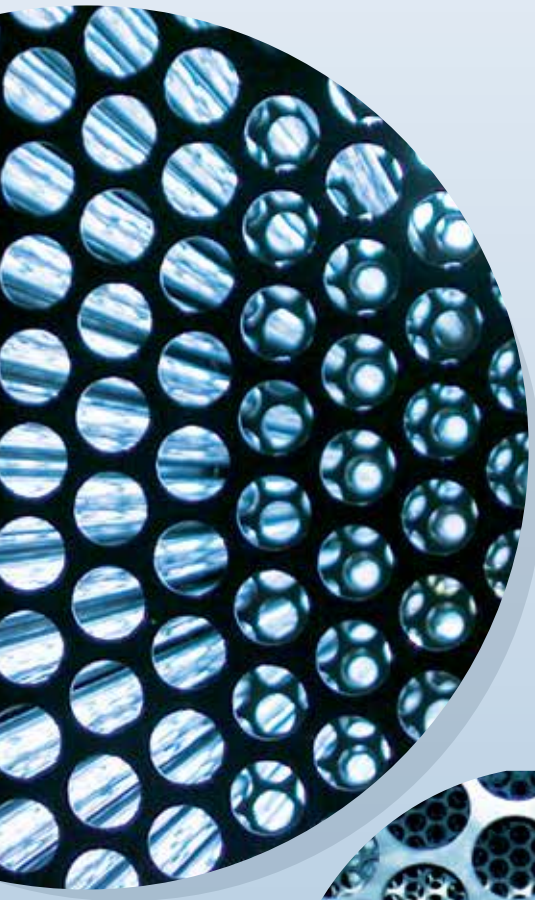
Another topic are biomimetic brackish water RO membranes, which provide comparable recovery rates at lower energy consumption, i.e. a reduced carbon footprint is accomplished at a comparable desalination performance. In order to compare such membranes with conventional membranes, we are conducting full scale pilot tests at the Chennai Koyambedu Water Reclamation plant (TTRO plant).

ZEROPUR®
and
Biomimetic Membranes:

Next-Generation Solutions for ZLD and Energy-Efficient Desalination

Thermal Desalination technologies

Multi-effect distillation (MED)



Thermal desalination (multi-effect distillation) takes place in a series of vessels (effects) in which the principle of condensation and evaporation at reduced ambient pressure is applied. This permits the saline water to undergo boiling without the need to supply additional heat after the first effect.

Thermal desalination – the advantages

- Stable and proven process
- Minimal or no need for pre-treatment
- High output water purity level (≤ 10 ppm TDS)
- Ideal in combination with power plants
- Simple operation with low maintenance costs

Achieving synergy - MED

The MED desalination process is normally used for medium-sized and large-scale thermal desalination plants where thermal energy is available in the form of low-pressure steam (≥ 0.3 bar abs.) or waste heat, e.g. in combination with thermal power plants or industrial complexes. It therefore represents the most economic distillation process from an energy efficiency perspective.

Main advantages

The MED process operates at low temperatures with high thermal efficiency, providing:

- Low thermal energy consumption
- Low operating costs

Selected references

AVR, Rotterdam, The Netherlands: 24,000 m^3/d, process water
CMI, Marmara, Türkiye: 3,360 m^3/d, process water

MED-TVC - enhanced efficiency

Standard MED plants are equipped with thermal vapour compressors for enhanced efficiency.

As a rule, the TVC desalination process is employed for small to large-scale thermal desalination plants where thermal energy in the form of medium pressure steam (>3 bar) is available, e.g. in combination with thermal power plants or industrial complexes and this results in low operational and investment costs.

Therefore, from cost-efficiency standpoint, TVC distillation is the most advantageous, steam-heated process for medium-sized plants.

Main advantages

The TVC process operates at low temperatures with high thermal efficiency, providing:

- Small to large train sizes
- Low investment costs

Selected references

Tobruk, Libya: 13,333 m^3/d, potable water
Suralaya, Indonesia: 6,000 m^3/d, process & potable water
Rembang, Indonesia: 6,000 m^3/d, process & potable water,
GMDC, Kutch, Gujarat, India: 2,400 m^3/d, process water
Benghazi North, Libya: 4,800 m^3/d, process water

Multi-stage flash (MSF) - large-scale thermal desalination technology

MSF - the big solution. The MSF desalination process is utilised mainly for large-scale, thermal desalination plants where thermal energy in the form of low-pressure steam (>2 bar) is available, e.g. in combination with thermal power plants or industrial complexes.

Saline water is heated by steam and then fed into a series of vessels (effects) where reduced pressure leads to immediate boiling (flash) without the need for additional heat.

Main advantages

- Large train sizes
- Low energy consumption

Selected references

Burrup Penninsula, Australia: 3,600 m^3/d, process & potable water
CHP, Taba, Egypt: 2,000 m^3/d, potable water

MED-MVC - the stand-alone solution

Where an external steam source is unavailable for heating, standard MED plants are equipped with mechanical vapour compressors (MVC). These provide heat for water evaporation through mechanical steam compression.

The MED-MVC desalination process is normally used for small to medium scale thermal desalination plants where thermal energy is unobtainable. The mechanical compressor is electrically or diesel driven.

Main advantages

- No need for external thermal energy
- A robust process

Selected references

SIRTE, LIBYA:
10,000 $^3/d$, potable water
REFURBISHMENTS
Khoms, Libya: 30,000 $^3/d$, process water
Zliten, Libya: 30,000 m^3/d, potable and process water

WABAG

sustainable solutions. for a better life.

WABAG offers sustainable solutions for:

- Drinking water treatment
- Industrial water treatment
- Sea and brackish water desalination
- Water reclamation
- Municipal wastewater treatment
- Industrial wastewater treatment
- Sludge treatment

WABAG is one of the world's most innovative water treatment companies with know-how in specific technologies and in-house developed processes such as:

• Fine sieving	MICROPUR®
• Biofiltration	BIOPUR®
• Moving bed biofilm reactor	FLUOPUR®
• Activated sludge processes	Hybrid™, MICROPUR-CAS®
• Sequencing Batch Reactor (SBR)	CYCLOPUR®
• Membrane bioreactor	MARAPUR®, MICROPUR-MBR®
• Membrane filtration	RO, MF, UF, NF CERAMOPUR®, CERAMOZONE®
• Denitrification	BIODEN®, ENR®
• Oxidation processes	ADOX®, BIOZONE®
• Adsorption processes	CARBOPUR®, PACOPUR®
• Anammox	DAMOPUR®
• Thermal desalination	MED, TVC, MVC
• Membrane Crystallization, MEE	ZEROPUR®
• Deep bed filtration in various designs	
• Energy-optimised sludge treatment	ENOPUR®

The WABAG Group represents a leading multinational player with companies and offices in over 20 countries and a focus on emerging markets in Europe, Africa, Near/Middle East, Sout East Asia and India.

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