DTRI

المؤسسة العامة لتحلية المياه المالحة
Saline Water Conversion Corporation (SWCC)

ANNUAL REPORT
2022

بسم الله الرحمن الرحيم

قال تعالى:

وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ

"هدفــي الأول أن تكـون بلادنــا نموذجــاً ورائــداً فــي العالــم على كافة الأصعـدة، وسأعمــل معكــم علــى تحقيــق ذلــك"

خــادم الحرميــن الشريفيــن

الملك سلمــان بــن عبدالعزيــز آل سعــود

"اعتمدنا تطلُّعات طموحة لقطاع البحث والتطوير والابتكار، لتصبح المملكة من رواد الابتكار في العالم، وسيصل الإنفاق السنوي على القطاع إلى 2.5% من إجمالي الناتج المحلي في عام 2040م، ليُسهم القطاع في تنمية وتنويع الاقتصاد الوطني من خلال إضافة 60 مليار ريال إلى الناتج المحلي الإجمالي في عام 2040م، واستحداث آلاف الوظائف النوعية عالية القيمة في العلوم والتقنية والابتكار، بمشيئة الله"

سمو ولي العهد

الأمير محمد بن سلمان بن عبدالعزيز

أنَّ أولويات الوزارة تشملُ تمكينَ الشركاء في منظومة البحث والتطوير والابتكار في تحفيز الابتكار وتوطين التقنيات لتقديم الحلول الفعلية في قطاعات الوزارة،باستخدام أحدث التقنيات مثل تقنيات المياه و التقنيات الحيوية وتقنيات الذكاء الاصطناعي وإنترنت الأشياء والاستفادة من الثورة الصناعية الرابعة، حيث أنَّ النهجَ التكاملي والشمولي للأولويات والتطلعات الوطنية يستلزمُ قدرًا كبيرًا من التنسيق والتعاون الفعال والمثمر مع مختلف الجهات، وهذا حتمي في ظل المتطلبات والفرص التي يفرضها الوضع الراهن، ولضمان وضع المملكة في مصاف الدول المُمكِّنةِ للبحث والتطوير والابتكار.

معالي وزير البيئة والمياه والزراعة

م. عبدالرحمن بن عبدالمحسن الفضلي

"مستقبل التحلية يُصنع هنا، بأفكار وأبحاث وابتكارات فريق معهد الأبحاث والابتكار وتقنيات التحلية، المزيد من الحلول والتقنيات والآفاق التي لا حدود لها، والمزيد أيضاً من الجهود لصناعة الفارق في تقنيات المياه وحلولها"

معالي المحافظ

م.عبدالله بن إبراهيم العبدالكريم

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SECTION 1 LETTER FROM THE DIRECTOR

The world currently is suffering from water scarcity where 4 billion people are facing water shortage at least a month per year, with an estimated financial risk impact around 300 billion dollars. The MENA region is among the fastest-growing due to continued strong, ~3.5% p.a., real GDP growth and ~2% p.a. population increase where the expected worldwide growth in demand is approximately 20% between 2020-2050. Thus, sufficient water supply is a prerequisite for reaching several of the United Nations' sustainable development goals. Since the establishment of the

DesalinationTechnologies Research Institute (DTRI) in 1987 AD, the Institute has worked in many different aspects to serve the water industry worldwide by building its strength to grow into a global player. In terms of scale SWCC is the largest desalinated water producer in the world, with more than 47 years of know-how in the water industry. It aims for performance excellence with all services at the highest standards, to drive research and innovation, to be the champion for advances in desalination technology and to deliver innovation in the water industry. These aims are the key drivers of DTRI's activities, with the goals of efficient, cost-effective, and sustainable features to support everyone everywhere - both urban and rural populations.The support of His Excellency the Minister of Environment and Water and His Excellency the Governor of the SWCC has been essential to provide a highly developed research infrastructure and distinguished research, engineering, and technical teams with a high Saudization rate. The Institute has been able to build on its essentials, firstly, by strengthening the core to enhance and stabilize current work performance, focus on growing core service offerings in seawater, increase revenue collection from existing practices, and drive synergies where feasible at the SWCC corporate level.

Secondly, to expand beyond water desalination by increasing the scope of technology in play, expanding service to cover the whole water industry, making and growing connections to develop and commercialize R&D in collaboration with solutions providers, and expand technical consultations to non-SWCC plants within KSA and across the GCC and MENA regions.

Thirdly, to lead the pack to revolutionize the industry by engaging with leading water-focused entities in joint research initiatives, becoming the reference for water technologies and industry through thought-leadership, evolving into a global player by becoming financially self-sufficient, expanding technical consultation services to customers worldwide, and commercializing the majority of patents it has developed. I am pleased to write this letter on the occasion of the issuance of this annual report for the year 2022 Desalination Technologies Research Institute, which reflects the research activities of investment, development and research projects and defect repair projects, as the Institute played a pivotal role in serving the water industry through its various development activities. Thus, I would like to take this opportunity to thank everyone who has contributed to the implementation of these distinguished research activities, including research, technical and administrative staff. In conclusion, this report contains a comprehensive overview of all research activities carried out by the Institute for the year 2022, including cooperative research agreements with leading local and international companies in the desalination industry and research with the aim of developing and setting the standard for technology in the water industry.

Eng. Tariq Alghaffari
Executive Director Of DTRI

SECTION 2 ABOUT DTRI-SWCC

The Saline Water Conversion Corporation (SWCC) is a pioneer in desalination water production and the current world leader in production capacity, producing 18% of the world's desalinated seawater. In 1987, SWCC founded the Desalination Technology Research Institute (DTRI) to carry out fundamental and applied research in desalination and assist the plants in the SWCC system to implement world's best practice.

Over the past 35 years DTRI has made many advances in the development of new technologies in the desalination field, with 12 granted patents. DTRI researchers have published 150 peer-reviewed research papers in the science and engineering of desalination and presented more than 280 papers in national and international conferences. In supporting SWCC plants in proposing best practice solutions for operational issues and measures to enhance current operational practice, DTRI has completed over 174 applied research projects, finalized over 400 troubleshooting and analysis projects. DTRI has also completed 110 evaluation projects giving rigorous scientific evaluation of desalination-related products from outside companies (e.g., antiscalant, antifoaming agents, and membranes). This support contributes to SWCC's core mission by increasing plant efficiency, availability, and production, reducing the costs and impact of water production.

VISION

To be the world's leading institute in research and innovation in the water industry and environmental solutions.

MISSION

Leading innovation in desalination technology for efficient and financially efficient water production and sustainable environmental development for everyone everywhere.

To drive world-class research, technological development and innovation activities to deliver advanced water solutions stemming from innovative water technological industry and business development approaches, to contribute to long-term water security (through advanced water services delivery).

RESEARCH PRIORITY

The graph below shows the different priority criteria of DTRI based on market attractiveness. Priorities 1 and 2 indicate the current ongoing projects & initiatives supporting the vision and mission of SWCC-DTRI. In addition, those priorities are flexible enough within DTRI to invest and work on different emerging technologies that could come up later on.

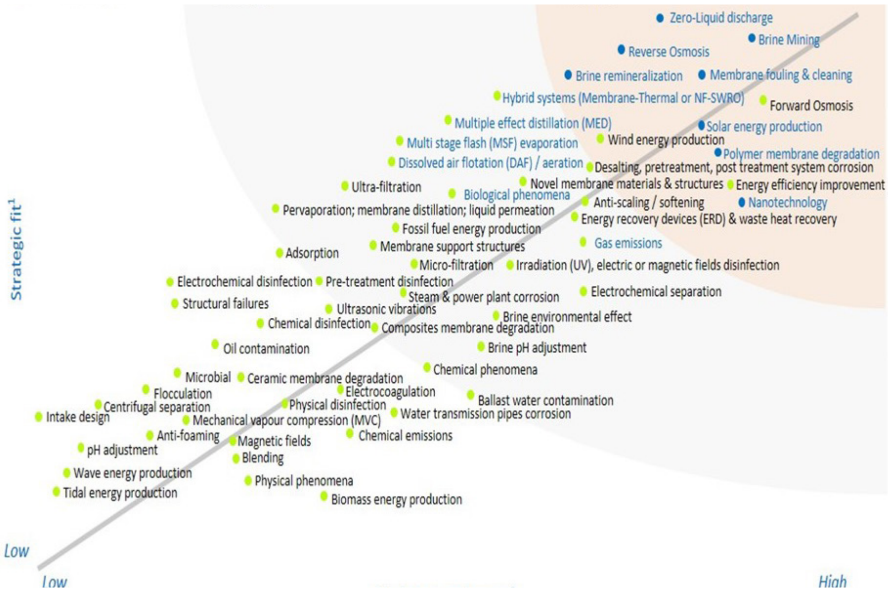


Figure 1 Research Priority

SECTION 3 PROJECT OVERVIEW

In 2022, DTRI carried out 71 projects, grouped under the six main categories of Research, Enhancement, Implementation, Design, Study and Evaluation. These categories are defined as follows:

Research:
Developing and testing new desalination technology in DTRI laboratories or pilot plants.

Enhancement:
Modifying the current operational practice in SWCC plants to increase the plant efficiency, availability, safety, water quality, or other deliverable.

Implementation:
Scaling-up DTRI pilot research to the commercial scale.

Design:
Carrying out detailed engineering design for commercial projects.

Study:
Conducting feasibility studies for new initiatives and ideas.

Evaluation:
Evaluating and testing commercial products such as antiscalants, antifoaming agents, and membranes.

PROJECT CLASSIFICATION

Summarized in this report are 36 research projects, 6 enhancement projects, 13 implementation projects, 5 design projects, 3 feasibility studies and 13 product evaluations.

PROJECT TYPE

- 36 Research
- 06 Enhancement
- 13 Implementation
- 05 Design
- 03 Study
- 13 Evaluation
- 15 Troubleshooting

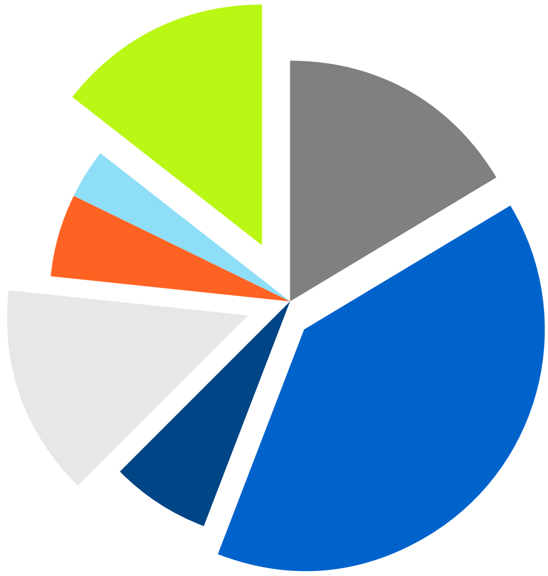


Figure 2 DTRI Project Classification based on research nature

PROJECT STATUS

Of the projects covered in this report, 29 have been completed during 2022, 37 are ongoing, 11 are under procurement and 14 are in the registration stage.

PROJECT STATUS

- 37 On going
- 11 Procurement
- 14 In registeration
- 29 Complated

Figure 3 DTRI Projects Status

SECTION 4 PROJECT DETAILS

4.1 HIGHLIGHTED PROJECTS

Design and Construction of ZLD Demonstration Plant at Haql SWRO Desalination plant for production of pure NaCl crystal salt, liquid Bromine and Magnesium metal

For more than a century, humanity has been impressed by the range of materials available from the ocean and has sought to extract them in an economic fashion. Desalination concentrate, or brine, would appear to be a better source of anything that can be extracted from the ocean than seawater. A large part of the energy involved to extract any mineral is in removing water and desalination brine already obviously has a large amount of water removed. Any process will also be more efficient the smaller the volume that needs to be processed to extract a give amount of chemical: for the same amount of product, desalination brine will take less energy to move about a plant than seawater, and have a lower capital cost.

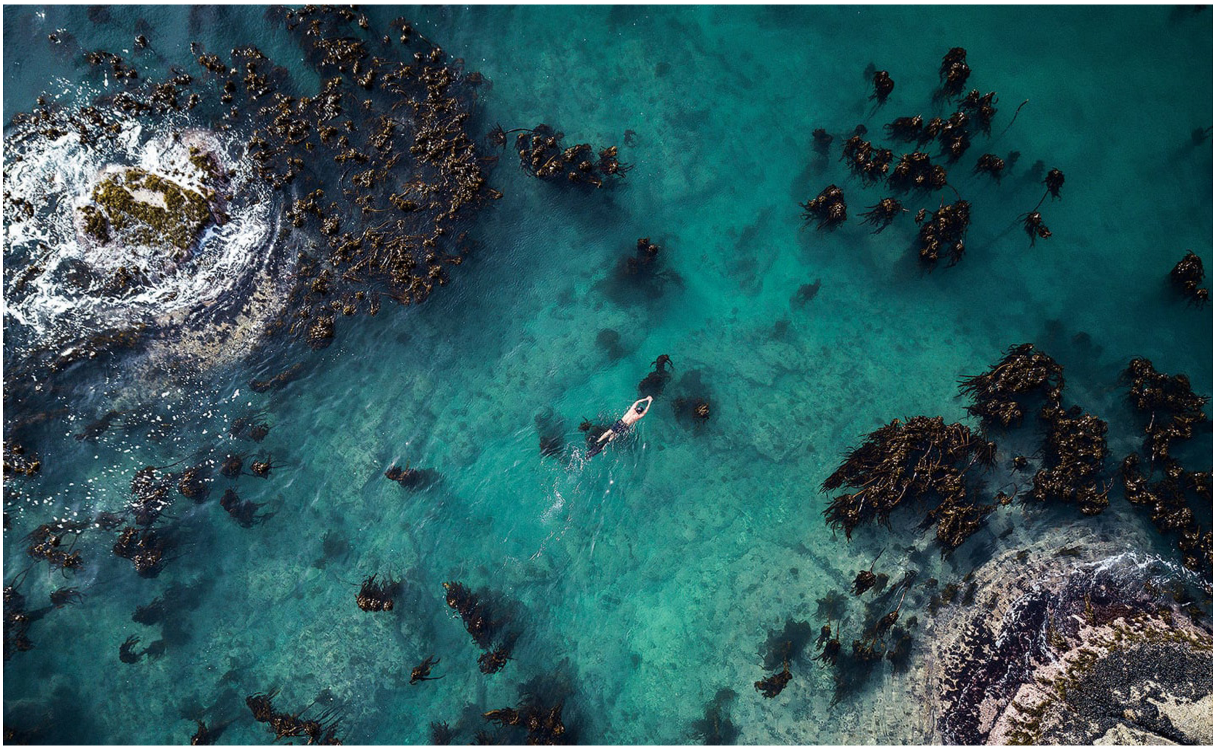
At the Haql SWRO plant, SWCCC will be constructing a demonstration plant designed by DTRI to illustrate three economically-viable brine mining processes for products that have historically been extracted from seawater: sodium chloride, bromine, and magnesium metal. This will show the technical feasibility of the commercial scale plant, also designed by DTRI, which aims to produce enough sodium chloride for all the industrial users in Jubail Industrial City.

The first key principle of the demonstration plant is nanofiltration (NF): membranes that can selectively reject more highly charged ions, such as magnesium, calcium, and sulfate, while allowing less charged ions, such as sodium and chloride, to pass through. The benefits of this are twofold: a much more concentrated stream containing magnesium, and a stream containing almost all of the sodium and chloride that can be efficiently concentrated with new membrane-based brine concentrator technology – if the other components were present, they would precipitate out and foul the membrane. NF membranes have been continuously improving in selectivity, which is why such a plant has not been built before.

After membrane concentration to about 25% solids, the sodium chloride fraction will be crystallized in a thermal crystallizer, giving sodium chloride of greater than 99% purity suitable for use by the Kingdom's chemical industry. The crystallizer will also produce a small volume of concentrated solution that is rich in potassium and bromine. This solution will be treated by standard technologies to extract bromine, an important chemical used in oilfield clearing which is currently not produced in the Kingdom.

The magnesium-rich reject of the NF process will be treated to produce magnesium hydroxide, which will be dehydrated to magnesium oxide and then reduced to magnesium metal- a key strategic material of the 21st century increasingly used in cars, aircraft, and consumer electronics. A newly developed thermal process will be used to produce metallic magnesium in which the magnesium oxide reacts with carbon with about half the energy cost and carbon footprint of the conventional thermal process.

The project will demonstrate that is technically feasible for the Kingdom to go from being a net importer to a net exporter of sodium chloride, bromine, and magnesium metal, becoming self-sufficient in these critical materials without the need for extensive land-based mining operations.



Carbon Capture Storage and Reuse using Algae

SWCC has enacted several environmentally conscious initiatives to combat global warming. Aside from transitioning from thermal cogeneration desalination facilities to less energy-intensive SWRO technologies, SWCC is launching an ambitious agenda for Carbon Capture Storage and Reuse (CCS-R) using algae.

Carbon dioxide (CO_2) is a byproduct of all thermal and combustion processes and is responsible for 76% of all Green House Gas (GHG) emissions. The residence time for CO_2 in the atmosphere is over 1000 years making it the prime suspect in the GHG emissions-Global warming relationship. Capturing carbon dioxide and storing it are two energy-intensive processes that make carbon capture and storage economically challenging. But algae is a low-cost, efficient alternative that removes CO_2 from the environment and packages it as a commercially viable oil.

SWCC intends to offset its carbon emissions for existing thermal, SWRO, brine refining, and hydrogen production initiatives by CCS-R. When using algae for carbon capture and storage, its increased biomass production can be used for making biofuels, biodegradable plastics, pharmaceutical products, and a host of other commercially viable commodities that include fertilizers and animal feed.

The conversion of CO_2 to reusable-commercially viable commodities opens up new potential opportunities for developmental partnerships, employment opportunities, and revenue streams while fulfilling; SWCC's need for CCS-R and the Kingdom's 2060 mandate for Net Zero Carbon emissions.

Control of Disinfection By-Products (DBPs) in Desalinated Seawater Production and Transmission System.

Bromate ion can form when water containing any amount of bromide ion is disinfected using common oxidants such as hypochlorite. The maximum amount of bromate ion is regulated all over the world, because of concerns about its toxicity and its role in generating other toxic and carcinogenic by-products, such as trihalogenated methanes. In the Kingdom of Saudi Arabia, bromate levels must not exceed 10 parts per billion (ppb) in potable water. Reverse osmosis (RO) of seawater generates product water with relatively high bromide concentrations compared to surface waters: until relatively recently, however, World Health Organization (WHO) recommendations on boron concentrations in potable water required the use of a second RO stage, which also reduced total dissolved solids and hence bromide. The strategic shift to RO rather than thermal desalination methods and the relaxation of WHO boron standards has led to the recent emergence of bromate as a species of concern in water transmission systems in SWCC.

In field trials at one of SWCC's large SWRO desalination plants, DTRI researchers have demonstrated that addition of a small amount of ammonia (about 200 ppb) to produced water with an elevated bromide content is effective not only in preventing bromate formation in water storage tanks, but throughout the transmission system. As far as 200 km from the source, bromate and trihalomethane concentrations were reduced to below the detection limit. DTRI has filed a patent on the novel technology and is seeking to roll it out to all SWRO plants where bromate concentrations have been high enough to be of concern.

4.2 COMPLETED PROJECTS

4.2.1 TROUBLESHOOTING AND FAILURE ANALYSIS PROJECTS

1. Deposit Sample Analysis from Control Valve at Pumping Station PS No.2 Yanbu-Madinah Transmission Systems
2. Material Analysis of Metallic Sample from Jubail Plant
3. Material Analysis of Main Oil Pump Samples from Jubail Plant
4. Material Identification of RO System Victaulic Coupling Bolts from Ras Al Khair Plant.
5. Investigation on Riser Tube Rupture from Boiler Unit # 65 in Jubail Phase II Plant.
6. Investigation on Tubes Rupture of Boiler # 6 from Yanbu Plant phase II
7. Failure Analysis of Ultra-filtration (UF) leakage in SWRO Khafji Plant
8. Failure Analysis of Economizer Tubes in Heat Recovery Steam Generator 52(HRSG 52), Ras Al Khair Pl ant
9. Second Failure Analysis of Heat Recovery Steam Generator 52 (HRSG 52) leakage in Ras Al Khair Plant
10. Membrane Autopsy and Assessment After Veolia Cleaning In Place (CIP) Process
11. Investigation of the cause for High SDI in the Ras Al Khair SWRO Plant
12. Khobar MSF Plant Contamination of Polyphosphate Tank.
13. Investigation of MSF 35 Deaerator Failure in Al-Jubail SWRO Desalination and Power Plants.
14. Al Khafji SWRO Plant’s Samples (Biological Assessment).
15. Autopsy Polypropylene Cartridge Filters Al Jubail SWRO Plant

4.2.2 EVALUATION PROJECTS

1. Evaluation of De Nora Chlorine Dioxide Generation system in Ras Al Khair Plant
2. Evaluation of PureLine Chlorine Dioxide generation system (DC2 – 2 chemicals) in RO product water of SWCC Jubail Desalination plant
3. New Inhibitor for BFW Treatment to Control Corrosion of Boiler tubes of RAK Plant
4. Prequalification trial of application of Nalco Chlorine Dioxide generation technology in SWCC Khobar Plant Product Water
5. Testing and evaluating the newly developed Carbon Nano-Tube Membrane of Shinshu University
6. Evaluate antifoam for UniSal solution company in Khobar Plant
7. Evaluation of USCI Company Antiscalant PHA In Jubail Plant

4.2.3 RESEARCH PROJECTS

1. Environmentally Friendly Cleaning for Reverse Osmosis Membranes by Hyper-saline NaCl Solution.
2. Electrochemical Corrosion Behavior Studies of different metallic alloys and cement lining delamination in Water Transmission systems

4.2.4 IMPLEMENTATION PROJECTS

1. Shoaiba NF Project for Magnesium addition to product water in Shoaiba RO Phase 4 Desalination Plant (VOP No.38)
2. Instrumentation System to Predict and Diagnose Rotating Machinery Faults.
3. Cooling the Distillate Water in Ras Tanura Plant

4.2.5 STUDY PROJECTS

1. Economic Feasibility Study to Operate a Multi-Effect Evaporation Unit at a Temperature of 85-95 °C

4.2.6 ENHANCEMENT PROJECTS

2. YANBU Phase 2 MSF Performance Improvement

3. YANBU Phase 2 MED Performance Improvement

4.3 OTHER PROJECT

1. A study to reduce the dosing rate of anti-scalant by (10 to 20 %) in one MSF unit in Ras Alkhair

2. Anti-microbial peptide (AMP) for membrane biofouling control

3. Brine backwash in Yanbu SWRO plant

4. Bypass of dissolved air flotation (DAF) system in Ras Al Khair SWRO plant

5. Cartridge filter failures in the New Al Jubail 450,000 m3 SWRO Plant

6. Clean-in-place system for the Cartridge Filters in SWRO desalination plants

7. Design and Construction of ZLD Demonstration Plant at Haql SWRO Desalination plant for production of pure NaCl crystal salt, liquid Bromine and Magnesium metal

8. Development of automatic Vehicle for seawater sample collection and monitoring with Tabuk University (Mariner 6)

9. DMF media depth increase in Ras Al Khair SWRO plant

10. Evaluate different solar collectors to be coupled with desalination

11. Evaluation of low energy BiTurbo NF RO system (FEDCO)

12. High CF wind power for areas with moderate wind power densities

13. Increasing renewable penetration in Haql desalination plant to achieve Green Desalination process

14. Low-pressure NF membranes for SWRO brine concentration

15. Membrane Biofouling Control_ Development and Evaluation of Advanced Cleaning Strategies (DTRI-KAUST)

16. Membrane Replacement at Jeddah SWRO Desalination Plant

17. Metallic Organic Framework for Brine Mining

18. NACE IMPACT PLUS Audit of Desalination Plant

19. Novel Method for Hard Fouling Removal Increases Water Production to Design Capacity

20. Off-line Inspection Findings of above Storage Water Tank from Yanbu-Madinah Transmission Systems

21. Osmotic Cleaning to Mitigate SWRO Membrane Fouling

22. Performance improvement Al-Shoaiba SWRO Desalination Plant (I)

23. Performance improvement Al-Shoaiba SWRO Desalination Plant (II)

24. Performance improvement project in Shoaiba 2 and Al Khobar 3 MSF plants

25. Pilot Crystallizer Unit for Producing High Purity NaCl Salt

26. Robot for inspection and cleaning of pipe lines

27. Second Failure Analysis of Heat Recovery Steam Generator 52 (HRSG 52) leakage in Ras Al-Khair Plant
28. Testing & evaluating the newly developed Carbon Nano-Tube membrane of Shinshu University
29. Utilization of hydrogen from Electro-chlorination System
30. Vibration Analysis and Diagnosis system

SECTION 5 LABORATORY REPORT

The DTRI central laboratories are equipped with state-of-the-art equipment for the analysis of samples related to desalination. They analyze samples from sea water to potable water, material related failures to biofouling, biological activity to chemical related issues and concentrated brines. The central laboratories support the SWCC plants and DTRI researchers and have performed over 23,000 different analyses in 2022, which includes analysis of potable water samples from around the kingdom for quality assurance.

The central laboratories have also increased their capability in 2022, implementing four major pieces of instrumentation.

SPECTRO ARCOS INDUCTIVELY COUPLED PLASMA – OPTICAL EMISSION SPECTROSCOPY

Due to their high salinity, seawater and brine samples for element elemental analysis by Inductively Coupled Plasma (ICP) need to be diluted. However, high dilution factors cause difficulties in analysis and less accurate results, particularly for trace elements, such as lithium. To overcome this limitation the central laboratories have implemented a SPECTRO ACROS Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) for element detection at high salinity (up to 200 g/L). This enables the detection of trace elements in seawater and brines without dilutions to increase accuracy of analysis for research in mineral harvesting from desalination brines. The system also includes an extended spectral range in the UV region (130-770 nm) for analysis of halogens, such as bromine and chlorine, with high accuracy and excellent detection limits.

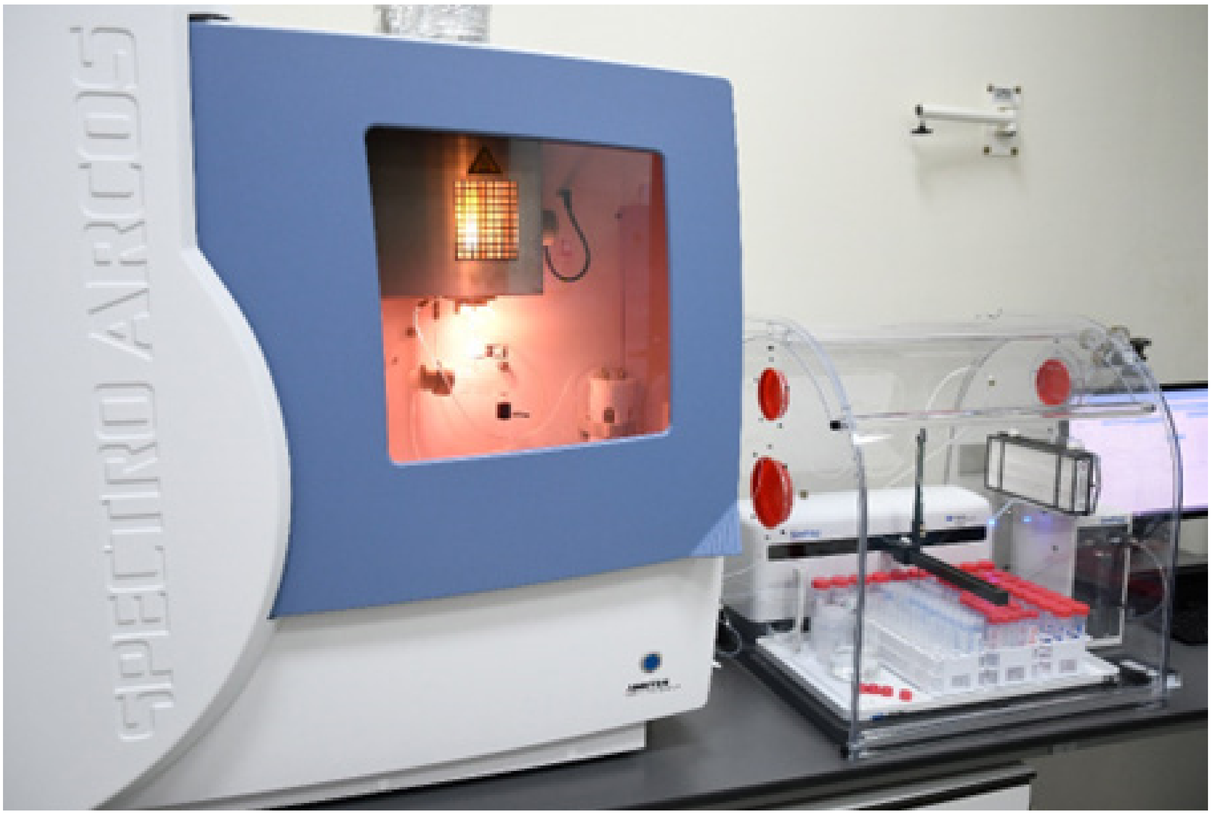


Figure 4 Optical Emission Spectroscopy

MAGRITEK 80 MHZ NUCLEAR MAGNETIC RESONANCE

To support the synthetic chemistry research at DTRI a Magritek Spinsolve Carbon 80 MHz Nuclear Magnetic Resonance (NMR) has been installed. The device uses magnetic resonance of the 1H and 13C atoms of a molecule to give its structural information based on the location and types of peaks in the spectra. This technique is essential for carrying out investigations in synthetic organic chemistry and makes it possible for DTRI to develop novel corrosion inhibitors, antiscalants and membrane precursors.

Figure 5 Nuclear Magnetic Resonance

TESCAN SCANNING ELECTRON MICROSCOPE

A TESCAN Vega4 Scanning Electron Microscope (SEM) has been installed at DTRI to provide high magnification microscopy to easily characterize diatoms, biofilms, corrosion type, corrosion products, scale and other research samples and is capable of revealing features less than 1 µm in size. The SEM is also equipped with the latest generation Oxford Ultim Max 65 Energy Dispersive X-Ray Spectroscopy (EDS) detector providing elemental analysis with 1 µm spatial resolution either of specific features of interest or over a large area.

Figure 6 Scanning Electron Microscope

DOC-LABOR LIQUID CHROMATOGRAPHY ORGANIC CARBON DETECTION AND ORGANIC NITROGEN DETECTION

The Liquid Chromatography Organic Carbon Detection and Organic Nitrogen Detection (LC-OCD-OND) machine enables the characterization of synthetic and natural-water soluble organics in industrial and non-industrial water systems and is one of three systems in the Kingdom of Saudi Arabia. The device can measure and characterize total organic carbon (TOC) and dissolved organic carbon (DOC) and is essential in measuring and characterizing the TOC and DOC of industrial processes that rely on membrane filtration, which may be adversely affected by sudden ecological or chemical changes in feed waters that may present diverse organic distribution profiles.

Figure 7 Liquid Chromatography Organic Carbon Detection and Organic Nitrogen Detection

SECTION 6 AGREEMENTS / MOU

SCOPE OF THE AGREEMENTS

1. Studying the possibility of valuable elements and metal extraction of brine solution.
2. Evaluation of Green hydrogen production from the sea water.
3. Improve the under vacuum chlorine dioxide generator efficiency for SWCC product water treatment.
4. Improve the purification plants pre-treatment by removing iron and manganese by using chlorine dioxide.
5. Establishing a process for controlled fractional precipitation of the concentrated monovalent-ion-rich brine produced by SWCC to produce sodium chloride crystals of controllable quality acceptable for applications in the chlor-alkali industry.
6. Establishing a process for controlled fractional precipitation of the supernatant remaining from monovalent-ion-rich brine after sodium chloride has been precipitated to produce precipitated crystals enriched in potassium chloride of controllable quality which can be purified by established flotation methods to produce product acceptable for fertilizer applications.

7. Establishing a process for controlled fractional precipitation of the divalent-ion-rich nanofiltration (NF) reject produced by SWCC to produce magnesium sulfate crystals of controllable quality acceptable for fertilizer applications.
8. Establishing a process for controlled fractional precipitation of the supernatant remaining from divalent-ion-rich brine after magnesium sulfate has been precipitated.
9. Market and concept studies of magnesium chloride, magnesium hydroxide, magnesium sulfate, potassium chloride, potassium sulfate, sodium chloride, and other potential salts of commercial interest as to be determined in discussion.
10. Establishment of appropriate quality parameters for magnesium chloride, magnesium hydroxide, magnesium sulfate, potassium chloride, potassium sulfate, sodium chloride, and other potential salts of commercial interest as to be determined in discussion.
11. Marketing and sales of the mineral salt products for the mineral salts listed above
12. FMD3 x SWCC: The Exploration of Porous Materials Platforms for Water Desalination Applications.
13. To obtain data relating to the effectiveness of RO and NF membranes prepared using the renewable material chitosan as a basis for ion rejection.
14. Multi-objective optimization of nanofiltration cascades for Na/Mg separation from brine
15. To obtain information on feasibility of Membrane Distillation (MD) for treating brine
16. The utilization of Drone technology as remote sensing and artificial intelligence to mitigate operation issues in desalination plants will hence reduce operation cost and increase desalination plant reliability and minimize emergency shutdown time.
17. Design of a novel drone which could facilitate the operation of desalination and that can be connected to a remote sensing system.

GOALS/EXPECTED OUTPUT

1. Research agreement.
2. Start manufacturing, supplying and installing a chlorine dioxide generation system.
3. Carrying out laboratory work at the facilities of Eden and its partner organizations as required.
4. Carrying out laboratory work at the facilities of SWCC as required.
5. Assessing the suitability of the laboratory processes developed as a basis for commercial processes to isolate minerals of commercial significance (as shown above, but not necessarily limited to these) from brines produced by SWCC desalination plants and fractions thereof.
6. Developing industrial process designs based on the assessment outlined in 3.
7. Designing one or more pilot plants for implementing these industrial process designs on a scale of 1 to 10 m3 of brine per day.
8. A marketing strategy for selling products derived from SWCC's potential brine-mining activities.
9. To obtain data relating to the effectiveness of photo reversible ion-exchange resins supported by metal organic frameworks for selective absorption/ desorption of cations of interest for brine mining applications.
10. Development of sustainable membranes for brine mining
11. To optimize the performance of multi-stage nanofiltration processes for the most efficient and cost-effective separation of Mg from desalination brine
12. To obtain information on feasibility of MD for treating brine in Ummlujj desalination plant.
13. Development project to design a novel drone which could facilitate the operation of desalination unit by connection of a drone with a remote sensing system.

SECTION 7 PAPERS PUBLISHED / CONFERENCE PARTICIPATION

During 2022 DTRI researchers have published 18 peer-reviewed scientific papers and presented 51 papers in conferences.

7.1 PAPERS PUBLISHED

1. Alayande, A. B., Lim, J., Kim, J., Hong, S., Al-Amoudi, A. S., & Park, B. (2022). Fouling control in SWRO desalination during harmful algal blooms: A historical review and future developments. Desalination, 543.

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2. Albaker, W. I., Al-Hariri, M. T., al Elq, A. H., Alomair, N. A., Alamoudi, A. S., Voutchkov, N., Ihm, S., Namazi, M. A., Alsayyah, A. A., AlRubaish, F. A., Alohli, F. T., Zainuddin, F. A., Alobaidi, A. A., Almuzain, F. A., Elamin, M. O., Alamoudi, N. B., Alamer, M. A., Alghamdi, A. A., & AlRubaish, N. A. (2022). Beneficial effects of adding magnesium to desalinated drinking water on metabolic and insulin resistance parameters among patients with type 2 diabetes mellitus: a randomized controlled clinical trial. Npj Clean Water, 5(1).

- https://doi.org/10.1038/s41545-022-00207-9

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7.2 CONFERENCE PRESENTATIONS

Title	Conference
Carbon footprint of various brine concentrators in zero liquid discharge process	**IDA Ocean brine mining**
Economics of Brine Mining Production of Sodium Chloride and Bromine	**IDA Ocean brine mining**
Energy and Exergy Analysis of the NF RO BC system	**IDA Ocean brine mining**
Valorization of seawater concentrate	**IDA Ocean brine mining**
Scope of Work of 2 Million Tons/Year NaCl and Br Project	**IDA Ocean brine mining**
Overview of DTRI System for Brine Mining of NaCl and Br	**IDA Ocean brine mining**
Brine Mining Cornerstone of DTRI Research	**ALADYR**
Harvesting Sodium Chloride and Bromine from Brine for the Chlor-alkali Industry	**ALADYR**
Brine mining for high value metals and minerals	**ALADYR**
Full-scale Facility for Re-mineralization of Desalinated Water with Magnesium Derived from Brine	**ALADYR**
High Temperature Multi Effect Desalination 95°C demonstration in DTRI pilot plant	**The 14th Gulf water conference**

Title	Conference
Prospect of Utilization of Solar Energy in SWCC Existing MED Desalination Satellite Plants	**The 14th Gulf water conference**
Multistage Nanofiltration System for Supplementing Drinking Water with Magnesium Extracted from Brine	**The 14th Gulf water conference**
Brine Mining – the Path Forward	**The 14th Gulf water conference**
Optimizing performance of granular media filters	**The 14th Gulf water conference**
Monitoring Of The Produced And Transported Water Quality Of SWCC Desalination Plants	**The 14th Gulf water conference**
8 Months of Successful Pilot Operation for Highly Purified and Concentrated NaCl Brine Production	**Singapore International Water Week (SIWW)**
Anti-Miroorganism peptide for membrane biofouling control	**13th Conference of the Aseanian Membrane Society (AMS13)**
Shoaiba NF-Mg Plant - Operational Strategy	**IDA Innovation Driven Desalination**
Clean-In-Place System for Cartridge Filters in Ras Al Khair Desalination Plant	**IDA Innovation Driven Desalination**
Innovative Backwashing System of Dual Media Filters	**IDA Innovation Driven Desalination**
The UF-FO-MD Hybrid System for Resources Recycle from Wastewater using SWRO Brine as FO Draw Solution	**IDA Innovation Driven Desalination**

Title	Conference
Innovation Trends in the Desalination Industry	**IDA Innovation Driven Desalination JobCor**
Approach Towards Green Desalination	**IDA Innovation Driven Desalination**
Innovation Trends in the Desalination Industry	**IDA Innovation Driven Desalination**
Carbon Footprint of Desalination Processes and the Way Towards Green Desalination System	**IDA Innovation Driven Desalination**
Investigation on Fire Tube Boiler Failure from CO2	**JobCor**
Overview of DTRI System for Brine Mining of NaCl and Br	**European desalination society**
Scope of work of 2 mil. Tpa NaCl and Br project	**European desalination society**
Economics of Brine Mining	**European desalination society**
Brine Mining – A New Horizon in Desalination	**European desalination society**
A Fouling comparison study of algal, bacterial, and humic organic matters in seawater desalination pretreatment using UF ceramic membranes	**European desalination society**

Title	Conference
Clean-In-Place system for cartridge filters in Ras Al Khair power and desalination plant	**European desalination society**
Performance improvement of dual media filter in Ras Al Khair desalination plant	**European desalination society**
Green Chemicals for Desalination and Brine Management	**European desalination society**
Concentrating Brine: Challenges and Solutions	**European desalination society**
Bromine Extraction from Crystallizer Purge	**European desalination society**
Subsidizing water cost by value-adding to desalination plant concentrate: key criteria for success	**European desalination society**
Supplementing desalinated drinking water with Mg mineral extracted from brine	**European desalination society**
Artificial intelligence and innovation in desalination	**IDA Innovation Driven Desalination**
Innovations in Desalination to reduce environmental impact	**IDA Innovation Driven Desalination**
Simulation Study for the Performance of Pervaporation vs Membrane Distillation processes for Treating SWRO brines	**IDA World Congress**
Noble approach for net zero carbon emission desalination configuration facilitated in hydrogen production	**IDA World Congress**
Investigating the salt crystallization phenomena of Red sea and Arabian gulf SWRO brines by solar evaporation	**IDA World Congress**

Title	Conference
The initiatives of operation excellence of pretreatment system in Ras Al Khair SWRO plant	**IDA World Congress**
AOM characterization and removal efficiency using various SWRO pretreatment techniques	**IDA World Congress**
The UF-Fo-MD hybrid system for resources recycle from brine	**IDA World Congress**
Seawater RO Desalination Process: A Cost-effective Solution for Potable Water Scarcity	**IDA World Congress**
Critical Aspects of Marine Corrosion and Failure Management	**NACE CORCON**
SWCC For Future	**Cairo Water Weeks (CWW)**
Recycling Brine For Mining Valuable Minerals	**Cairo Water Week (CWW)**
The environment, ecological impact, and its effect on desalination	**Saudi Water and Innovation (SWI-Hackathon 2022)**
Idea to Reality - Two Commercial Projects for Ocean Brine Mining in Saudi Arabia	**The 14th International Desalination Workshop (IDW 2022)**
Desalination Industry and Future Technologies	**Korea International Water Week (KIWW) 2022**

SECTION 8 FUTURE OUTLOOK

The future outlook of the Institute has been set by SWCC's vision as follows:

1. **Be the undisputed global leader in the water industry by:**
    - Owning, developing, engineering, implementing, operating production systems and integrated water service systems.
    - Investing in water corporations worldwide including partnerships in development, operation or management of water systems;
    - Reducing the cost of water to levels allowing financially viable use for agriculture.
2. **Extend into new water services along the value chain by:**
    - Providing water engineering and consultation services;
    - Providing services for IWPs, IWPPs and other integrated water solutions providers;
    - Providing integrated water solutions and services to KSA mega projects, industrial complexes and urban areas;
    - Leading the industry cluster and supporting local content development, Made-in-Saudi and Invest-in-Saudi programs.
3. **Pursue sustainable supply by:**
    - Renewing and extending the production fleet with energy efficient capacities;
    - Implementing energy projects as part of water production systems to decrease CO2 emissions and support the Saudi Green Initiative;
    - Developing and implementing water technologies to limit the impact of desalination on water ecosystem and marine life;
    - Providing sustainable water solution services for urban, industrial, and agricultural purposes.

4. **Foster innovation and technology development in the water sector by:**

- Innovating and incubating technologies in reliable, cost-competitive and clean water within the Circular Economy framework;
- Stimulating and co-investing into localization of the water sector in both upstream and downstream equipment and consumables manufacturing and services;
- Fostering the growth of Saudi small and medium businesses in the water sector;
- Attracting and developing talent;
- Supporting digital transformation and expansion of AI-based applications.

The future outlook of the DTRI is to work efficiently to forward all of these ambitions. Aligning the DTRI with SWCC to achieve these ambitions will bring benefits for the Kingdom:

- KSA's international recognition and image will benefit strongly in solving the water scarcity problem, critical for achieving several of humanity's Global Sustainable Development Goals.
- The growth and expansion along the value chain will foster further innovation in the sector, and will allow the growth of capabilities and resilience, further strengthening KSA's security of water supply.
- This growth will offer business opportunity for SWCC's KSA-based suppliers, supporting further growth of localization rates beyond 60% by 2030.
- Foreign Direct Investment – including ESG funds –will be attracted by the credibility and reputation of the global proposition centered on KSA's unique experience in the water industry.
- The focus on sustainability will support KSA to reduce CO2 emissions and fulfill the Saudi Green Initiative goals as well as preserving the marine environment and ecosystems by applying world's best-practice discharge technologies.

APPENDIX. SUMMARY PROJECT REPORTS

A01: A Standard Method For Determining Power Consumption And Water Costs Of Thermal Desalination In Cogeneration Plants

1. **Background / History / Initiatives / Needs**

    - Different methods with different bases are followed in estimating the water cost of thermal desalintion in cogneration plants, with no standard method followed which raises a lot of debated.
    - Great variation in results may lead to false decision from economic point of view and determining the environmental impact of thermal desalination plants

2. **Key principle**

    - The proposed method is based on a solid thermodynamic background for a robust and clear methodology for water and power cost for cogeneration plant and the approach used for distributing the fuel and capital and operation costs.

3. **Achievement / Economical benefit / Technical advancement**

    - The final technical report was completed and submitted

A02: A Study To Reduce The Dosing Rate Of Anti-Scalant By (10 To 20 %) In One Msf Unit In Ras Al Khair

1. **Background / History / Initiatives / Needs**

    - Ras Al Khair MSF unit produce more than 92,000 m3/d. They use a concentrated anti-scalant to be injected in the system without dilution. After the injection, the concentrated anti-scale will behave as a film near the wall of the pipe which will partially clean the tube bundles.
    - It was suggested to dilute the anti-scale before injecting it to the system by using a static mixer and recycle the brine water from the system to dilute the anti-scale.

2. Key principle

- For best possible mixing of the anti-scalant chemical into the recycling brine it is recommended to modify the existing dosing piping such, that there is a permanent brine flow through the DN20 mm pipe from the brine recycle pump discharge pipe to the suction pipe, into which the anti-scalant chemical would dosed. Further it is recommended to install a static mixer into the dosing line to allow a pre-mixing of the chemical before entering into the brine recycle suction pipe. The modified pipe arrangement should allow a brine flow through the DN 20 pipe from the pump discharge to the suction, which would allow a mixing ratio of the chemical of > 50 before dosing into the suction pipe.

3. Achievement / Economical benefit / Technical advancement

- All materials have been delivered. after modification of the line, an optimization will lower the dosing rate by (10 to 20 %).

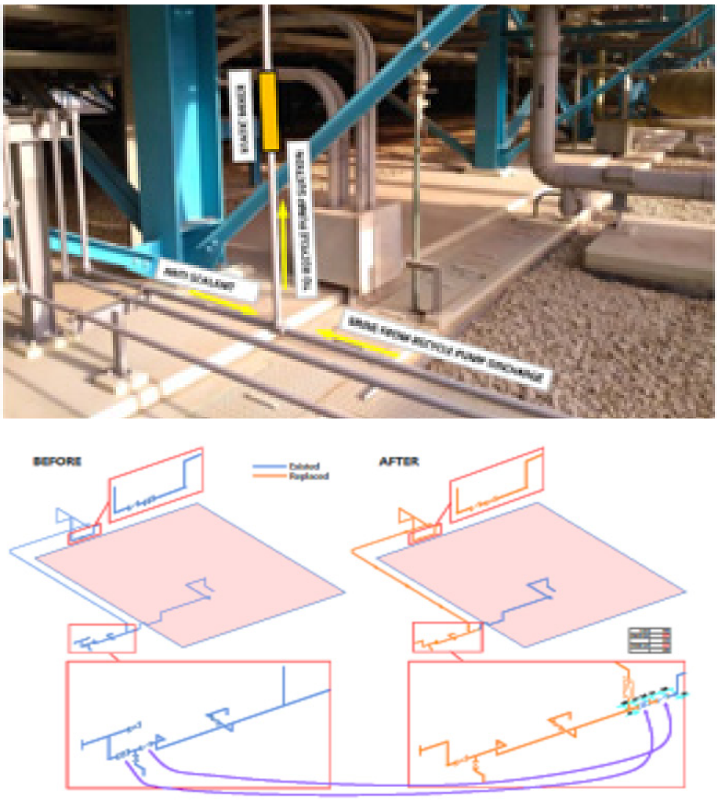


Figure 8 Skid for Anti-scalant Modifed Dosing System in RAK

A03: Anti-Microbial Peptide (Amp) For Membrane Biofouling Control

1. Background / History / Initiatives / Needs

- Membrane biofouling is one of the main challenges of seawater RO desalination process, which can cause up to 24% of the SWRO OPEX. To limit the biofouling, chemical biocides are intensively used for biofouling prevention and membrane cleaning. However, the usage of chemical biocides is expensive and not environmentally friendly. Considering the green initiative of the Saudi Arabia, it is necessary to develop an alternative membrane biofouling control strategy.

2. Key principle

- Natural anti-microbial peptide (AMP) is a good potential membrane biofouling control substance which are naturally released from the inner immune system of microorganism during their growth. These peptides can physically penetrate the cells of bacteria, and thus destroy them and limit the consequent biofilm formation on SWRO membranes.

3. Achievement / Economical benefit / Technical advancement

- By harvesting the AMP from bacteria, it has been shown that AMP could reduce 80% membrane biofouling in wastewater treatment using FO membranes. This project is to evaluate the effectiveness of AMP on SWRO membrane biofouling control. And the preliminary evaluation on seawater treatment has shown that the AMP could also reduce up to 50% flux decline caused by the biofilm formation of spiked marine yeast (Fungus).

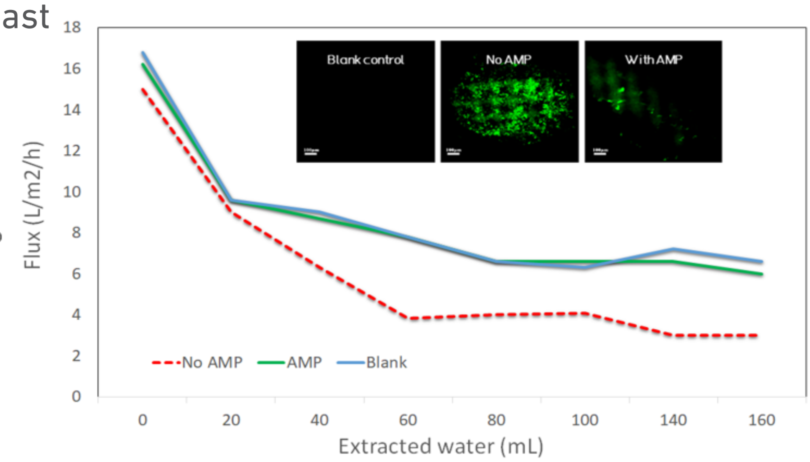


Figure 9 Effect of Anti-microbial peptide on Flux

A04: Brine Backwash In Yanbu Swro Plant

1. Background / History / Initiatives / Needs

- In conventional backwashing system, brine discharged from energy recovery device (ERD) is separated by two streams. One flows to the backwash water tank. And the other is discharged to outfall. Discharge valve is partly open to maintain the back pressure in the discharge piping. Brine in backwash water tank is supplied to DMF by backwash pump. A set of flow meter and control valve will adjust the flow rate of brine.
- In case of Yanbu plant, there is no discharge valve. So, the pressure of discharge piping after ERD is not sufficient to supply brine to backwash tank. But all the brine will be discharged to outfall. So, filtered water has been used as a backwash water in the DMF system.

2. Key principle

- By the installation of discharge valve in the discharge piping, brine will be supplied to backwash water tank. And it can be used as a main source of DMF backwash.

3. Achievement / Economical benefit / Technical advancement

- DMF can supply 21,960m3/day of filtered water to RO system. It will increase the plant operation flexibility and availability.

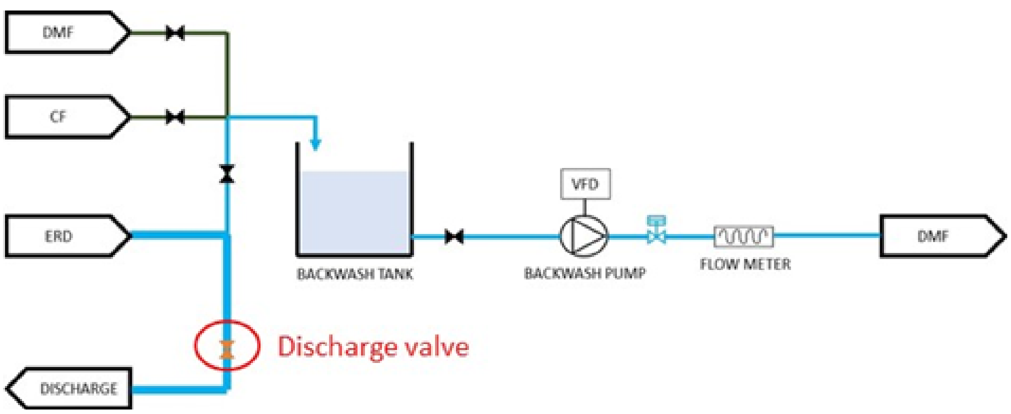


Figure 10 Schematic diagrams of DMF backwashing system after discharge valve installation.

A05: Bypass Of Dissolved Air Flotation (Daf) System In Ras Al Khair SWRO Plant

1. Background / History / Initiatives / Needs

- The main purpose of DAF system is to remove suspended solid, algae and oil & grease. Below 2 NTU of raw seawater turbidity, turbidity removal efficiency is little bit low. And when raw seawater turbidity is lower than 1.2 NTU, turbidity removal efficiency started to be minus values. Minus value means turbidity of DAF outlet is greater than turbidity of intake.
- There is no bypass in DAF system. So, it is continuously operated.

2. Key principle

- By the raw seawater turbidity, DAF operation will be decided. If raw seawater turbidity is greater than 2 NTU, DAF system will be in service. Otherwise, DAF system will be bypassed.

3. Achievement / Economical benefit / Technical advancement

- By bypass of DAF system, it will save 1.5 M USD/year of energy cost. And maintenance cost will be decreased.

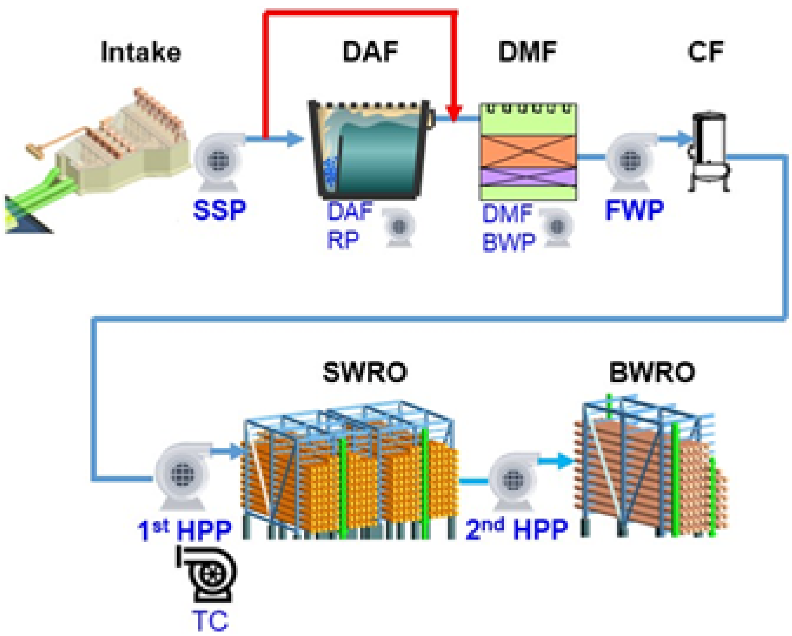


Figure 11 Schematic diagrams of Prposed DAF Modification System

A06: Cartridge Filter Failures In The New Al Jubail 450,000 M3 SWRO Plant

1. Background / History / Initiatives / Needs

- Frequent cartridge filter replacements are reported less than the usual 3-month period in the new 450,000 m3. The Plant uses melt-blowdown polypropylene filters that provide high surface contact area and particulate retention with minimum pressure drops and a high filtration capacity. Filters are robust and do not degrade in seawater. However, they can break down when and pucker when exposed to chlorine gas, sulfuric acid, and nitric acid.
- Physical observation of filters revealed a severe case of puckering and material distortion.

2. Key principle

- Autopsy of cartridge filters
- Light and electron microscopic evaluation
- Biochemical evaluation
- Identification of the potential cause of failure

3. Achievement / Economical benefit / Technical advancement

- Technical report
- Identification of the problem
- Consultation advice

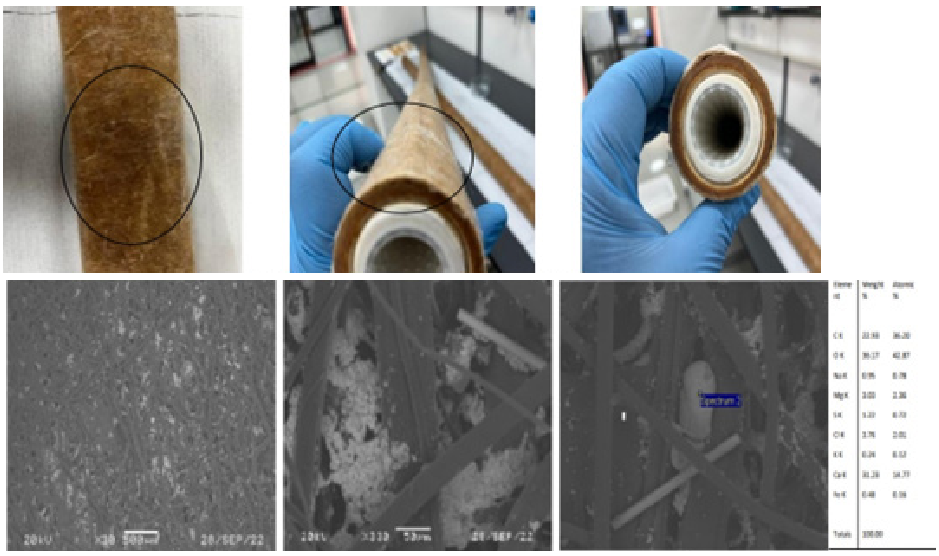


Figure 12 Riceved Cartridge filter Sample and SEM Elemental Analysis

A07: Clean-In-Place System For The Cartridge Filters In SWRO Desalination Plants

1. Background / History / Initiatives / Needs

- The cartridge filters (CF) system which is a critical part of the pretreatment system for the SWRO desalination plants is usually replaced every 3 months mainly due to contamination of the suspended solids and other contaminants from the seawater. In addition, ferric chloride which is used in the DMF to coagulate the contaminants is usually accumulated in the CF. as a result, the flow rate is decreasing, and the pressure differential is increasing so the performance drastically falls.
- This practice is costly and leaves a tremendous amount of waste, for instance, one of the plants of the SWCC on the Eastern coast of Saudi Arabia is replacing 52,204 filters annually with a total cost of 802,636 SAR. Therefore, DTRI initiated a chemical cleaning system to increase the lifetime of the CF and minimize the replacement cost

2. Key principle

- A chemical cleaning system was installed on one of the SWCC plants. HCl acid was added to the system and mixed with service water to get a pH range of 2.5 to 3.5. Then, the solution was pumped to wash the existing cartridge filter vessel in the SWRO and return to the system a few times. At the final stage, the solution will be soaked in the CF vessel for one day before flushing and returning to the service

3. Achievement / Economical benefit / Technical advancement

- After the implementation of the CIP system in a large-scale desalination plant the following outcomes were achieved:
  -The lifetime of the CF elements increased by 51%
  -The amount of filtered water increased by 42%
  -The cost saving in CF is 109,000$ annually.

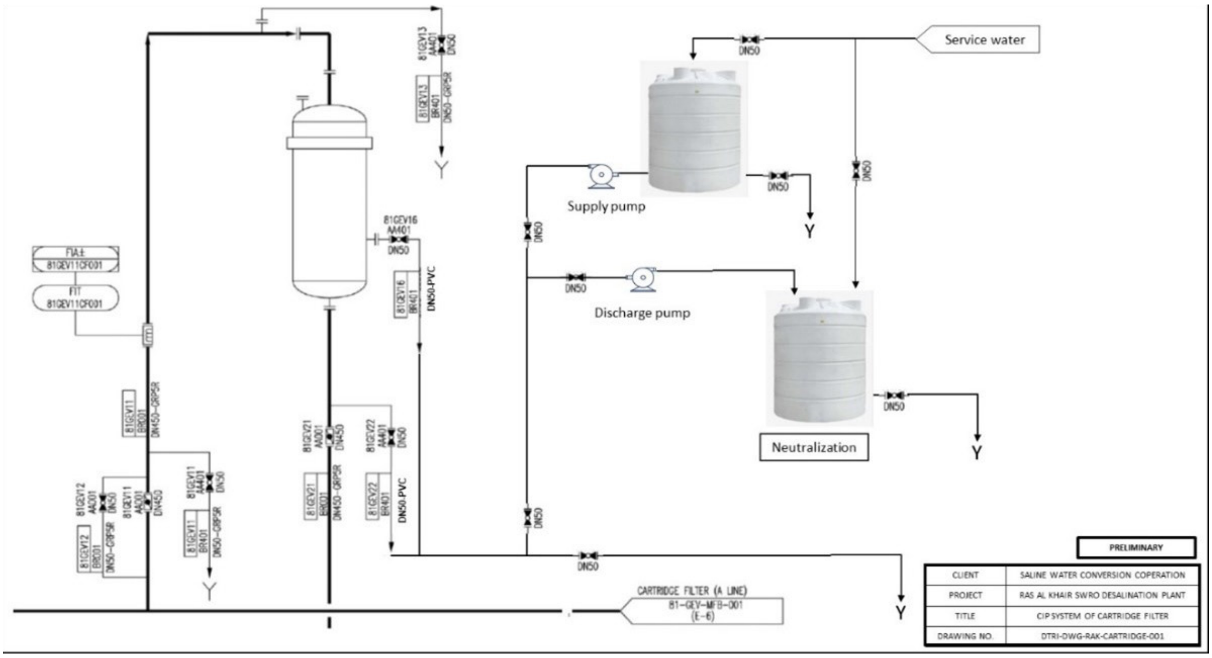


Figure 13 Insttaled Clean In Place System in RAK

A08: A Comprehensive Study Of Bromate Formation In Produced And Transmitted Water From The Shoaiba Plant

1. Background / History / Initiatives / Needs

- Disinfection of produced water from desalination plants is an important procedure to control bacterial infection and maintain water quality. Common disinfectants used in SWCC are chlorine, and sodium hypochlorite (NaOCl). Unfortunately, these chemical disinfectants are found to produce organic and/or inorganic disinfection by-products (DBPs) of potential health concern by oxidizing naturally occurring organic and inorganic material in water, such as bromide ion (Br^-) which is easily oxidized to bromate (BrO3–).
- During the last decade, bromate formation appeared in produced and transmitted water from the Shoaiba plant from time to time with levels that exceed the maximum limit (> 10 µg/L) based on the standard of drinking water in the kingdom of Saudi Arabia.

2. Key principle

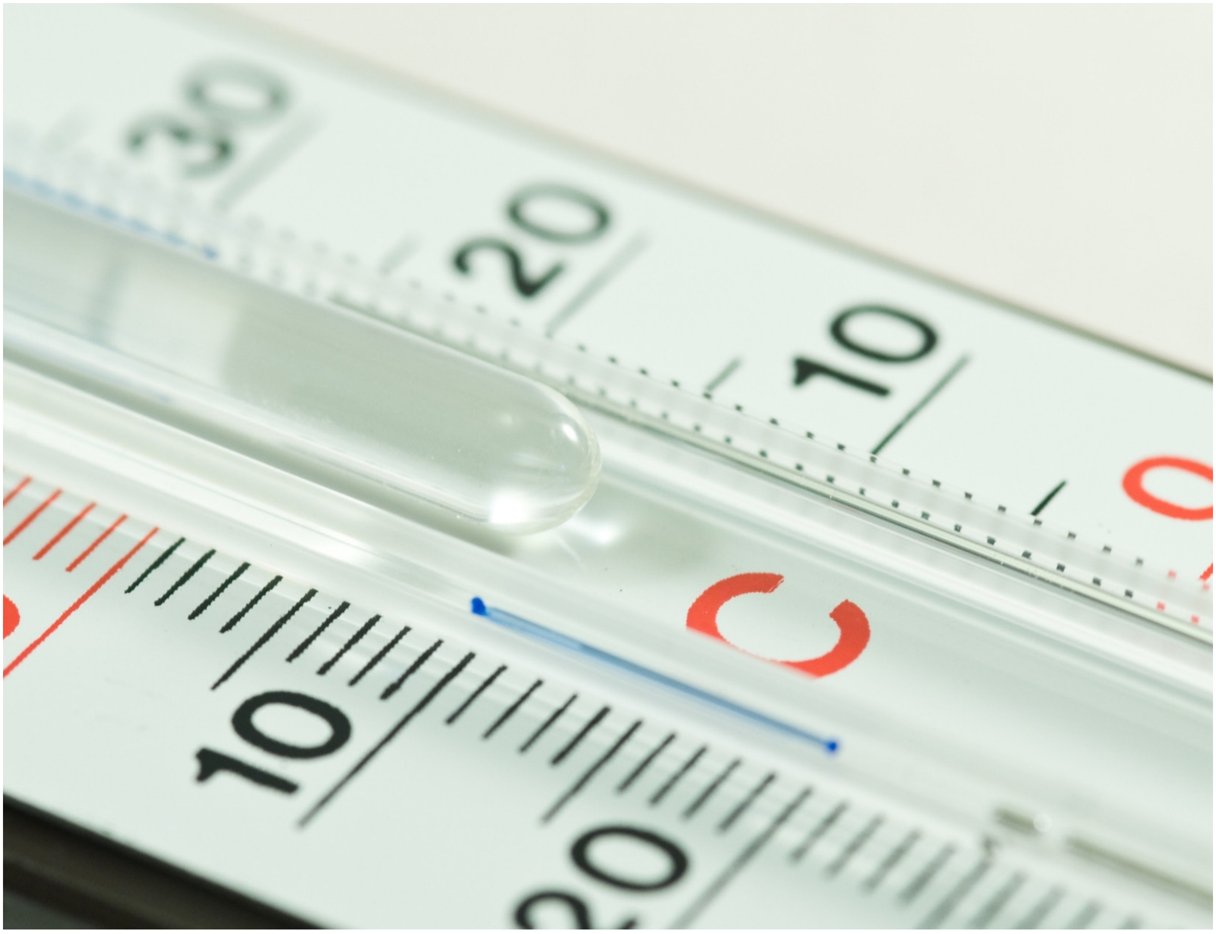
- The main target of this study is to know the main factors which are enhanced bromate formation in produced and transmitted water from Shoaiba plant.

3. Achievement / Economical benefit / Technical advancement

- More than 300 samples during a period of 2-1-2022 to 9-3-2022 were collected from produced and transmitted water from Shoaiba plant.
- The samples were collected from 40 different sample locations and the main of that locations are as a following :
    - 6 sampling points from produced water: phase-1, phase-2, phase-3(RO1, RO2, MSF-3) and RO4.
    - 8 sampling points from pump stations: PS1 - A, PS1 – B, JPS, Mina A, Mina B, Qawyza, PS2- A and PS2-B
    - 3 sampling points from strategic tank: Million Tank, Qawyza Tank and Briman tank.
- Parameters such as pH, temperature (°C), TDS, Alkalinity, calcium, chloride ion [Cl^-] bromide ion [Br^-], R.Cl2, [BrO3 ?] , Ca, K, Mg, Na, As, Se, Cr, Cd, Pb, Hg, Cu, Fe, Ni, Al, Co, Mn and Zn for produced and transmitted water from Shoaiba plant were analyzed.
- The retention time of transmitted water was studied.
- The results showed that the factors which are enhanced the bromate formation in produced and transmitted water from Shoaiba plant are T, R.Cl2, pH, [Br^-], and the retention time of transmitted water. However, the main factors which may play a very important roles in enhanced the bromate are the temperature, pH and the retention time of produced and transmitted water.

Table 1: The Effect Of Temperature Of Produced Water In Enhanced Of Bromate Formation On 2021

Phases	Shoaiba (Phase-1), Thermal	Shoaiba (Phase -2), Thermal	Shoaiba (Phase-3 MSF), Thermal	Shoaiba (Phase-3 RO1)	Shoaiba (Phase-3 RO2)
Jan	<2	6.5	<2	-	<2
Feb	<2 -5.7	4.8	2.4 - 3.4	<2 – 4.6	<2
Mar	<2	2.3 – 4.7	2.8 – 6.4	<2 – 4.6	<2
Apr	<2	4.9 – 6.5	3.1 – 4.1	<2	<2
May	<2 – 3.6	5.3 – 8.0	3.6 – 8.0	<2	<2 – 3.9
Jun	<2 – 3.2	<2 – 3.6	2.1 – 3.1	2.2 – 4.1	<2 – 2.4
Jul	3.6 – 4.7	2.6 – 3	3.7 – 5.0	3.0 – 5.5	<2 – 3.4
Aug	<2 – 6.1	2.6 – 5.1	<2 – 2.4	<2 – 2.3	<2
Sep	<2 – 4.8	<2 – 3.5	2.1 – 5.3	<2 – 2.5	<2
Oct	3.1 – 6.8	2.2 – 3.2	<2 – 3.5	<2 – 3.3	<2
Nov	< 2 – 6.3	< 2 – 3.6	4.6 – 5.8	<2	<2
Dec	< 2 – 4.6	2.7 – 4.2	< 2	3.1 – 3.6	<2



A09: Carbon Capture Storage And Reuse Using Algae (Ccs-R)

1. Background / History / Initiatives / Needs

- Carbon dioxide, with the longest atmospheric residency time, accounts for almost 76% of all greenhouse gas emissions, which is the cause of global warming. Although SWRO is not directly involved in greenhouse gas emissions (through fossil fuel combustion processes), the use of electricity to run the technology ascribes an energy consumption carbon footprint. Therefore, SWCC has strategically considered this reality and is exploring innovative carbon capture and sequester technologies. Algae is the most efficient, least energy-intensive carbon capture and storage green solution to the challenges of Carbon Capture and Sequester (CCS). In addition, the oils, proteins, and sugars potentially produced from alhae have economic value for the biofuel, food, pharmaceutical, cosmetic, dye, animal and fish feed, fuel, and probiotic industries.

2. Key principle

- Microalgae are cultivated photosynthetically, consuming sunlight, CO2, and nutrients and producing oxygen, oils, proteins, sugars, etc.
- In addition to the CO2 sequestering, the generated organic waste from desalination plants could be biodegraded and converted to bio-methane under anaerobic conditions, and the microalgae cultivation could adsorb the cogenerated CO2 from bio-methane production without CO2 emission.

3. Achievement / Economical benefit / Technical advancement

- Literature reviews of related research and studies have been finished, and a novel CO2 sequestering concept utilizing anaerobic digestion and microalgae cultivation aiming at CO2 sequestering and waste disposal within desalination plants have been developed. A review paper about this novel concept is under preparation and will be submitted at the beginning of 2023. Moreover, lab-scale experimental setups, such as photo-bioreactor and anaerobic digester, are in procuring process. The photo-bioreactor is expected to be delivered in early 2023, and lab-scale demonstrations will start.

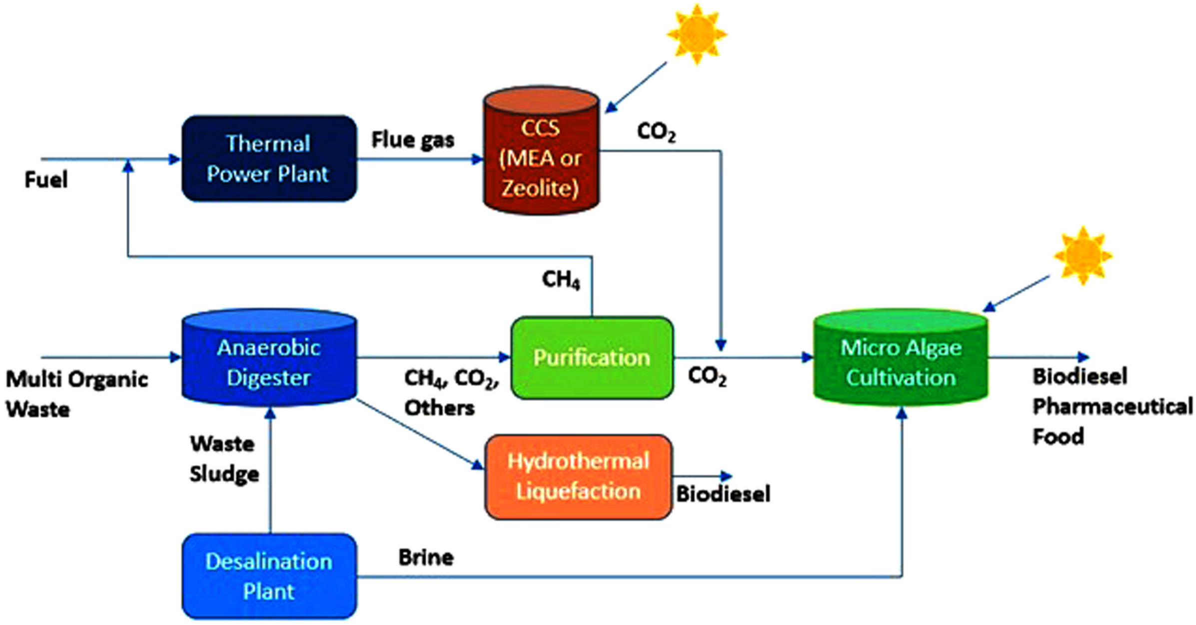


Figure 14 Carbon Capture Storage and Reuse using Algae

A10: Control Of Disinfection By-Products (Dbps) In Desalinated Seawater Production And Transmission System

1. Background / History / Initiatives / Needs

- Bromate concentrations are regulated in almost all jurisdictions due to the potential carcinogenicity and chronic toxicity of this ion. In the Kingdom of Saudi Arabia, bromate levels must not exceed 10 µg/L (ppb) in potable water. Reverse osmosis (RO) of seawater generates product water with relatively high bromide concentrations compared to surface waters; until recently, World Health Organization (WHO) recommendations on boron concentrations in potable water required the use of a second RO stage, which also reduced total dissolved solids and hence bromide. The shift to RO rather than thermal desalination methods and the relaxation of WHO boron standards has led to the recent emergence of bromate as a species of concern in water transmission systems in SWCC.

2. Key principle

- Control of DBPs (bromate & trihalomethanes -THMs) formation in produced and transported water by adding a little amount of Ammonia (0.2 ppm)

3. Achievement / Economical benefit / Technical advancement

- A very effective low-cost method to control bromate and THMs formation in produced water from Shoaibah –phase 2.
- Patent filed.

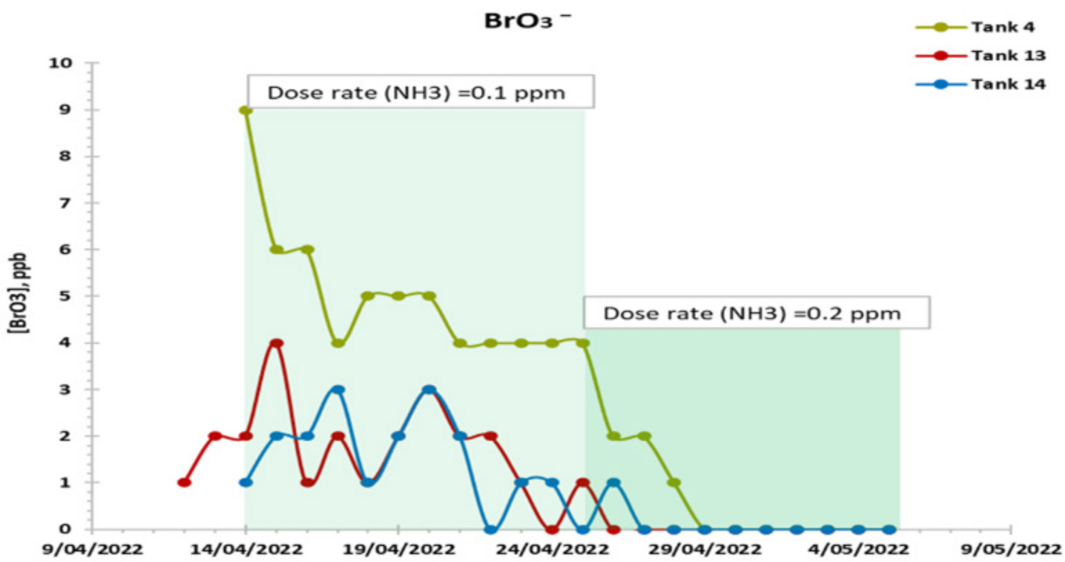


Figure 15 Bromate concentration in distribution tanks of Shoaibah – phase 2

A11: Demonstration Of Carbon Capture System With High Efficiency Amine Solvent And Development Of 'Carbon To X' Conversion Process

1. Background / History / Initiatives / Needs

- In desalination processes, carbon dioxide is used in post-treatment system to remineralize product water by dissolving calcium carbonate in it. Carbon dioxide used to be achieved by capturing it from the ventings in vacuum system of thermal desalination units, but as thermal processes are phasing out, it is now generated by firing fossil fuels.

2. Key principle

- The amount of carbon footprint to generate carbon dioxide can be offset when the same amount of carbon dioxide is captured from the flue gas of thermal power plant and sequestered in SWRO process. The idea is to capture carbon dioxide in one of thermal power plant by using high efficiency amine solvent and distribute captured carbon dioxide to SWRO plant to avoid burning fossil fuels to generate carbon dioxide.

3. **Achievement / Economical benefit / Technical advancement**

- It is estimated that CO2 consumption in SWRO would reach 200 ~ 400 tons per day. If this amount of CO2 is captured in the thermal power plant and utilized in SWRO plants, it is equivalent to substitute 75 ~ 150 liter of diesel consumption every day, 27,375 ~ 54,750 liter annually.
- Schematic diagram / Figure / Photo

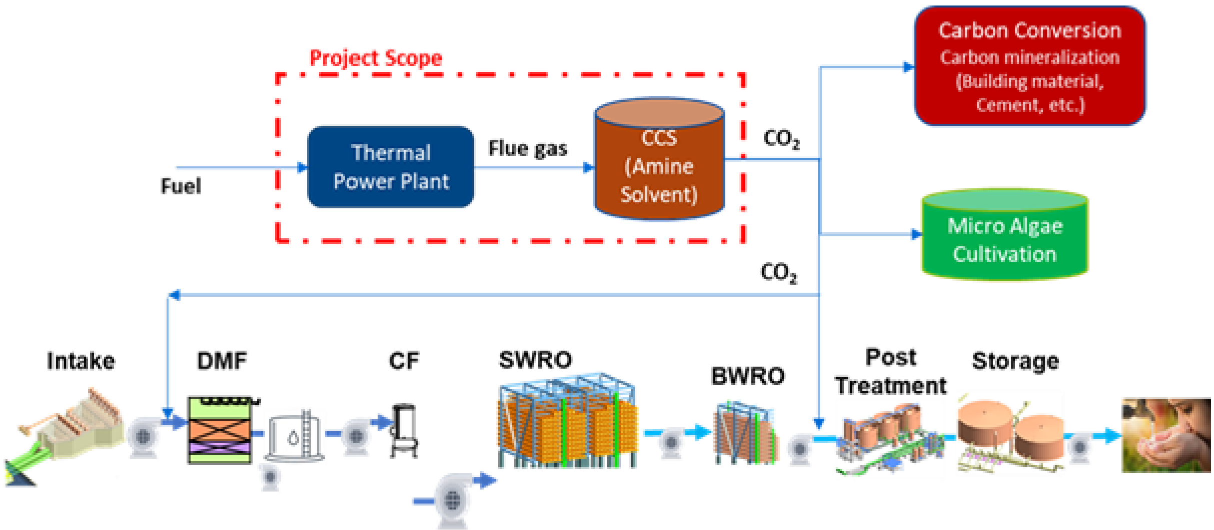


Figure 16 Carbon Capture system with High efficiency Amine Solvent

A12: Design And Construction Of ZLD Demonstration Plant At Haql SWRO Desalination Plant For Production Of Pure Nacl Crystal Salt, Liquid Bromine And Magnesium Metal

1. **Background / History / Initiatives / Needs**

- After exceling in the field of desalination, SWCC is venturing into the brine mining pursuit for extraction of valuable minerals from seawater. DTRI has already developed and patented an innovative process scheme for concentration of SWRO brine and extraction of salts and metals from the SWRO brine. The first phase of the process scheme enables SWCC to produce pure sodium chloride and liquid bromine. The front end engineering design (FEED) of a large commercial project has been developed by DTRI for brine mining to produce about 2 million tons of pure NaCl salt and 3800 tons of liquid Br_2 per year. Before execution of this commercial project, it has been decided to construct a small zero liquid discharge (ZLD) project in Haql to demonstrate the processes involved in the commercial project.

2. Key principle

- The processes selected for Haql ZLD demonstration plant include a nanofiltration (NF) system that removes a large portion of the divalent ions such as calcium and magnesium from the SWRO brine, followed by a Membrane Brine Concentration (MBC) system that concentrates the brine up to 225 g/L and then crystallization which divides the concentrated brine into crystal salt and mother liquor. The liquor is further treated to extract bromine. The concentrate from NF process is also treated to produce $Mg(OH)_2$ and then Magnesium metal. Two types of MBC processes, involving Spiral Wound (SW) membrane and Hollow Fine Fibre (HFF) membrane, have been employed in the demonstration plant.

3. Achievement / Economical benefit / Technical advancement

- The brine mining technology developed and patented by DTRI is innovative and first of its kind. The objective of construction of the demonstration ZLD plant at Haql is not direct economic benefit, but to demonstrate technical reliance by evaluating the performance of the plant and establishing the viability of the process developed by DTRI. It can produce about 6 tons of pure NaCl salt and 6 kg of liquid bromine per day in the first phase of development which may be sold in the market. The market rate of pure NaCl is $60 per ton and for bromine $3250 per ton.
- The process design of the ZLD plant has been completed. The preparation of the detailed equipment specification and procurement are in progress.

Schematic diagram / Figure / Photo

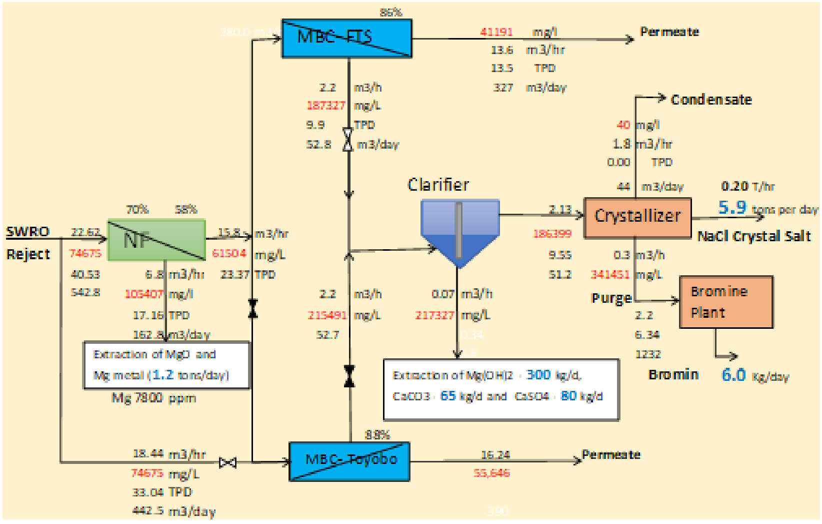


Figure 17 Process Flow Diagram (PFD) of the Haql ZLD Demonstration Plant

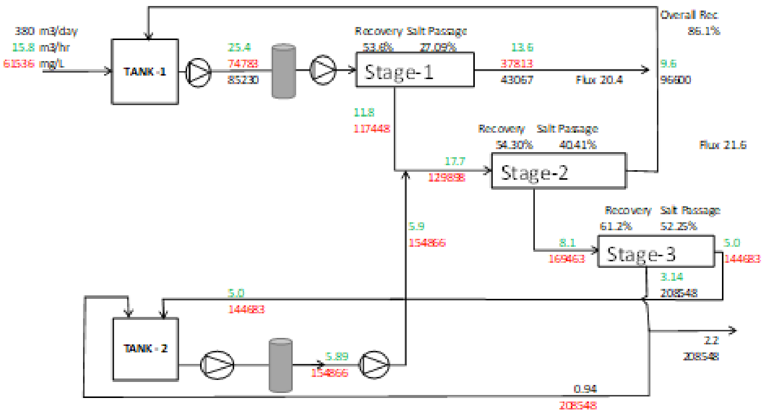
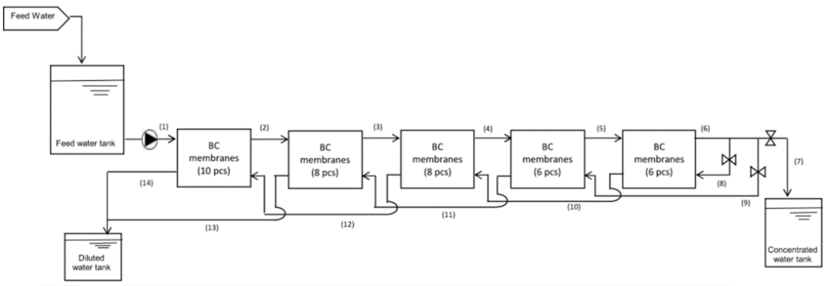


Figure 18 Mass Balance and Process Flow Diagram (PFD) of the MBC(SW) Process



No.		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Flow	m3/h	13.8	10.1	7.8	6.4	5.3	4.7	2.1
Conc.	g/L	62	84	108	132	160	181	181
Pres.	bar	~ 70	~ 70	~ 70	~ 70	~ 70	~ 70	-
Temp.	deg. C	30	-	-	-	-	-	-

No.		(14)	(13)	(12)	(11)	(10)	(9)	(8)
Flow	m3/h	7.0	4.7	3.3	2.4	1.9	1.3	1.3
Conc.	g/L	34	50	71	97	124	181	181
Pres.	bar	-	-	~ 7.3	~ 6.2	~ 11.8	~ 10.7	~ 15.7
Temp.	deg. C	-	-	-	-	-	-	-

Figure 19 Mass Balance and Process Flow Diagram (PFD) of the MBC(HFF) Process

A13: Development Of A Green Online Non-Oxidative Cleaning Method For Swro Membranes (Dtri-Kaust)

1. Background / History / Initiatives / Needs

- Green chemical cleaning is an alternative methodology that is not substrate-specific, less sensitive to pH fluctuations, and does not have product scalability or biofilm permeation limitations. The novel chemical is abundantly available from the breakdown components of protein metabolisms. This chemical has effectively been used to solubilize microbial biofilms, the primary cause of Seawater Reverse Osmosis (SWRO) membrane flux declines. The chemical is reported to disrupt hydrogen bonds that stabilize protein within the biofilm matrix and is involved in the lysis of cells and tissues. Both modes of action enhance biofilm dispersion and microbial deactivation, resulting in the recovery and stability of membrane flux.

2. Key principle

- Establish a suitable combination of Green cleaning chemicals for effective membrane cleaning.
- Determine the appropriate concentration mixtures and application cleaning protocols for effective Green cleaning.
- Modulate cleaning protocols according to changing operational temperatures for optimal cleaning applications.
- Assess potential effects on polyamide membrane microstructure concerning membrane damage, salt passage, or increased differential pressure after cleaning.
- Combine lab and Pilot Plant data and experience to project procedures and protocols for applying the Novel Green cleaning chemical in a commercial desalination Plant.

3. Achievement

- Project Approval
- Technical discussions between collaborating parties agreed

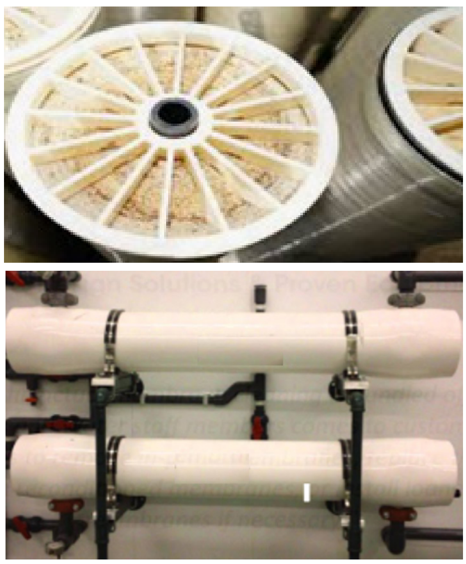


Figure 20 Green Online Non-Oxidative Cleaning method for SWRO membranes

A14: Development Of Automatic Vehicle For Seawater Sample Collection And Monitoring With Tabuk University (Mariner 6)

1. Background / History / Initiatives / Needs

- The project aimed at developing an autonomous surface vehicle (ASV) for use in water quality monitoring and bathymetric analyses at existing desalination plants and also for potential use in finding the appropriate location for future desalination plants. The resulting ASV (Mariner 8 or M8) has advanced capabilities, modular, and customizable and manufacturable. The development of M8 started from an existing prototype (M5) that was developed by SNCS/UT through the years and that went through many iterations of improvements, and testing and upgrades with the contribution and leadership of DTRI/SWCC.

2. Key principle

- The collaborative research and development effort between SNCS/UT and DTRI/SWCC entailed the following:
- Improve M5 such that the resulting M8 has advanced features that are necessary for water quality measurement and bathymetry analyses.
- Test M8 as needed in desalination plants in the Red Sea.

3. Achievement / Economical benefit / Technical advancement

- **A paper has been published:**
  - Paper title: Sustainable Seawater Desalination: Current Status, Future Expectations, and Environmental Implications
  - Authors: Muhammad Ayaz, M. A. Namazi, M. Ammad ud Din, Mohamed Ershath, Ali Mansour, elHadi M. Aggoune
  - Journal: Elsevier Desalination Journal (Q1/IF 10)
- **A patent application is being completed in order to file with the** Saudi Patent Office.
  - Title: A System for Water Sample Extraction

- Inventors: Mohamed A. A. Namazi, SWCC; Mohamed Ershath, SWCC; elHadi M. Aggoune, UT; Saleh Ali Albelwi, UT; Ashraf M. Marei, UT; Tariq Alhmieda, UT; Hani Awad Albalawi, UT; Hazem M. El-Hageen, UT
- Assignees: Saline Water Conversion Corporation (SWCC), University of Tabuk (UT)
- Patenting Office: Saudi Intellectual Property Authority

4. Schematic diagram / Figure / Photo

Figure 21 Robot Arm

Figure 22 Mariner 6

A15: Development Of New Scale Inhibitors

1. Background / History / Initiatives / Needs

- The formation of inorganic scale, principally calcium sulfate, is the main factor restricting the implementation of more efficient high-temperature thermal desalination methods and is a major constraint on membrane-based brine concentration to high total dissolved solids required for energy-efficient brine mining. Increasing the effectiveness of antiscalants will lead to energy and cost-savings and allow extension of MED and brine concentration technology into more extreme conditions. Currently, all active ingredients of antiscalant formulations are imported into the Kingdom, and this project aims at localizing production of these chemicals.

2. Key principle

- We have developed a novel antiscalant concept for polymeric scale-inhibitors where the incorporation of end-group functionality directs adsorption to the most active growth sites in growing microcrystallites of inorganic scale, retarding growth. The aims of this project are to establish synthetic protocols for 'edge-active' scale-inhibitors, scale-up these protocols to production volumes required for pilot plant studies, map out the structure/property relationship surface for these inhibitors to enable optimization in laboratory scale studies, and then implement the most effective antiscalants on the pilot scale.

3. Achievement / Economical benefit / Technical advancement

- The ultimate goal of this project is production of scale inhibitors based on DTRI intellectual property in the Kingdom. These will replace imports as well as being more effective than existing products at the same concentration in the feed, and will increase the potential range of both thermal and membrane-based technologies into more extreme conditions. Preliminary laboratory results suggest that the antiscalants will also be applicable to other industries where inorganic scale is a problem, such as food processing and oil and gas.

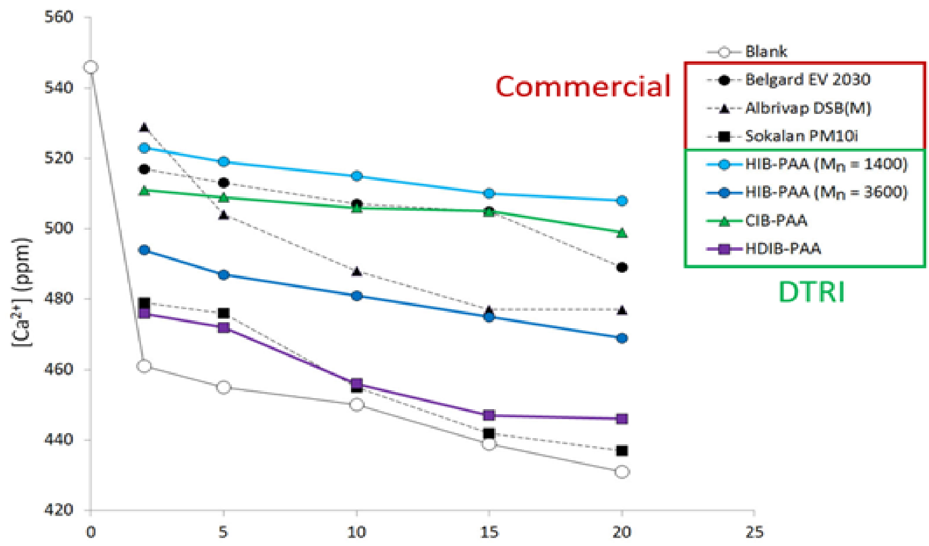


Figure 23 Calcum Consentration vs. Time of Different Scale Inhibitors

A16: Dissolved air flotation (DAF) system using carbon dioxide (CO2) gas

1. Background / History / Initiatives / Needs

- Ras Al Khair desalination plant is hybrid MSF and SWRO desalination plant. It consists of 8 units of MSF evaporators and 2 lines of SWRO processes. In SWRO process, hollow fine fiber membrane was adopted. And it required that feed seawater pH is 6.4. For the adjustment of feed seawater pH, sulfuric acid has been dosing before DAF system.

- Each MSF evaporator has venting system to remove non-condensable gases which consists of CO2, air and vapor. In present, part of non-condensable gases is used in the post-treatment system. And the other is vented into the air.

2. Key principle

- Vented non-condensable gases will be supplied to DAF system. If CO2 be dissolved to feed water, feed water pH decreases. Then, sulfuric acid for pH adjustment can be eliminated.

3. Achievement / Economical benefit / Technical advancement

- By elimination of sulfuric acid, we can save 1.1 M USD per annum.

- By stop of DAF air compressors and sulfuric acid dosing pumps, 0.3 M USD of energy cost can be saved annually.

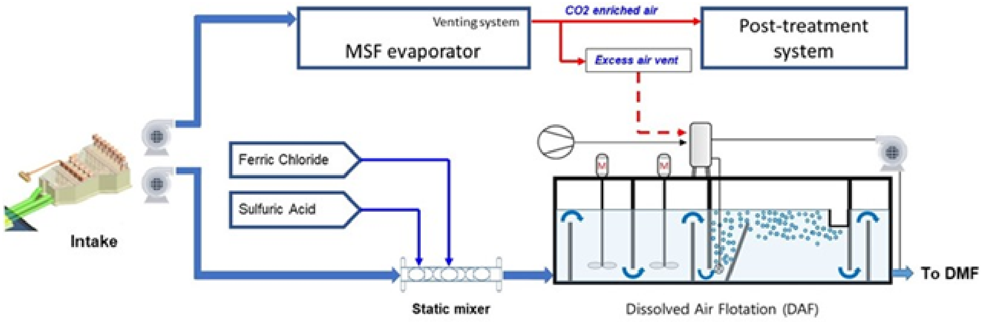


Figure 24 Schematic diagrams of Prposed DAF Modification System Using CO2

A17: DMF media depth increase in Ras Al Khair SWRO plant

1. Background / History / Initiatives / Needs

- During summer season in Arabian gulf sea, colloidal matter in raw seawater has been increased. At the time, most of pretreatment process is suffered high Silt Density Index (SDI) value. It results in the increase of differential pressures of cartridge filter and RO membrane.
- Water demand in Ras Al Khair has been increasing. So, extension project has initiated for additional water production.

2. Key principle

- Solid loading rate shows the relation between TSS of seawater, TSS of coagulant, feed flow rate, filter run time and media volume. If media volume increases, then, feed flow per filter or filter run time can be increased.

3. Achievement / Economical benefit / Technical advancement

- SDI will decrease and filter runtime will increase. If feed flow rate can be increased, 20,000m3/d of water production can be increased.

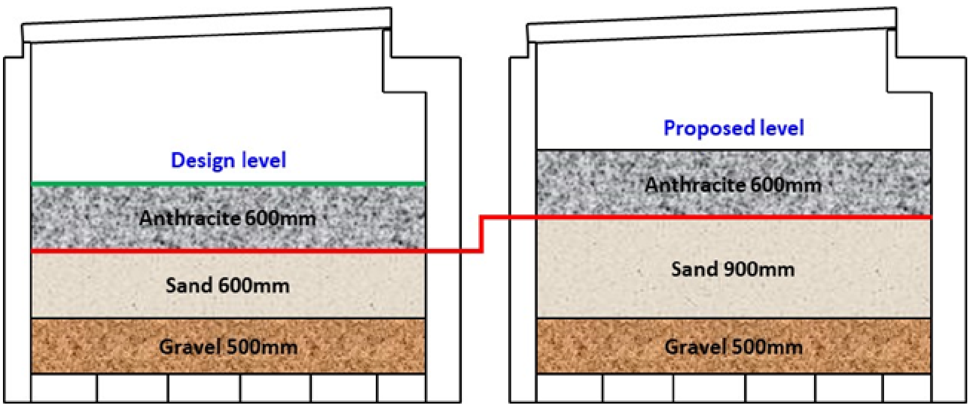


Figure 25 Prposed DMF Media Depth Layers

A18: Electrochemical Corrosion Studies Of Different Alloys And Cement Lining Material Of Water Transmission System

1. Background / History / Initiatives / Needs

- In Ras Al-Khair plant, it was decided to raise the TDS in product water where chloride concentration would be increased also. Since increasing chloride concentration could have an impact upon the corroding behavior of transmission pipelines materials, an integrated research study was conducted to evaluate materials' behavior in different chloride concentrations at different temperatures.

2. Key principle

- This study involved physical inspection of cement mortar lining of underground pipelines, weight loss method and electrochemical technique to measure corrosion rates & evaluate their corroding tendencies.

3. Achievement / Economical benefit / Technical advancement

- Performance evaluation of three different alloys has been accomplished. Stainless Steels were better than Carbon Steel in resisting general corrosion. However, they were prone to pitting corrosion more than carbon steel. Generally, increasing chloride concentration increases corrosion rate especially of Carbon Steel X-52 by no more than 0.11 mm/year. While temperature has a greater effect on corrosion rates with maximum increase of 0.262 mm/year.

Figure 26 Inlet and Outlet of Inspected Underground Pipeline

A19: Evaluate Different Solar Collectors To Be Coupled With Desalination

1. Background / History / Initiatives / Needs

- Evaluate different types of solar collectors under KSA weather climate and select the most suitable for desalination application

2. Key principle

- Using water as a heat storage media to collect and transfer solar radiation

3. Achievement / Economical benefit / Technical advancement

- Using multi-tier principal to reduce the capital cost and meanwhile keep the high efficiency for the first time which lead to achieve 170°C and currently targeted 180°C

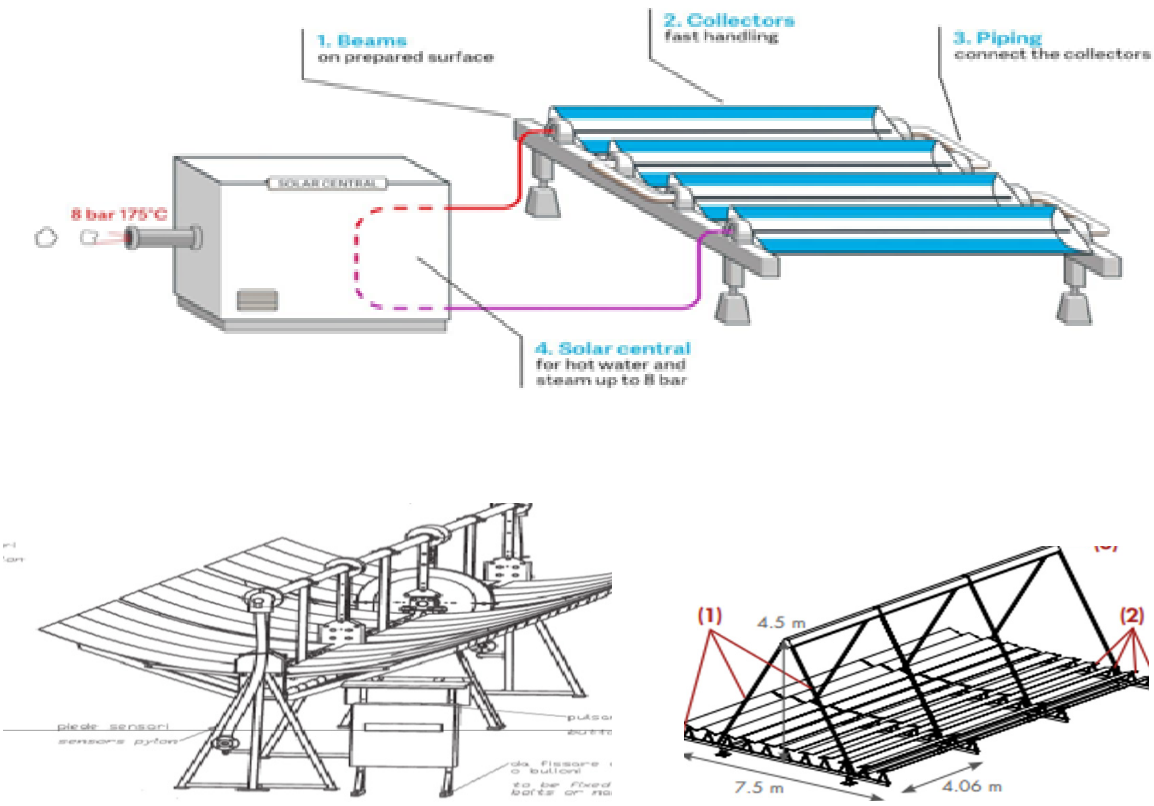


Figure 27 Different Types of Tested Solar Collectores

A20: Evaluation Of Low Energy Biturbo NF Ro System

1. Background / History / Initiatives / Needs

- On the way towards ocean brine mining, SWCC-DTRI strategically separate the discharge brine into two streams – one enriched with divalent ions and the other with purified monovalent ions, then concentrate the monovalent ions enriched stream further. In this way, interested minerals could be efficiently harvested in downstream. As a part of this effort, SWCC-DTRI is testing NF (Nano-Filtration) – SWRO (Seawater Reverse Osmosis) – (U)HPRO ((Ultra) High Pressure RO, up to 100~119bar) pilot system which adapts BiTurbo concept by FEDCO using the membranes from Hydranautics.

2. Key principle

- To observe NF membrane performance at high recovery (80%), especially on Magnesium and Chloride rejections.
- To reach up to 67% recovery in SWRO-HPRO, so that HPRO brine will have up to 110,000ppm.
- To evaluate the energy efficiency of the BiTurbo concept.
- Turbochargers could allow lower exhausting brine pressure (thus utilizing more pressure energy) and there is no risk of mixing which is beneficial for brine concentration.

3. Achievement / Economical benefit / Technical advancement

- In the initial pilot study in DTRI, Jubail, the rejection of Mg by NF was observed as 96.6%, which is very high comparing to market NF membranes which rejects 80~90% of Mg. Also, 67% of overall RO recovery (SWRO + (U)HPRO) was achieved with BiTurbo concept.

	Projected	Actual
HP Pump Press (Bar)	54.9	60.1
Feed Press (Bar)	60.6	64.6
Recovery (%)	67%	67%
Perm Flow (m³/h)	28.4	28.4
Stg 1 Brine Press (Bar)	60.4	64.3
Stg 2 Brine Press (Bar)	94.5	98.5
Stg 1 Boost Press (Bar)	5.7	4.5
Stg 2 Boost Press (Bar)	35.2	35.2
Stg 1 Exhst Press (Bar)	1.0	0.2
Stg 2 Exhst Press (Bar)	27.7	28.1
Brine Mg (mg/L)	544	565
Perm Cl (mg/L)	267	431
Brine Cl (mg/L)	94,784	92,900

Temp = 26°C

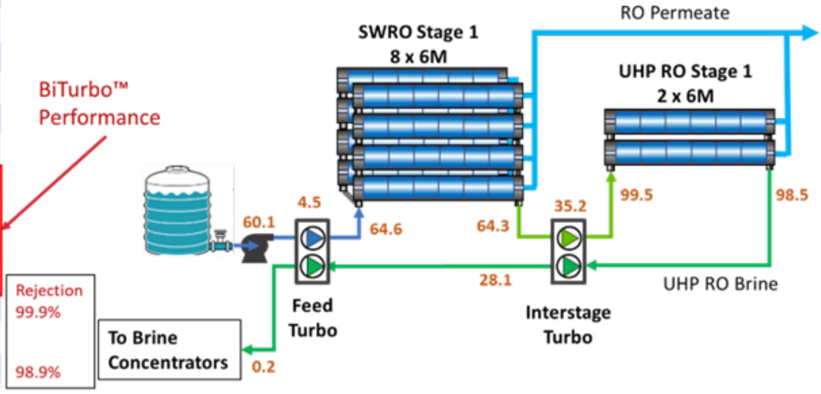


Figure 28 Results of DTRI pilot test

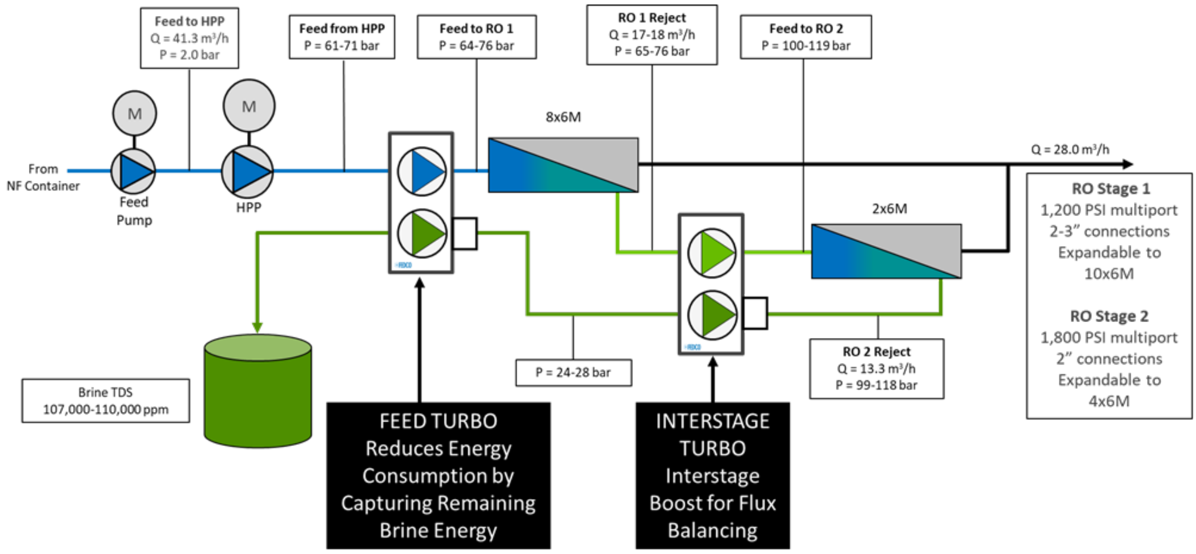


Figure 29 Schematics of BiTurbo Pilot Plant in DTRI, Jubail

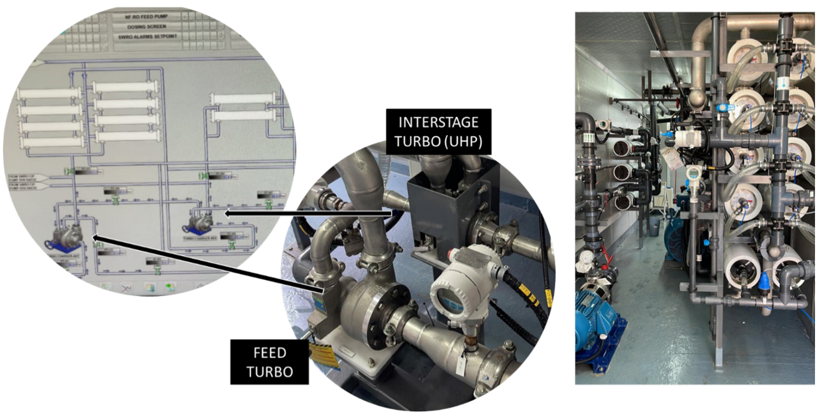


Figure 30 BiTurbo Pilot Plant in DTRI, Jubail

A21: Failure Analysis Of Economizer Tubes In Heat Recovery Steam Generator 52(Hrsg 52), Ras Al-Khair Plant

1. Background / History / Initiatives / Needs

- A failure investigation of heat recovery steam generator (HRSG) 52 was carried out in Ras Al-Khair plant to investigate leakage issues. Three tubes were received to be examined and analyzed. Two of them were corroded and failed, while one of the samples was a new tube with the same material composition and measurements as the failed ones in order to do further comparisons.

2. Key principle

- Tubes were prepared to be tested for material composition using Optical Emission Spectroscopy (OES) & Carbon-Sulfur (CS). Pits morphologies, corrosion product type & tube wall thicknesses were all indicated by Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX) technique.

3. Achievement / Economical benefit / Technical advancement

- Corrosion mechanism and product type were indicated. Pit morphologies, with smooth bottom were typical of Flow Accelerated Corrosion (FAC) type, which is mainly controlled by flow velocity especially in turbulent environments. Corrosion product type on tube #25 surface was having dispersed portions of Magnetite layer (Fe_3O_4). While it was close to the theoretical proportionality of Wustite (FeO) & Hematite (Fe_2O_3) layers on tube #26 surface. Since Magnetite is the most stable & adherent form of corrosion product, tube thickness reduction was lower in tube #25 with a value of 30%, while it approached 38% in tube #26 as compared to the new tube measurements.

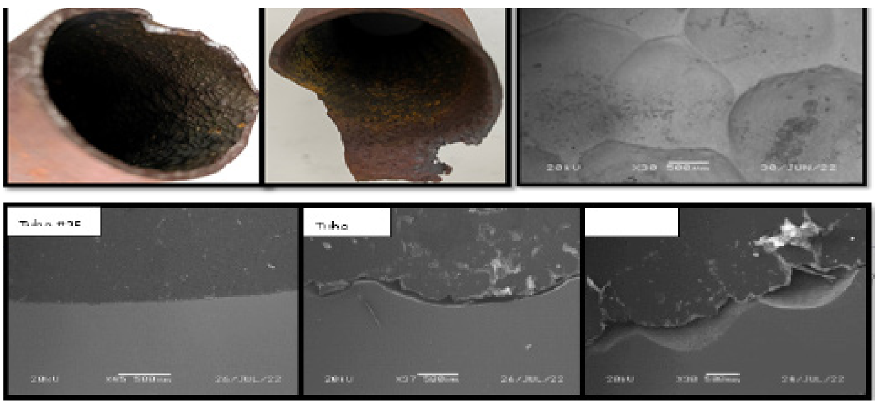


Figure 31 Recived Failed Tube with Microstructure Analysis

A22: Failure Analysis Of Ultra-Filtration (Uf) Leakage In Swro Khafji Plant

1. Background / History / Initiatives / Needs

- A leakage had taken place in Ultra-Filtration (UF) unit of SWRO Al-Khafji Plant (SWRO). In June, 2022 a site-visit had taken place by corrosion researchers' team. Seawater was dripping through almost all the couplings, joining the PVC or polyethylene elbows. Leakage was noticed at the couplings in different locations and at elbows joints. Cracking of the PVC elbows was also observed. Excessive corrosion was experienced by fasteners used to tighten couplings around elbows.

2. Key principle

- Leakage areas were physically inspected, samples were taken for further analysis. Carbon steel was the composing material of fasteners and couplings, analyzed by Optical emission spectroscopy (OES) and carbon sulfur analyzer.

3. Achievement / Economical benefit / Technical advancement

- Leakage of the couplings of the elbows was likely due to wet corrosion of the zinc coated fasteners in presence of marine environment (seawater dripping). There were some factors that might have contributed to aggravate the corrosion including; loading and crevice conditions at the threads of the fasteners, organic coating on couplings passivated (cathode) the large area of the coupling material. This may create a galvanic situation for the small zinc coated fasteners (anodes), PVC elbows might have initiated cracks at the stress concentration areas of the 90o (sharp) bend and high hardness of the PVC material is likely to contribute to early cracking of these elbows.

Figure 32 Ultra-Filtration Analyzed Joints

A23: Failure And Contamination Of Anti-Scalant System In Al-Khobar Thermal Plants

1. Background / History / Initiatives / Needs

- Periodic biological fouling is observed in antiscalant polyphosphate tanks and throughout the antiscalant system of the Al Khobar commercial MSF Plant. This issue has caused occasional blockage of pumps, increased energy and chemical consumption, and frequent foulant evacuation, which present work health safety issues for operators and engineers.
- Preliminary lab inspection reveals thick algae containing biofilm and a pungent smell indicative of H2S. The presence of hydrogen sulfide often indicates the presence of anaerobic sulfur-reducing bacteria (that convert elemental sulfur to hydrogen sulfide). Several other types of bacteria, including nonmethanogenic microbes, can also reduce elemental sulfur. Due to the age of the Plant, cautious remediation actions were recommended to ease the process impact and decrease the problem.

2. Key Principles

- Investigation of the root cause of the problem (biological/biochemical assessment)
- Recommendation of comprehensive remediation steps to reduce the problem
- Assessment of pipeline engineering design for feed water conversion from potable water to demineralized water and water line cleaning methods.
- The setup of a regime for periodic tank cleaning

3. Achievement / Economical benefit / Technical advancement

- 98% reduction in cleaning frequency and operational problems for AK-2 and Ak-3 systems
- Reduction in workforce allocation to manage the problem
- Decrease in pump trips and improved operation
- Improved water quality and effectiveness of anti-scaling

Figure 33 antiscalant polyphosphate tank

A24: Failure Of Heat Exchanger Tubes I Maaden Phosphate Production Plant

1. Background / History / Initiatives / Needs

- Multi-Effect Desalination facilities at Ras Al Khair currently operate at half of their collective production capacities at high fuel consumption. The increase in energy consumption and low water production is due to scale formation on heat exchanger tubes, galvanic, localized pitting, and biological corrosion on heat exchanger tubes. Scale formations alter the material's heat exchange coefficient resulting in less water production and higher energy consumption. Holes throughout heat exchanger tubes cause vapor loss to the cooling water external to heat exchange tubes. Vapor loss in condenser tubes reduces distillate production.

2. Key principle

- Inspection of Plant structures relevant to biological and fouling accumulations
- Sample collections for organic and inorganic analysis.
- Water quality analysis to access seawater and changing water quality conditions in heat exchanger feed water, product water, and brine.
- A study of scale components
- Correlation of results with plant production performance

3. Achievement / Economical benefit / Technical advancement

- Identification of root cause of failure
- Determined that water quality assessment from high organic load requires continuous monitoring
- Suggested material replacement for exchanger tubes to minimize corrosion impact

Table 2 Collected Samples Result

Samples	Parameters										
	pH	Conductivity mS/cm	TurbidityNTU	SO4-ppm	PO4-ppm	NO3-ppm	TOC mg/L	Coliform MPN/100ml	E.coli MPN/100ml	Enterococci MPN/100ml	HPC MPN/100ml
Feed Water	8.27	63.52	21.40	3700	1.13	1.80	6.13	<1	<1	4.1	19.70
Product Water	8.27	63.28	0.24	0	1.07	1.30	0.46	<1	<1	<1	<1
Brine	8.38	67.11	4.63	2900	1.30	6.40	3.72	<1	<1	14.2	9.30

A25: Feasibility Study For Potential Of Operating One Satellite MED Plant At A High TBT Of 85-95 °C

1. Background / History / Initiatives / Needs

- Most of SWCC's current large commercial thermal desalination plants are designed with a low performance rate of 6.4 to 9.8 kg/2326 kJ which results in a very high energy consumption of 12.6 to 17.8 kWh/ m^3. Simulation program showed that the consumption can be reduced to less than 7 kwh/m2 when a new MED thermal desalination unit is designed with top brine temperature (TBT) of 95 °C.

2. Key principle

- The results of the MED unit experiment (24 m3/day) at the DTRI pilot station showed successful results of operating the unit in TBT at 85 and 95 °C without scale formation. However, due to the small size of the unit, which may not be sufficient to represent the real situation of a commercial plant, a study was conducted in cooperation with the Japanese company Sasakura to study the possibility of modifying one of the MED units of the SWCC commercial satellite plant (4500 m3/day, currently out of service) to operate at higher temperatures at TBT 85-95 °C instead of the 65 °C design TBT and results showed that this is possible.

3. Achievement / Economical benefit / Technical advancement

- The final technical report of feasibility study for potential of operating one satellite MED plant at a high TBT of 85-95 °C was completed and submitted.

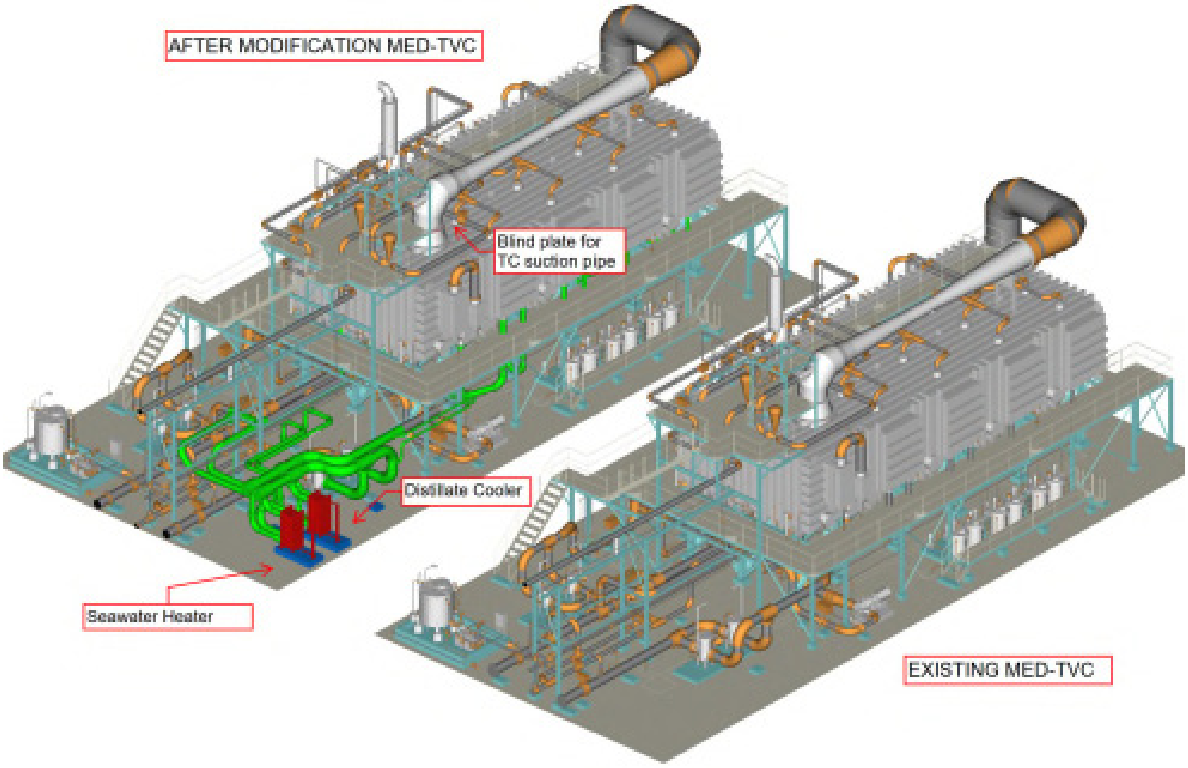


Figure 34 Proposed Modification for MED Unit

A26: High CF Wind Power For Areas With Moderate Wind Power Densities

1. Background / History / Initiatives / Needs

- The Saudi Green Initiative and the National Renewable Energy Program are considering the installation of significant renewable energy production capacities. Beside the replacement of fossil fuel consumption by renewable energy, by feeding renewable energy into the grid, it will be also important to replace parts of the existing fossil fuel power generation capacities by renewable energy capacities. This requires preferably high CFs (capacity factors). While current solar PV technologies have CFs only in the range of 0.20-0.25, wind turbines are available to reach CFs > 0.60 if suitable high wind power densities are available. Since we have in most areas in the Kingdom of Saudi Arabia only moderate wind power densities available, it will be required to introduce new wind turbine configurations which will allow to reach high CFs in areas with moderate wind power densities, so that wind power generation can be applied economically in more areas.

2. Key principle

- New wind turbine generator configurations suitable to reach high CFs in areas with moderate wind power densities will require a low specific installed capacity in the range of 100-150 W per m2 of rotor area, compared to the most suitable wind turbines currently available on the market, which have significantly larger specific installed capacities above 200 W/m2.

3. Achievement / Economical benefit / Technical advancement

- The described new wind turbine – generator configuration will allow the installation of wind turbines with economic renewable power generation in many areas with moderate wind power densities, currently not considered for the production of wind energy, or considered for wind power generation with relatively low CF, which is less suitable for the reduction of fossil fuel power generation capacities.

4. Schematic diagram / Figure / Photo

- The graphic below shows the increase of annual power generation with increasing CF, indicating the advantage of a wind turbine generator with high CF compared to existing wind power generation systems with lower CF or compared to solar PV systems.

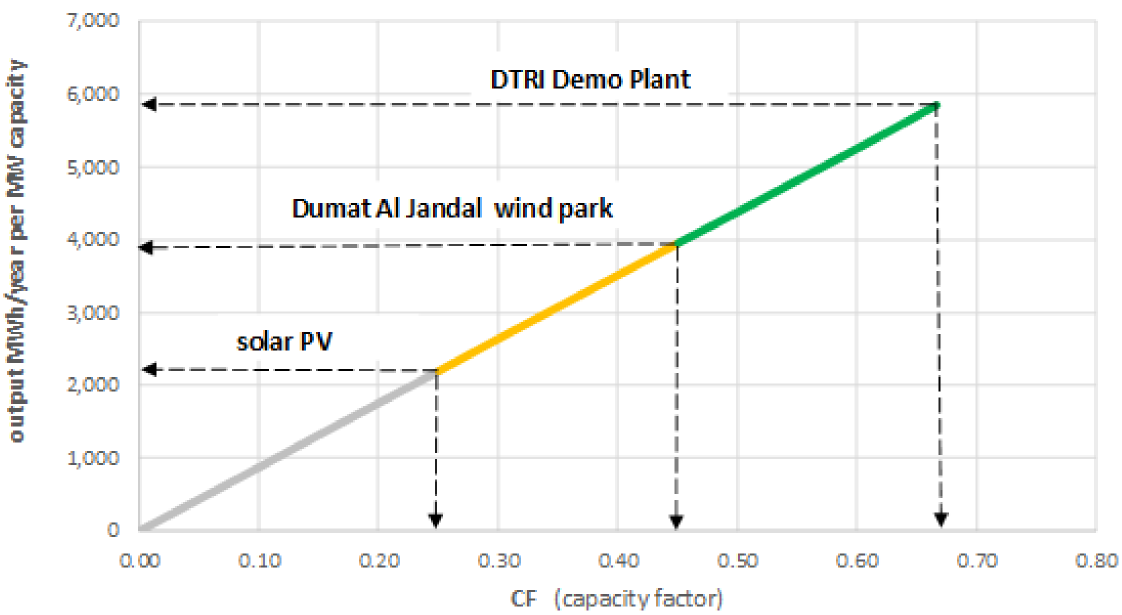


Figure 35 Capacity Factor for Different Solar and Wind System

A27: Increasing Renewable Penetration In Haql Desalination Plant To Achieve Green Desalination Process

1. Background / History / Initiatives / Needs

- Desalination processes currently available in the market are considered to be energy-intensive processes which consume large amount of fossil fuels to produce distillate or permeate and have a large carbon footprint. Various configurations for using renewable energy have been suggested and researched extensively, but have not yet achieved commercial viability due to the cost of energy storage systems.

2. Key principle

- There is a chance to synchronize two different load profiles of renewable energy in a region of Haql. In this area, the wind profile tends to be higher at night and lower during the day. This can be compensated by solar PV, leading to a relatively flat load profile around the clock when those are combined. In this way, there is a chance for the system to be fed by renewable energy sources reliably without an energy storage system.

3. Achievement / Economical benefit / Technical advancement

- According to our preliminary study, there is a chance to increase renewable energy penetration to more than 70% in Haql region, without energy storage device, when PV and wind are synchronized in a certain ratio.

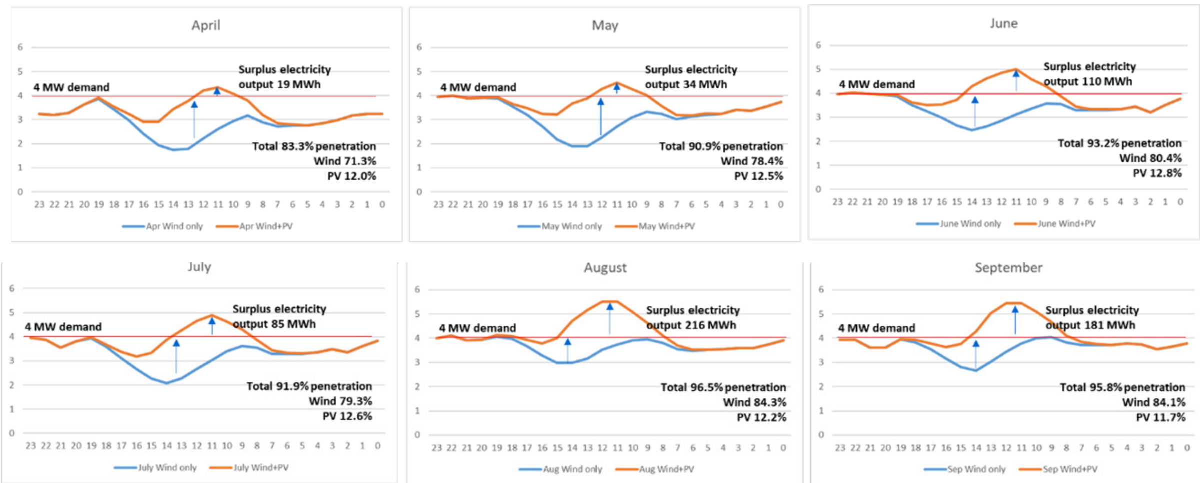


Figure 36 synchronize two different load profiles of renewable energy

A28: Investigation On Riser Tube Rupture From Boiler Unit # 65 In Jubail Phase Ii Plant

1. Background / History / Initiatives / Needs

- The DTRI corrosion team received an inquiry from Jubail Plant to identify root cause failure analysis of two failed riser tubes from the first quarter of riser tubes of boiler 65. DTRI corrosion staff received one riser tube sample to handle investigation and required analysis. Boiler 65 was commissioned in 1983 with steam output of 730 t/h at 92 bar and 515 °C.

2. Key principle

- Different techniques were utilized in order to indicate the root cause of this failure. Scale density and thickness were measured to give an indication whether chemical cleaning was required or not. Optical emission spectroscopy and carbon sulfur analyzer were utilized to identify material composition of the tube. Hardness tests were done to indicate the material's behavior. Also, material's microstructure was examined by optical microscopy. Scanning electron microscopy-Energy dispersive X-rays technique was able to reveal the constituents of scales on the steam and fire sides of the boiler.

3. Achievement / Economical benefit / Technical advancement

- All tests and observations showed that the riser tube was subjected to short term overheating inducing stress rupture, due to scale deposition and corrosion product accumulation. The measured scale density near the fractured area was 12.37 mg/cm2, which is acceptable. Microstructure was observed to have ferritic-pearlitic structure with precipitated carbides at grain boundaries, indicating exposure to elevated temperatures at the failed area. Carryover of copper and voids were also noticed giving the first evidence of creep damage. Acidic water was condensed on the failed area of the fire side due to high sulfur content.

A29: Investigation On Tubes Rupture Of Boiler #6 From Yanbu Plant Phase II

1. Background / History / Initiatives / Needs

- Boiler tubes were subject to corrosion issues in Yanbu plant. Between April and May 2022 seven boiler tube samples were received for analysis to identify the root cause of failure. Boiler 6 is one unit of the power generation facility in Yanbu Phase 2. The water side was being treated with hydrazine as an oxygen scavenger and trisodium phosphate to control the pH. However, this treatment was changed to Helamin treatment in December, 2019. Previous records showed frequent blockage of feed water pump strainers at both boilers 6 and 7 in 2015. The recorded conclusion was that blockage was due to copper-based deposits originating from the shell side of the HP heater.

2. Key principle

- Tubes were visually inspected then analyzed for material composition by Optical emission spectroscopy (OES) and carbon sulfur analyzer. Scale density of the steam side was measured following the ASTM standard chemical cleaning method. Microstructures of the boiler tubes were examined by an Optical Microscope. Ash samples were collected to be analyzed by Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX).

3. Achievement / Economical benefit / Technical advancement

- Scale density values exceeded the acceptable limit, indicating the necessity of acid cleaning of the tubes. The boiler tubes failure features were in the form of fish mouth opening as well as pin hole. Severe tube thinning was caused by deep cavities/gouges. It appeared that in some of the tubes, short and long-term overheating was the main mode of the failure. The original microstructure of the tubes is ferritic-pearlitic, while the failed area showed deteriorated microstructure with pearlite decomposition into ferrite with precipitated carbides at grain boundaries. This gave an indication that the tubes had been exposing to elevated temperatures particularly at the failed area. The obtained results of different ash deposits showed presence of sulfur and vanadium, which would further enhance the fire side corrosion potential. Results of some tubes showed a carryover of copper and nickel which would intensify the corrosion of steel. Using of Helamin with inappropriate feed-water quality, high oxygen level or improper dosing may have played a major role in propagating the failure.

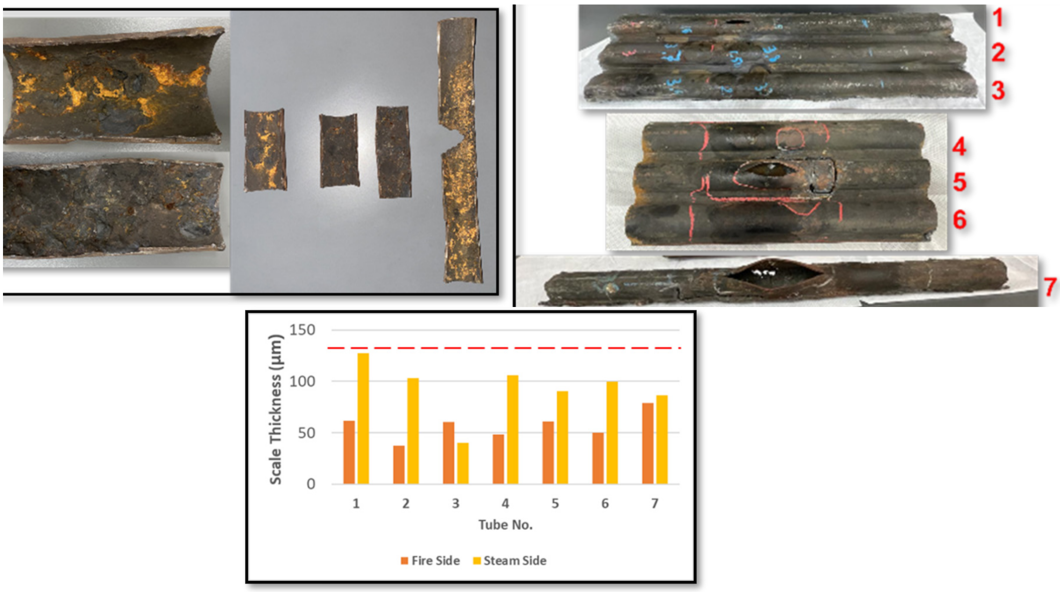


Figure 37 Received Faild Tubes

A30: Jwap Distillate Cooling Plant Rehabilitation

1. Background / History / Initiatives / Needs

- The SWCC Joint Water and Power (JWAP) plant in Jubail produces 800,000 ton/hr at a temperature of 44 °C. This high temperature is troublesome for consumers. It was suggested to study different options to reduce the distillate temperature to 38 °C.

2. Key principle

- Using dry air to cool distillate water through adiabatic cooling.

3. Achievement / Economical benefit / Technical advancement

- Different operation and technical options were studied, including and not limited to utilizing the existing facilities such as brine cooler and cooling towers. One well-known technical company made an offer to address the problem for 220 million SAR, while after investigation and design DTRI could suggest an alternative for 60 Million SAR.

A31: Low-Pressure NF Membranes For Swro Brine Concentration

1. Background / History / Initiatives / Needs

- The current membrane brine concentrator using Osmotically Assisted Reverse Osmosis (OARO) membranes (Fluid Technology Services) requires a high operational pressure (70 bar). To minimize the energy consumption of brine concentration process, common commercial NF membranes will be evaluated for their feasibility for brine concentration. The target of this project is to concentrate SWRO brine from 80,000 ppm up to 180,000 ppm at 40 bar, for downstream crystallization.

2. Key principle

- Commercial low pressure NF membranes are similar to OARO membranes in terms of their partial salt rejection and thus their ability to concentrate SWRO brine.

3. Achievement / Economical benefit / Technical advancement

- A simulation model based on performance evaluation data of 4" elements has been established for process design (as shown in the below Figure).

- The combination of two tested NF membranes (Dupont NF90 and SUEZ DK30F) could concentrate the SWRO brine from 78,000 ppm to 125,000 ppm at 22 bar in a three-stage configuration. At present, the simulation model is being further optimized with performance data of anther 6 types of NF membrane. According to the preliminary experimental data, the combination of another two NF membranes (Dupont NF4040 and CSM NE4040) might further enhance the brine concentration performance, which to be experimentally verified.

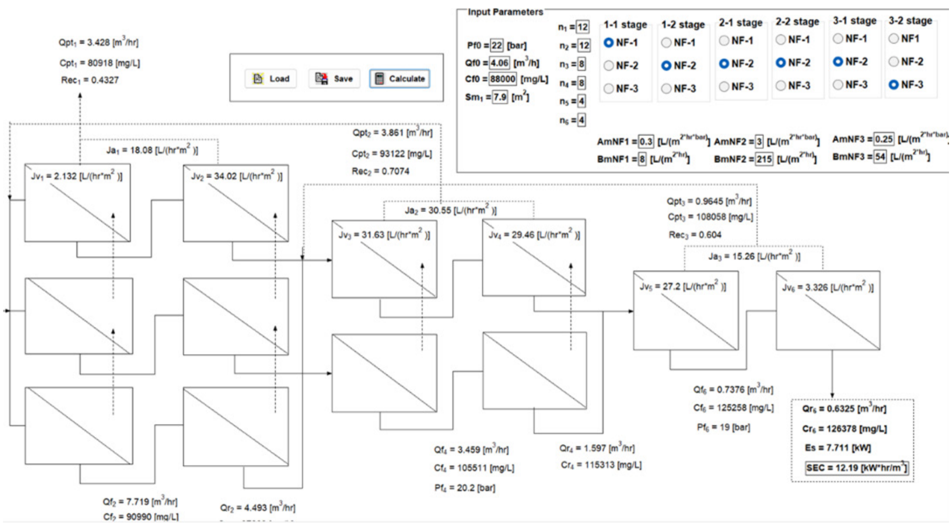


Figure 38 Low-pressure NF Simulation Process

A32: Membrane Biofouling Control: Development And Evaluation Of Advanced Cleaning Strategies (Dtri-Kaust)

1. Background / History / Initiatives / Needs

- Biofilm growth is defined as biofouling when the growth and metabolism of microorganisms, culminating in increased biofilm deposition, becomes substantial enough to cause an unacceptable decline in membrane performance. The normalized pressure drop and flux declines, and salt passage increases: these are considered operational problems in membrane installations when they vary more than 10% - 15% from start-up values. Variations of this size require corrective actions to improve membrane performance and avoid losing the manufacturer's warranty.
- Current chemical cleaning strategies do not effectively restore the original membrane performance in all cases. Chemical cleanings seem effective in arresting biological activity within the biofilm but have a limited effect on biomass removal from spiral-wound membrane elements (Figure 1). Rapid regrowth of bacteria (utilizing available micronutrients within the biofilm) leads to a rapid membrane performance decline (Figure 2). Advanced treatment and cleaning strategies (such as osmotic backwash treatment and intermittent air/water flush, biofilm cohesion strength engineering, feed-concentrate flow direction reversal, and biofilm solubilization) are required to address biofouling.

2. Key principle

- Develop novel cleaning methods for SWRO systems
- Evaluate the removal of biofilm and minerals from membrane surfaces using novel chemical(s)
- Online operation and testing of novel chemical(s) to determine the efficacy of commercial applications

3. Achievement / Economical benefit / Technical advancement

- Project Approval
- Technical discussions between collaborating parties (DTRI and King Abdullah University of Science and Technology) agreed upon

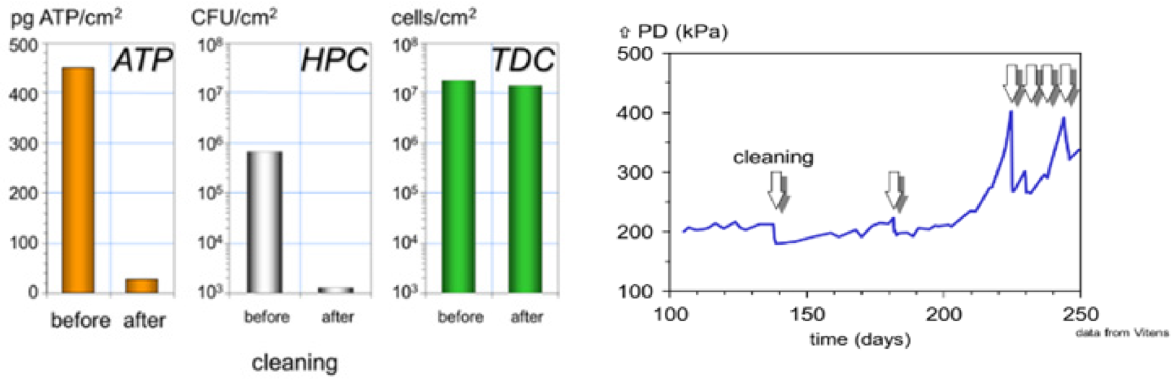


Figure 39 Anticipated Result for Membrane Cleaning Using ATP

A33: Membrane Replacement At Jeddah SWRO Desalination Plant

1. Background / History / Initiatives / Needs

- In line with the Saudi Arabia's Vision 2030, SWCC has a goal of realizing significant energy savings and low carbon footprint at its industrial establishments. SWCC has decided to achieve the goal through a number of actions such as using renewable source of energy, constructing new desalination plants using seawater RO (SWRO) technology instead of thermal desalination, operating the existing SWRO plants more efficiently using advanced energy recovery device and high pressure pumps, and replacing the old Hollow Fine Fiber (HFF) membrane with new advanced membranes that can save up to 20% of the energy in the RO system.
- The current old HFF membrane at three SWCC desalination plants (Ras Al-Khair, Jeddah 3 and Yanbu) is deficient in water production and is exorbitantly expensive per membrane element. Moreover, Toyobo is the sole HFF membrane manufacturer which promotes monopolistic business. There are two types of membrane which can be used to replace the current HFF membrane at Jeddah 3. They are new high permeable HFF membrane from Toyobo and spiral wound membrane from manufacturers such as Toray, Hydranautics, SUEZ, LG etc. The major benefits of replacing with the new HFF membranes are the trouble free consistent operation of the plant using the existing pre-treatment facilities and low capital cost due to minimal changes in the RO system. However, the product water quality in

terms of boron content is not met and the overall operational cost per annum is much higher for the new HFF membrane compared to the operational cost with the spiral wound membrane.

2. Key principle

- The permeability of the old HFF membrane is much too low. The permeate flux of HFF membrane is only 2 LMH compared to minimum 14 LMH for the spiral wound membrane. The replacement of HFF membranes with advanced membranes in Ras Al-Khair, Jeddah 3 and Yanbu plants, is a step towards meeting the goal of energy saving and reducing the carbon footprint. The replacement works at these plants will produce about 20% extra water at little to no additional energy. The energy saving will allow SWCC to improve its carbon footprint every year.

3. Achievement / Economical benefit / Technical advancement

- The technical documents for replacement of the old HFF membranes at Jeddah plant have been prepared for tendering the project. In addition, comparative analysis of the capital and operational costs for the use of new HFF membranes and Spiral Wound membranes in RO system of Jeddah desalination plant, has been completed. The summary of the capital and operational costs along with NPV of the investment for membrane replacement at 4% discount rate over 25 years are given below.

Table 3 HFF and Spiral Wound Comparison

Description	New HFF Membrane	Spiral Wound Membrane
Membrane Type	HE10155EI	SWC5 Max
Increase in production capacity	16.50%	20.20%
Additional water production, m3/day	39590	48408
Capital cost of replacement, SAR	143,341,229	214,643,520
Sale revenue of additional water production, SAR	28,900,700	35,337,840
Cost of annual membrane Replacement, SAR	16,151,520	8,708,370
Cost of chemical consumption, SAR	14,287,472	8,329,569
Cost of other expenses assumed the same as the present values	0	0
Annual operational cost saving after replacement	SAR 27,936,380	SAR 47,774,574
Payback duration, years	6	5
NPV of this investment @ 25 years of return	SAR 281,810,705	SAR 511,244,895

- The replacement with spiral wound membrane ensures high increase in water production up to 48,000 m3/day and the operational cost saving per year up to SAR 48 million compared to 40,000 m3/day increase in production and SAR 28 million saving in operational cost with the use of new HFF membrane. Although the capital cost is high for spiral wound membrane, the payback is possible within 5 years and long term return in 25 years is about SAR 511 million, which makes the use of spiral wound membrane better than the new HFF membrane.

4. Schematic diagram / Figure / Photo

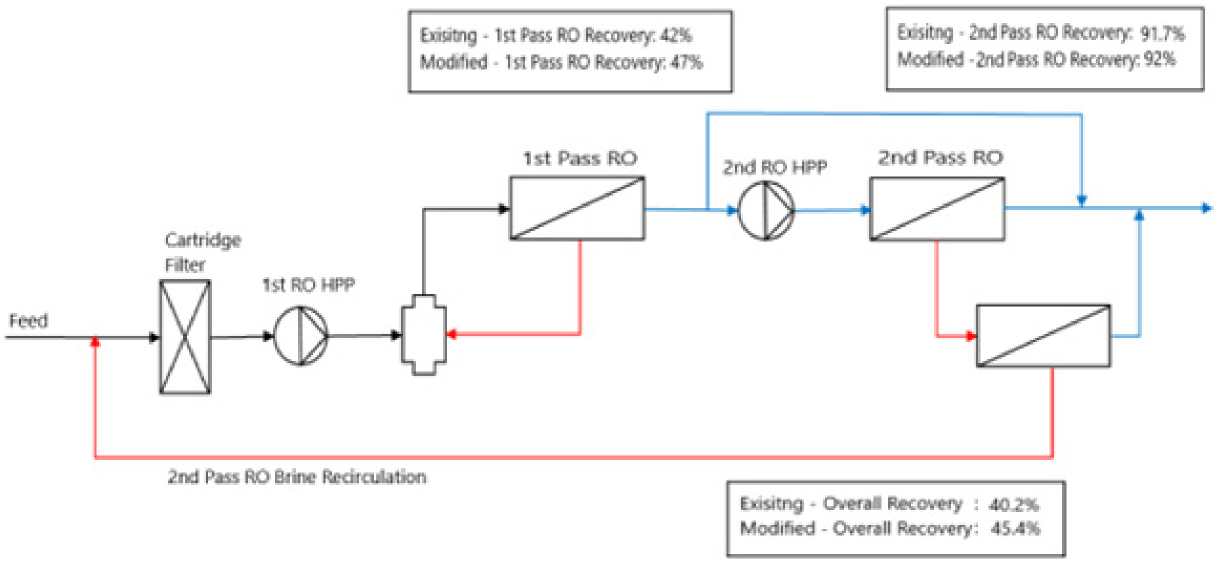


Figure 40 flow diagram of the Jeddah SWRO system with existing and modified recovery ratios

A34: Metallic Organic Framework For Brine Mining

1. Background / History / Initiatives / Needs

- The project is of importance as it targets the synthesis of new types of materials (Metal Organic Frameworks, MOFs) as a means of extracting ions from concentrated brine. These materials have a great potential for enhancement of selective absorption - e.g., K+ over all other ions, or Mg2+ over everything else. Work has been started, and precursors have been synthesized. These precursors will be taken forward to make the target molecules.

2. Key principle

- Utilizing our current stock of chemicals and instruments, we can use the synthesized precursors to make a library of MOF materials and then test it for brine mining applications.

3. Achievement / Economical benefit / Technical advancement

- The project is going smoothly, and we are not that far from reaching the first target molecule which will be used for testing.

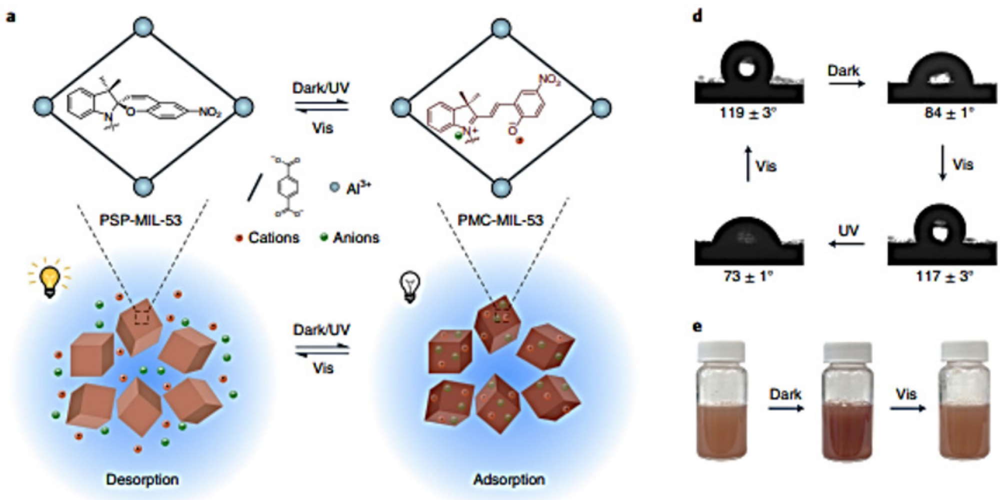


Figure 41 Diagram showing potential MOF material formation and possible applications.
Illustration was adapted from Ranwen Ou et al.

A35: NACE (National Association Of Corrosion Engineers) Impact Plus Audit Of Desalination Plant

1. Background / History / Initiatives / Needs

- SWCC is the largest water desalination company in the world. Corrosion management is a vital process to assure asset integrity via optimization of costs for corrosion control, operation and maintenance, to assure assets achieved the desired operational life.
- IMPACT Plus comprises an audit of the Corrosion Management of a company, and compares it with corrosion management practices of other businesses globally which have undertaken the audit process.
- Identification of gaps, supports the subsequent development of roadmaps to enhance performance and improvement initiatives to be taken. Such initiatives may address factors such as optimization of costs, environment control, minimization of losses due to corrosion failures etc.
- Improvement in corrosion management enhances operational performance, improves public confidence, to the ultimate benefit of the business.

2. Key principle

- IMPACT Plus audit of Ras AlKhair (RAK) RO plant is planned to support their desalination assets with insights to gaps and improvements in corrosion management practices, which may be subsequently developed to strategic actions to be deployed by SWCC.
- An IMPACT Plus audit will be undertaken in-person for one unit (RO – reverse osmosis unit) of RAK. The audit will comprise a single day review within the associated program of work.
- The IMPACT Plus process, using the Corrosion Management Maturity Model (CMMM), assessment tool, was developed by NACE/Association for Materials Protection & Performance (AMPP).

3. Achievement / Economical benefit / Technical advancement

- Quotation for the total cost of the audit of one plant received.
- SWCC team of sponsors from the plant is formed. Champion (Ali AlSahari) and SME (Nausha Asrar), from SWCC side are identified.
- Online pre-audit meting held on October 06. Plan presented by the IMPACT facilitator.
- Waiting for the local NACE representative to submit quotation.

4. Schematic diagram / Figure / Photo

Figure 42 The 10 Domains assessed in the CMMM Survey

A36: New Inhibitor For BFW Treatment To Control Corrosion Of Boiler Tubes Of Rak Plant

1. Background / History / Initiatives / Needs

- Ras Alkhair (RAK) HRSG plants reported corrosion problems after 1.5 years treatment of an inhibitor. DTRI materials and corrosion team inspected, analyzed and identified the root cause of the excessive corrosion of the economizer tubes. Following corrosion control plan was developed for execution:
  - Exploration of a new inhibitor as a better alternative of the existing inhibitor.
  - Recommendation of a corrosion monitoring system to check the online corrosion behavior of boiler/economizer tubes during chemical treatment.

2. Key principle

- Failure analysis of the economizer tubes to determine the cause of the problem.
- Assessment of the effectiveness of the inhibitor used by the plant.
- Exploration of the better chemical treatment and corrosion monitoring system to eliminate the corrosion problem of economizer tubes.
- Review of all the documents about the new inhibitor to ensure its effectiveness for corrosion control.
- Technical meeting with the plant people to present the new chemical treatment recipe to resolve the corrosion problem.

3. Achievement / Economical benefit / Technical advancement

- Failure analysis of the corroded boiler tubes performed, cause identified and recommendations for mitigation of the problem submitted.

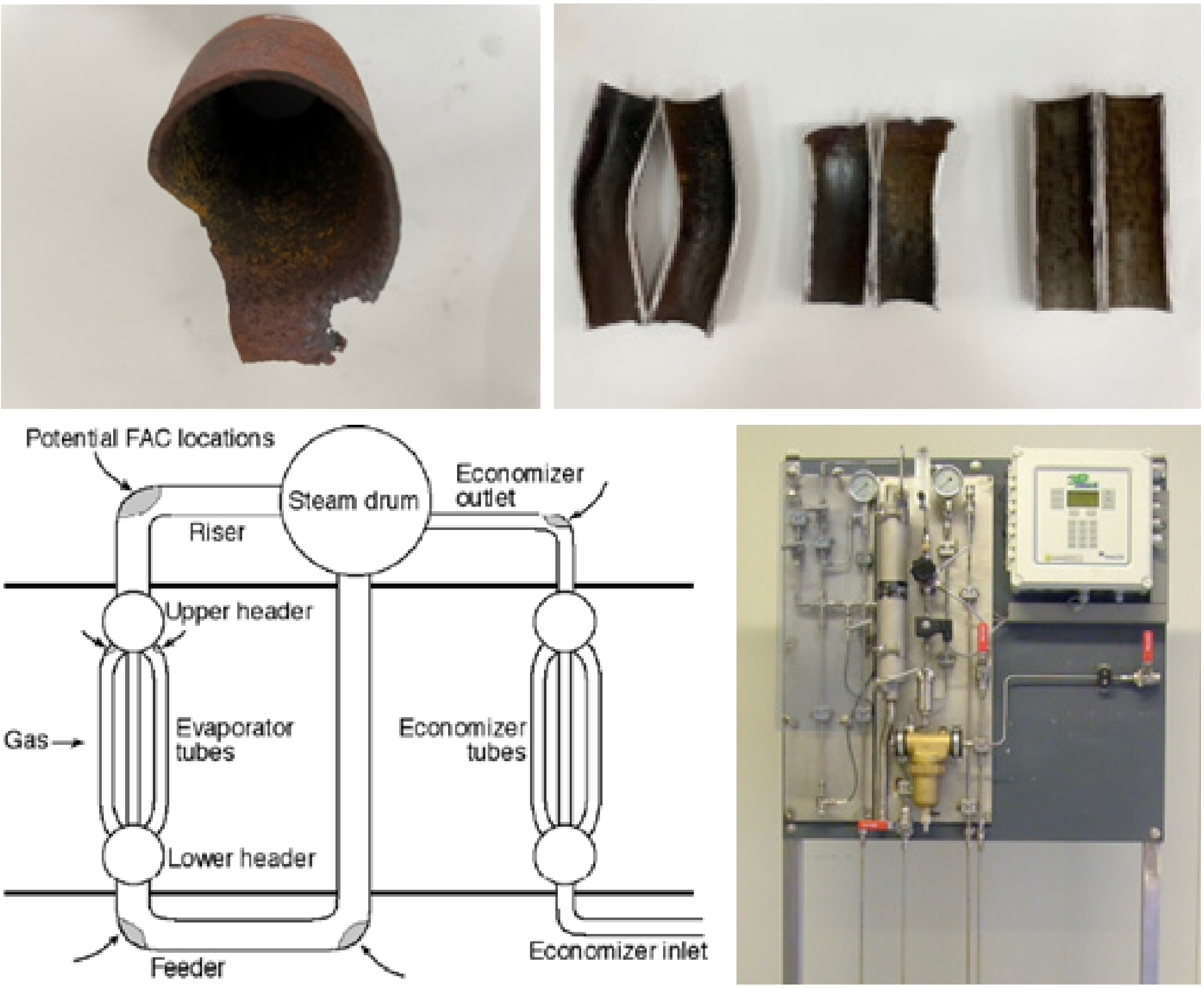


Figure 43 Flow accelerated corrosion (FAC) of the economizer tube

A37: Novel Method For Hard Fouling Removal Increases Water Production To Design Capacity

1. Background / History / Initiatives / Needs

- Unit 35 of the Al-Jubail cogeneration Desalination and Power Plant presented massive blockage of its deaerator. Upon inspection, cemented Pall rings were observed throughout the deaerator. Production of the MSF system was 940 m3/hr. Concentration ratio (CR) increased to 1.45, and ball cleaning replacements increased in frequency from 21 days to 14 days.

2. Key principle

- Chemical, biochemical, and molecular analysis of the problem.
- Identification of the composition of the hard foulants.
- Devise a method of cleaning.
- Testing of method.
- System evaluation.
- Execution of cleaning method on deaeration unit.
- Evaluation of cleaning effectiveness.

3. Achievement / Economical benefit / Technical advancement

- 261 m3/hr increase in production (23% Increase).
- Reduction in CR values (from 1.45 to 1.39).
- 28% Reduction in antiscalant consumption.
- Reduction in frequency of ball cleaning replacement.
- Decrease in ball cleaning replacement frequency from two weeks to three weeks.

Figure 44 Ball Ring Before and After Cleaning

A38: Off-Line Inspection Findings Of Above Storage Water Tank From Yanbu-Madinah Transmission Systems

1. Background / History / Initiatives / Needs

- Leakages and corrosion issues have been addressed in Tank No. 4 of the Yanbu-Madinah transmission systems. An investigation was carried out on the bottom plate of this potable water tank. Four potable water above-ground storage tanks have been utilized to store the product water of Yanbu Phase II. These tanks were commissioned in 1998 and have worked properly since that time with minor maintenance to maintain their performance. Tank No. 4 is made up of carbon steel and isprotected internally and externally by two different methods: coating as a passive method and cathodic protection as an active method. All four water tanks were designed, fabricated and tested in accordance to API-650 standard.

2. Key principle

- Tank bottom plate, walls and ceiling were all inspected. Beside the physical inspection, elemental analysis of corrosion product and scales was conducted by Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX) and by X-ray Fluorescence (XRF) techniques. The goal was to determine the source of the leakage issues, which was hypothesized to be because of aged internal coating layer facilitating the penetration of salts through it to the steel surface.

3. Achievement / Economical benefit / Technical advancement

- The leakage was caused by pinhole coating corrosion which was attributed to ion permeation through the aged/semipermeable internal coating. Galvanic corrosion was indicated between inlet connections of stainless steel and tank walls of carbon steel with a deteriorated internal coating. Sludge covered the bottom plate with an approximate thickness of 10-15 cm. It was randomly removed from different locations showing numerous blisters underneath. Different types of scales were also found. It was highly recommended to apply advanced types of coatings on internal surfaces to provide higher protection levels.

A39: Osmotic Cleaning To Mitigate SWRO Membrane Fouling

1. Background / History / Initiatives / Needs

- Reverse Osmosis is a popular technique for desalination of seawater and brackish water to produce clean and potable water. However, the membrane used in this process is vulnerable to fouling by different types of contaminants such as organic matter, microorganisms, mineral salts and colloidal particles. The irreversible deposition of these leads ultimately to formation of thick and sticky layers (e.g., biofilm and hard scales) on the membrane surface. These result in increased operation and maintenance costs due to higher operational pressures and more frequent membrane cleaning and replacement.

2. Key principle

- The experiment operates on separated units that are fed by the same seawater under the same operational conditions. One unit (Test unit) is connected to a tank filled with hypersaline solution (15% of NaCl). The other unit (Control unit) has conventional conditions. The backwash is only conducted to the test unit three times a week by feeding the unit with the hypersaline solution to allow the permeate to transfer back by forward osmosis mechanism. The permeate will remove the accumulated fouling on membrane surface. The duration of every backwashing is two minutes and the data of both units is collected daily to monitor the operation.

3. Achievement / Economical benefit / Technical advancement

- Osmotic cleaning should lead to operational cost reduction by minimizing chemicals consumption, maintaining membranes performance, and minimizing the accumulation of irreversible fouling on membrane surface.

Figure 46 Membrane Autopsy which under osmotic cleaning

Figure 45 Membrane Autopsy conventional operation

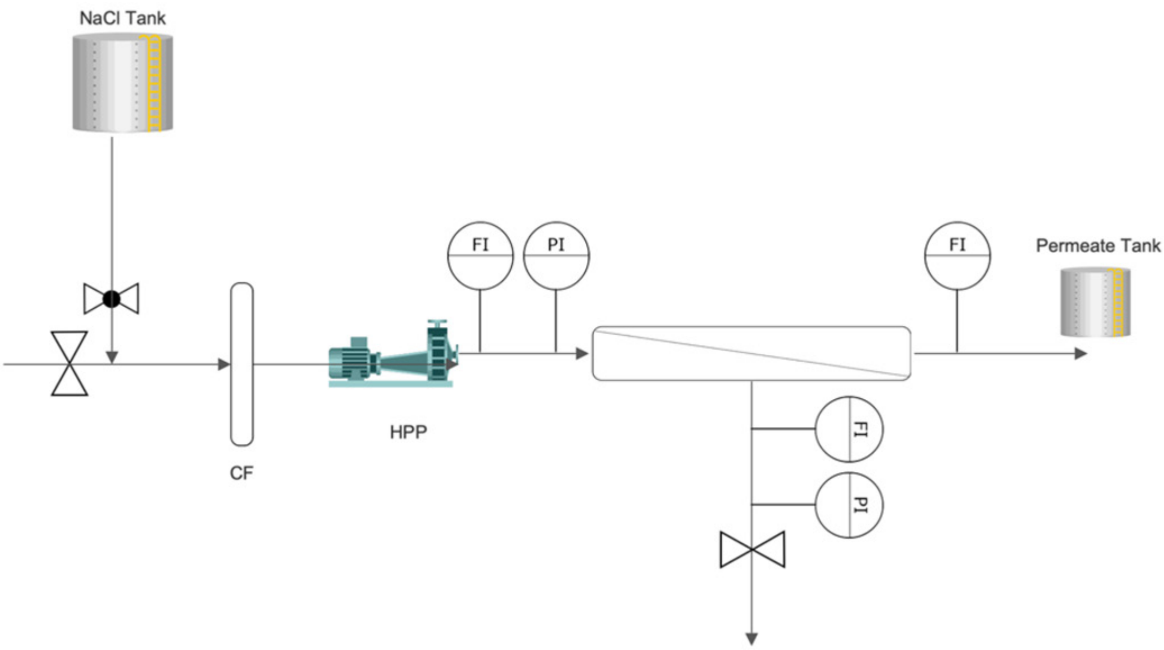


Figure 47 Conventional SWRO unit coupled with osmotic cleaning system

A40: Performance Improvement Al Shoaiba SWRO Desalination Plant (I)

1. Background / History / Initiatives / Needs

- A performance decline was observed in train B10 of the Al Shoaiba commercial SWRO Plant. Differential pressure spiked to 2.4 bar, and product conductivity increased to 1067 µS/cm. One effect of the COVID-19 quarantine was supply chain shortages of the tetrasodium EDTA and citric acid used to improve the performance of SWRO membranes, making it necessary to seek a substitute cleaning protocol.

2. Key principle

- DTRI initiated the chemical evaluation and design of a cleaning method protocol in conjunction with the chemical manufacturer VEOLIA and the specifications of the membrane manufacturer (Toray). Cleaning in Place (CIP) was conducted on a designated train with a novel chemical after approval and under the supervision of DTRI. Membrane autopsies were undertaken to determine cleaning effectiveness and potential membrane oxidation.

3. Achievement / Economical benefit / Technical advancement

- 18% improvement in differential pressure.
- 3% decrease in product conductivity.
- The chemical treatment was approved for CIP application in SWCC Plants with the recommendation to optimize the protocol.

Table 4 Measured Parameters Before and After CIP

Parameters	Units	Before CIP	After CIP
Differential Pressure	Bar	2.09	1.71
Feed Pressure	Bar	62.71	61.96
Concentrate Pressure	Bar	60.47	59.92
Product Conductivity	uS/cm	846	819

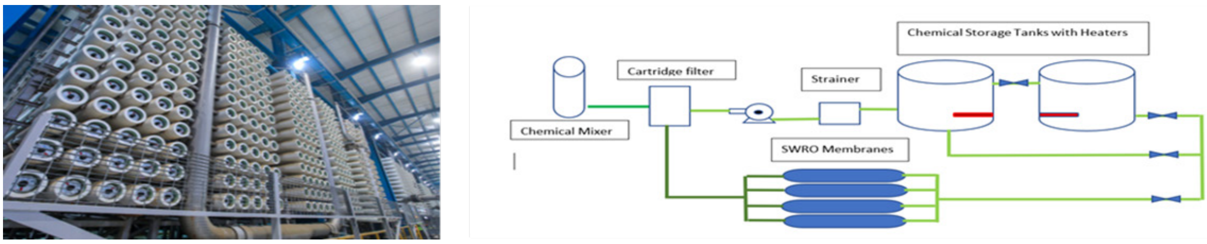


Figure 48 CIP Skid

A41: Performance Improvement Al Shoaiba SWRO Desalination Plant (II)

1. Background / History / Initiatives / Needs

- The Al Shoaiba SWRO Plant has a production capacity of 450,000 m3 /day and faces issues of biological fouling) that resulted in high energy consumption and decreased water quality for the second pass system and product water. In addition, membrane oxidation led to the replacement of many feed elements in first-pass pressure vessels. The effect of the COVID-19 quarantine resulted in supply chain shortages of Tetra Sodium EDTA, and citric acid used to increase the performance of SWRO membranes.

2. Key principle

- DTRI initiated the chemical evaluation and design of a cleaning method protocol in conjunction with the chemical manufacturer NALCO and the membrane manufacturer's (Toray's) specifications.
- Cleaning in Place (CIP) was conducted on a designated train with a novel chemical after approval and supervision of DTRI.
- Performance evaluation was conducted to determine the suitability of new CIP chemicals
- Chemicals with operational protocols accepted for the supply chain supply and Plant use, respectively

3. Achievement / Economical benefit / Technical advancement

- 14% improvement in differential pressure
- 3% increase in product conductivity
- Chemical was improved for CIP with a recommendation to optimize the protocol

Table 5 Measured Parameters Before and After CIP

Parameters	Units	Before CIP	After CIP
Differential Pressure	Bar	2.05	1.77
Feed Pressure	Bar	62.00	59.90
Concentrate Pressure	Bar	59.75	57.90
Product Conductivity	uS/cm	1400	1440

A42: Performance Improvement Project In Shoaiba 2 And Al Khobar 3 MSF Plants

1. Background / History / Initiatives / Needs

- After initial assessment for operation data for 2021 for the Shoaiba phase 2 and Al Khobar phase 3 MSF plants, we found that the last stage brine temperature is higher than design, leading to reduced flashing range. We suspected that venting from the last stage was insufficient. Venting from the last stage is joined with the venting from the deaerator by design, so if venting from the deaerator is more than design flow, venting from the last stage could be restricted. Venting flowrate from the deaerator could also be excessive if stripping steam is supplied above the required flowrate, especially during summer period, so adjustment of stripping steam could result in improvement of venting from the last stage.

2. Key principle

- Excessive stripping steam from the 1st stage of heat rejection section would reduce venting flowrate from the last stage and elevate the last-stage brine temperature. Raised brine temperature would reduce production as well as thermal efficiency in terms of performance ratio. So, adjusting stripping steam valve by closing could improve the venting from the last stage, improving both production and thermal efficiency.

3. Achievement / Economical benefit / Technical advancement

- We have tested in Shoaiba 2 unit 11 and unit 12, and Al Khobar 3 unit 12. The result showed that production was increased from 1348.8 to 1381.5 m3/h and 1748.2 to 1816.4 m3/h respectively in Shoaiba 2 unit 11 and unit 12, and 1290.6 to 1313.7 t/h in Al Khobar unit 12. Results show there is a potential to improve thermal efficiencies in thermal desalination units by looking at long term operation data and by adjusting operating parameters.

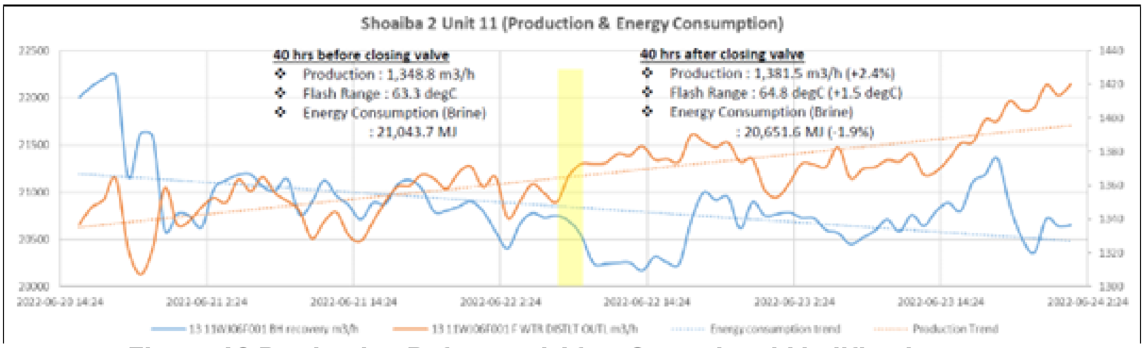


Figure 49 Production Before and After Operational Modification

A43: Pilot Crystallizer Unit For Producing High Purity Nacl Salt

1. Background / History / Initiatives / Needs

- Utilizing the discharged brine from SWRO plants for commercial products is a promising industry nowadays. SWCC represented by its research arm DTRI is moving toward the implementation of commercial scale processes for producing sodium chloride of acceptable quality for the chlor-alkali industry. Accordingly, testing and evaluating a provided crystallizer for the production of high purity NaCl salt with <5% moisture and less than 100 mg/kg of Magnesium is the purpose of this project. The feed for the crystallizer will be the concentrated stream from the existing pilot brine concentrator system.

2. Key principle

- A thermal-Vacuum crystallizer will be used to precipitate salt from concentrated brine, giving NaCl crystals and a purge stream rich in non-NaCl seawater components. It will be a novel approach for extracting high purity NaCl salt from reverse osmosis brine.

3. Achievement / Economical benefit / Technical advancement

- The crystallizer is already delivered to DTRI pilot plants and is under commissioning.
- The results of this study will potentially lead to the creation of a new market for desalination brine and a new industry
- This will support the economy and localization efforts in the Kingdom.

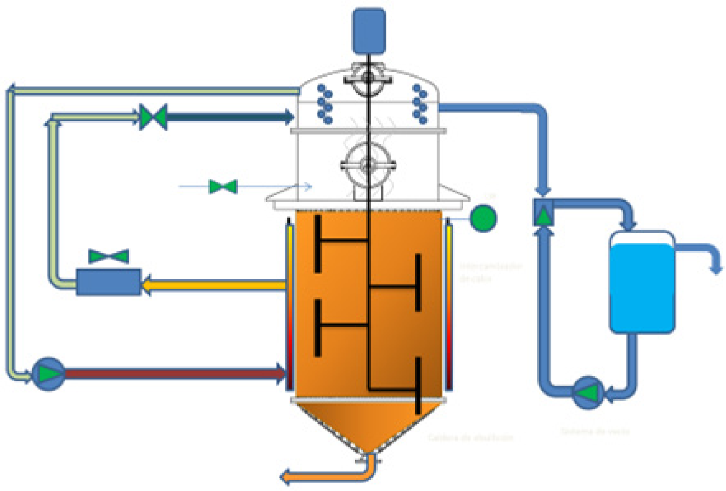


Figure 50 Schematics for Crystallizer Unit

A44: Preliminary Design Of Multi Set Drone

1. **Background / History / Initiatives / Needs**

   - Continuing developments in technology lead to new opportunities for utilizing technology in desalination. This project aims to use drones in order to facilitate operation and maintenance of desalination operations, lead to enhanced efficiency and reduced cost.

2. **Key principle**

   - Using multi set drone to investigate potential operational issues and leakages.

3. **Achievement / Economical benefit / Technical advancement**

   - Establishment of a team between DTRI and Tabuk university, in cooperation with the AI department in SWCC, and development of a preliminary design of a multi set drone for desalination plant applications.

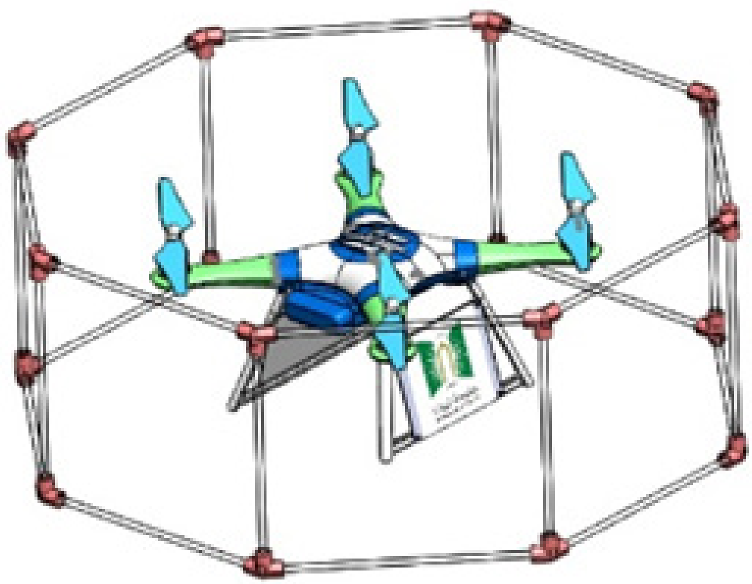


Figure 51 Schematics for the drone

A45: Production Of Bromine And Bromine-Related Products From Desalination Brine

1. Background / History / Initiatives / Needs

- Among the many chemicals potentially extractable from desalination brine, bromine is uniquely attractive. Firstly, it was economically extracted from seawater on an enormous scale throughout the 20th century, so processes for extracting it from desalination brine are firmly established on existing technologies. Secondly, bromide salts made from bromine are used in large amounts in oilfield clearing solutions, but there is no current production of bromine in the GCC. Multiple technoeconomic studies have found that bromine extraction shows the highest rate of return of any brine mining process.

2. Key principle

- The aim of this project is to establish a pilot plant for the initial steps of bromine extraction from aqueous solution. In this process bromide is oxidized to bromine, and bromine is removed from solution by air blowing and absorbed in basic solution to give a rich feedstock for the well-established second-stage of bromine purification. This will allow optimization of operating conditions (while the concept of the technology is well established, it has only been applied before to seawater and saltmarking bitterns, not the desalination brines we are interested in). More importantly, it will allow investigation of forming solutions suitable for oilfield clearing directly, without going through a highly purified bromine.

3. Achievement / Economical benefit / Technical advancement

- The sodium and calcium bromide currently used in the Arabian Gulf oilfields are imported from Jordan and are derived from the bromine-rich waters of the Dead Sea. There is unmet demand in the GCC and it should be able to produce these salts at a competitive price from desalination brine. If it is possible to produce them at an appropriate quality in a process that omits the second stage of bromine purification, the process will become much more competitive: as well as import replacement, a promising export market could be established.

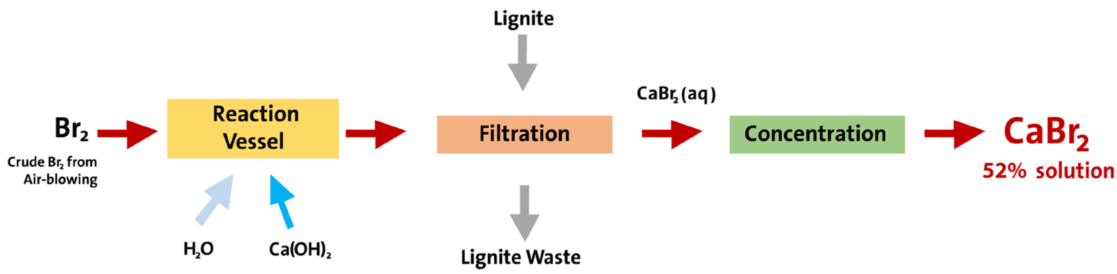


Figure 52 Bromine Extraction Process from Brine

A46: Production Of Economically Valuable Minerals From Nanofiltration Reject

1. Background / History / Initiatives / Needs

- In terms of potential economic value per cubic meter of brine, by far the greatest value lies in sodium chloride and in magnesium salts. SWCC has well-advanced plans for commercial production of sodium chloride but has as yet only done very preliminary work on extracting value from the magnesium salts. Magnesium sulfate is an important fertilizer, and magnesium metal is an important strategic metal for 21st century industries.

2. Key principle

- An initial step of nanofiltration to separate brine into monovalent ion-rich and divalent ion-rich streams is critical for obtaining mineral products of acceptable quality and cost. The aim of this work is to determine the cost and energy 'thermodynamic critical path' for producing saleable products from nanofiltration reject using existing technologies to enable accurate techno-economic analysis of the initiative.

3. Achievement / Economical benefit / Technical advancement

- Magnesium sulfate can be obtained by an established process from magnesium rich brines, such as that produced by nanofiltration of desalination brine. There is a large market for magnesium sulfate on the Indian subcontinent which the Eastern Province ports are ideally located to serve. Magnesium sulfate could also be used locally for 'fertigation' of high-value crops dependent on desalinated water. Preliminary estimates suggest that production of magnesium sulfate from desalination brine would be cost effective, making this a significant avenue for reducing the cost of water to the consumer. Magnesium metal is not currently produced in KSA. While there are significant deposits of magnesium carbonate in the Kingdom which could be used to support a local magnesium industry, these terrestrial resources are limited, and the 'infinite' resource of the ocean would be preferable. In the event a magnesium metal industry is established in the Kingdom and desalination brine is a cost-effective source of magnesium oxide or magnesium chloride feedstock, this would create more value to subsidize the cost of water than any other industrial opportunity.

A47: Ras Tanura Distillate Cooling Plant Rehabilitation

1. Background / History / Initiatives / Needs

- The Ras Tanura pipeline carries around 900 ton/hr of water produced at the IWPP plant in Jubail to Ras Tanura city, with a typical water temperature of 44 °C. It was suggested to install a cooling tower plant to cool down the unit, however the provider failed to operate the unit properly.

2. Key principle

- Using dry air to cooled distillate water through adiabatic cooling.

3. Achievement / Economical benefit / Technical advancement

- Rehabilitation of the unit through redesign and modification, as well as modifying the operational methodology. This lead to an increase of 14% in plant performance and stabilization of the unit operation.

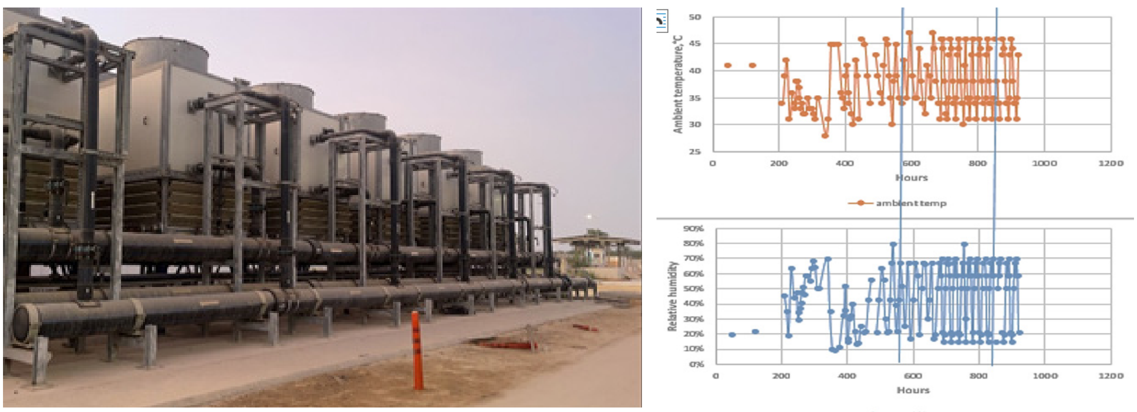


Figure 53 Ras Tanura Cooling System

A48: Robot For Inspection And Cleaning Of Pipelines

1. **Background / History / Initiatives / Needs**

- Currently the pipelines connecting the major desalination plants at Jubail and Ras Al Khair to the capital of Riyadh are undergoing numerous aging-related challenges, such as corrosion and failure of cement mortar. Monitoring and assessment of these pipelines is a critical ongoing requirement.

2. **Key principle**

- Using new technology to inspect and clean the line, using sensors for investigation and communication tools allowing actions to be taken in real time.

3. **Achievement / Economical benefit / Technical advancement**

- The use of new technology to inspect and clean the line which lead to increases in water supply reliability, reducing shutdown periods to the minimum.

A49: Second Failure Analysis Of Heat Recovery Steam Generator 52 (Hrsg 52) Leakage In Ras Alkhair Plant

1. **Background / History / Initiatives / Needs**

- The heat recovery steam generator (HRSG-52) at Ras Al Khair had been subject to repeated leakage issues. The consecutive failures of HRSG-52 economizer tubes is an indication of the presence of destructive factors leading to continued impairment of the tubes. In the first case, a comprehensive failure study was carried out on the same HRSG, which was shut down to do the required maintenance and operated again for only four months before experiencing the same leakage failure. DTRI received four tubes to do the required analysis, one of them unused.

2. **Key principle**

- The tube samples were prepared for identification of corrosion product type. Topography images of the pits and tube material composition were determined by Optical Emission Spectroscopy (OES). Tubes were analyzed by Scanning Electron Microscope-Energy Dispersive

X-ray (SEM-EDX) for corrosion product type, pit morphologies, tube wall and scale thicknesses. A metallurgical microscope was used to identify the microstructural grain boundaries and scale layer thicknesses.

3. Achievement / Economical benefit / Technical advancement

- Flow Accelerated Corrosion (FAC) type was detected from pit morphologies. Addition of Mo and Cu could significantly reduce FAC rate in the alloy steels. Analysis revealed the absence of Magnetite layer (Fe3O4) (most stable form of corrosion product) and instead a Wüstite layer (FeO) was found indicating fluctuations of different parameters like temperature or pH in that location. Copper was found on the inner surfaces of all of the three tubes, which might be related to corrosion of Cu-Ni tubes in the previous stage, letting copper ions reach steel surfaces. And since copper has a higher electrochemical potential than iron, aggravation of corrosion rate is expected.

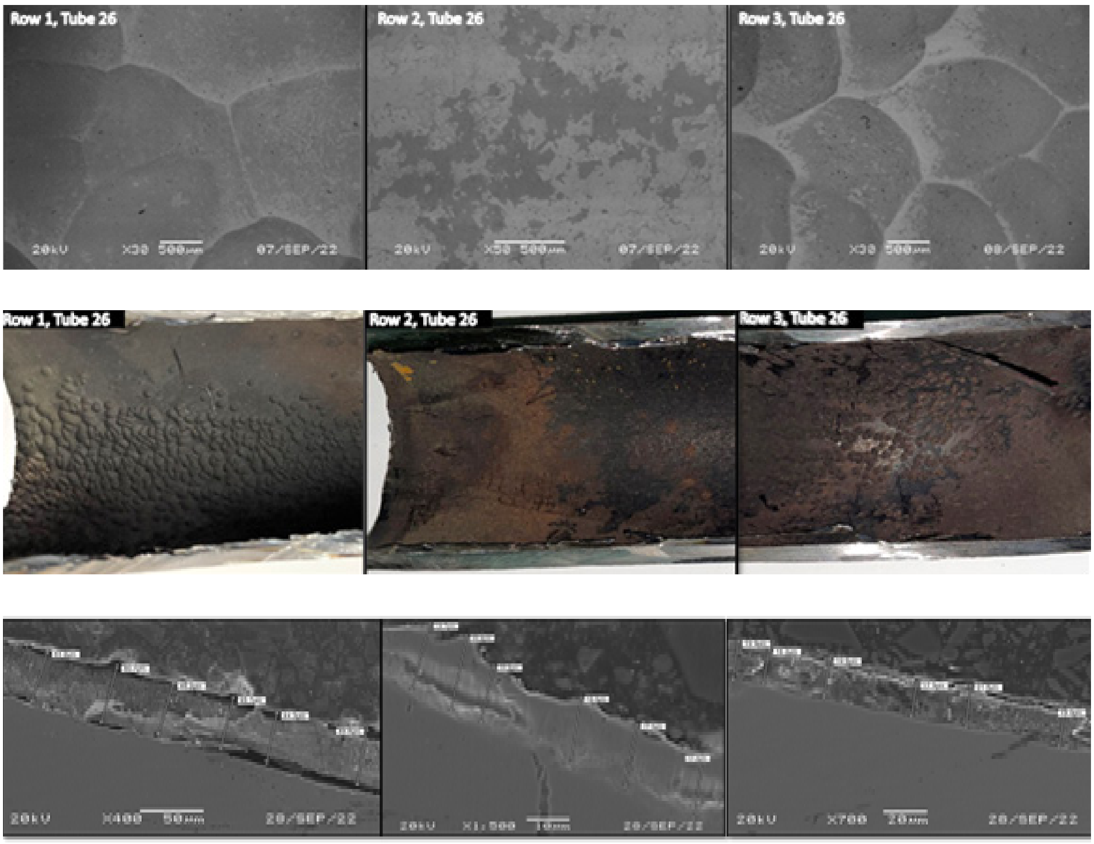


Figure 54 SEM Internal Aspect of the Failed Tube

A50: Shoaiba NF Project For Magnesium Addition To Product Water In Shoaiba RO Phase 4 Desalination Plant (Vop No.38)

1. Background / History / Initiatives / Needs

- Magnesium (Mg) in drinking water is essential for human health. It is an important mineral for cardiovascular health and for combating diabetes. Many medical investigations have revealed the important of Mg in drinking water, and based on this literature, SWCC announced new quality specification for produced water in October 2020 including 15-25 ppm of Mg. This was a pioneering action by SWCC before the introduction of new regulation on drinking water by WHO which is expected include minimum 5ppm of Mg. In 2022, a joint medical study was carried out in Saudi Arabia between SWCC, Imam Abdulrahman Bin Faisal University, and King Fahd Hospital regarding the beneficial effects of Mg in drinking water for combating diabetes; the results of this study were published in Nature Partner Journal (npj) Clean Water:

https://www.nature.com/articles/s41545-022-00207-9

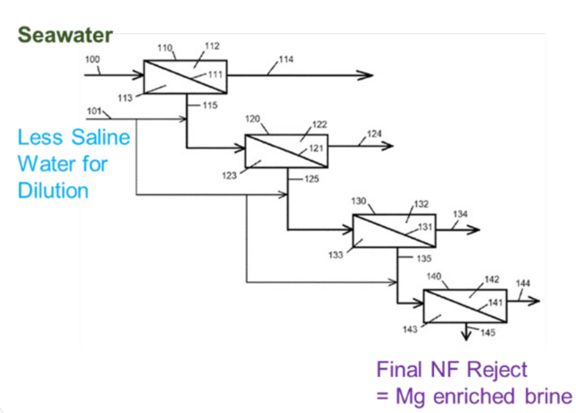
2. Key principle

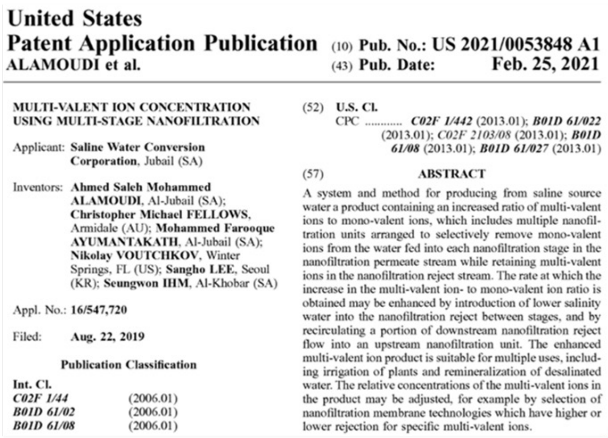
- Magnesium is one of the most abundant minerals dissolved in seawater. In 2019, SWCC-DTRI developed a patent-pending technology which uses a multiple-stage Nano-Filtration (NF) membrane system. With this technology, Magnesium and calcium (healthy minerals) can be efficiently extracted from seawater while minimizing unnecessary sodium and chloride. The concept was demonstrated in the SWCC-DTRI pilot plant in Jubail.

3. Achievement / Economical benefit / Technical advancement

- Shoaibah was selected to construct the world's first multi-stage NF system with inter-stage dilution (NF-Mg plant). After awarding the project in May 2021 and starting site works in July 2021, the first Mg-enriched brine was produced in Mar. 2022, and the Shoiabah NF-Mg plant has been in full production of Mg-rich brine from seawater since May 2022. The produced Mg-rich brine is mixed with 400,000m3/d of product water in Shoaibah Phase 4 to make its Mg ≥ 15ppm, which will serve about 1.3 million people with healthy Mg-enriched water.

4. Schematic diagram / Figure / Photo





United States
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ALAMOUDI et al. (43) **Pub. Date: Feb. 25, 2021**

MULTI-VALENT ION CONCENTRATION USING MULTI-STAGE NANOFILTRATION

Applicant: **Saline Water Conversion Corporation**, Jubail (SA)

Inventors: **Ahmed Saleh Mohammed ALAMOUDI**, Al-Jubail (SA); **Christopher Michael FELLOWS**, Armidale (AU); **Mohammed Farooque AYUMANTAKATH**, Al-Jubail (SA); **Nikolay VOUTCHKOV**, Winter Springs, FL (US); **Sangho LEE**, Seoul (KR); **Seungwon IHM**, Al-Khobar (SA)

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(57) **ABSTRACT**

A system and method for producing from saline source water a product containing an increased ratio of multi-valent ions to mono-valent ions, which includes multiple nanofiltration units arranged to selectively remove mono-valent ions from the water fed into each nanofiltration stage in the nanofiltration permeate stream while retaining multi-valent ions in the nanofiltration reject stream. The rate at which the increase in the multi-valent ion- to mono-valent ion ratio is obtained may be enhanced by introduction of lower salinity water into the nanofiltration reject between stages, and by recirculating a portion of downstream nanofiltration reject flow into an upstream nanofiltration unit. The enhanced multi-valent ion product is suitable for multiple uses, including irrigation of plants and remineralization of desalinated water. The relative concentrations of the multi-valent ions in the product may be adjusted, for example by selection of nanofiltration membrane technologies which have higher or lower rejection for specific multi-valent ions.

Figure 55 SWCC patent pending technology: multi-stage NF (nano-filtration) system with inter-stage dilution

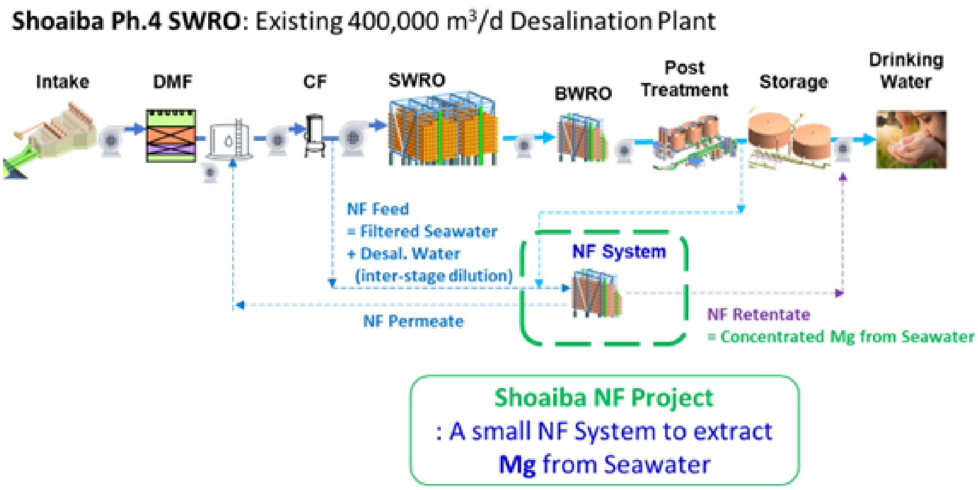

Figure 56 Schematics of Shoaiba NF-Mg plant

Figure 57 Shoaiba NF-Mg plant

A51: Testing & Evaluating The Newly Developed Carbon Nano-Tube Membrane Of Shinshu University

1. **Background / History / Initiatives / Needs**

    - Controlling fouling formation on membranes is a very critical aspect of the SWRO process. As a result of high recovery operation in RO process, the fouling rate will potentially become very high. Organic, inorganic, biomaterials, and colloidal substances are all materials that can contribute to fouling. Usually, commercial SWRO plants have a chemical cleaning schedule for removing the reversible fouling, but an unremovable fraction of fouling is irreversible. Therefore, Shinshu University has developed SWRO spiral wound membranes that have high fouling resistance.

2. **Key principle**

    - The innovative membrane material developed by Shinshu University (incorporating carbon nanotubes) is expected to give a reduction in most types of fouling by changing the topography and surface chemistry of membranes.

3. **Achievement / Economical benefit / Technical advancement**

    - The test has been done

A52: Utilization Of Hydrogen From Electro-Chlorination System

1. **Background / History / Initiatives / Needs**

    - Hydrogen is currently being produced in the existing electro-chlorination systems used by SWCC plants for generating disinfectants from seawater in situ. The current status of the process is to dump hydrogen to atmosphere. DTRI is planning to make use of this hydrogen to add value to the overall desalination process.

2. **Key principle**

    - Ras Al Khair and Yanbu 3 plant currently produce sizable amounts of hydrogen which has the potential to be used in water production.

3. Achievement / Economical benefit / Technical advancement

- Hydrogen production calculation and conceptual configuration of a hydrogen collection process have been completed.

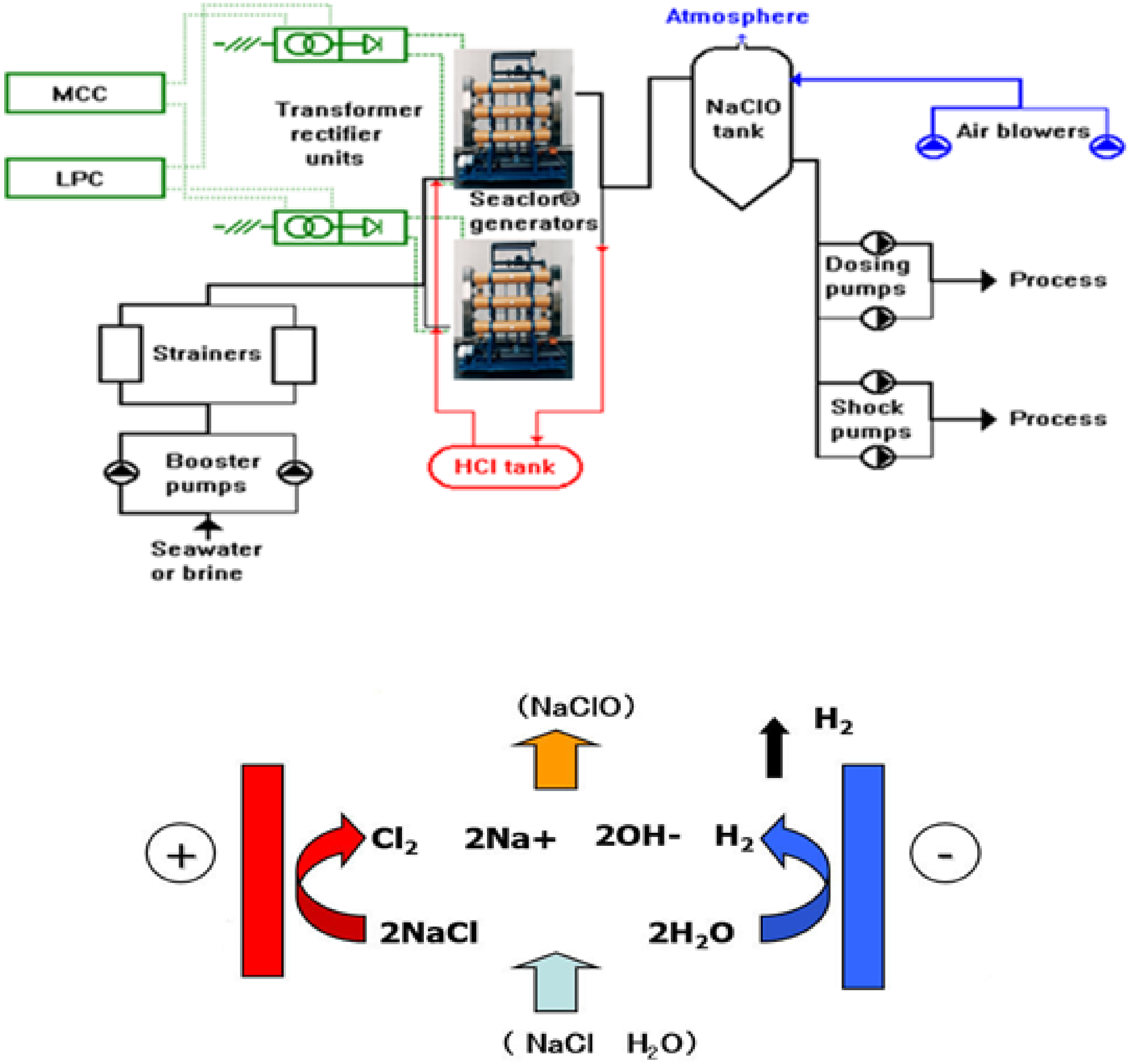

Figure 58 Illustration of Wasted Hydrogen Utilization

A53: Verification Of DTRI Patent Using Zeolites In The Pretreatment Stage To Enhance Desalination Economics

1. Background / History / Initiatives / Needs

- A patent application was made by DTRI for a process, which initially proved the effectiveness of deteriorated zeolites in adsorbing calcium and magnesium ions, consequently reducing scaling probability. This project is a verification of this patent application using a new batch of zeolites. This adsorption process could be incorporated within different desalination technologies to increase the process efficiency and reduce the overall production costs.

2. Key principle

- Zeolite has the capability to adsorb calcium and magnesium ions which are the main source of inorganic scale formation. Removing these ions would overcome this main obstacle and enhance desalination productivity. Lab tests are being conducted to find the optimized conditions of zeolites performance.

3. Achievement / Economical benefit / Technical advancement

- Plan and design of experiment was prepared. Lab tests have started using seawater before and after passage through Dual Media Filter (DMF) as testing solutions. Initially, tests are being conducted in both static & dynamic conditions at 25°C and 40°C, to evaluate its performance in winter and summer seasons.

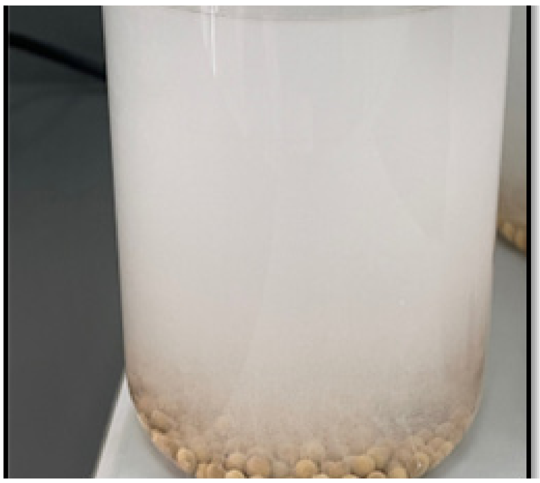

Figure 59 zeolites Experiment as Seawater Pretreatment System

A54: Vibration Analysis And Diagnosis System

1. Background / History / Initiatives / Needs

- Vibration of rotating machines such as pumps, compressors, and turbines is a major cause of wear and failure. Maximizing the use of existing vibration sensors to have full monitoring for all rotating machines would lead to reduced shutdown periods and increase plant availability.

2. Key principle

- Using vibration sensor readings to diagnose at-risk pumps.

3. Achievement / Economical benefit / Technical advancement

- Phase one of the project, predicting the status of the pump and the failure time from vibration sensor output at the Ras Al Khair plant, has been finalized. Currently DTRI is working on the system evaluation to predict spare parts requirements.

Figure 60 Installed Vibration Analysis and Diagnosis system in RAK

A55: Water Quality Monitoring Of Produced And Transmitted Water From Swcc Plants

1. Background / History / Initiatives / Needs

- Providing safe and good quality drinking water is the highest priority of SWCC. Water produced by SWCC plants are regularly monitored for the water quality incompliance with national and international regulations, particularly for physical and chemical parameters, toxic heavy metals (such as Hg, Se, Pb, As, Cd, Cr, Fe, Ni, Cu, Al, Co, Mn, Zn) and toxic disinfection by-products (DBPs) such as bromate and THMs (trihalomethanes) arising from sea water chlorination.

2. Key principle

- Desalination Technologies Research Institute (DTRI) has been entrusted with monitoring water quality control for produced and transmitted water from SWCC plants.

3. Achievement / Economical benefit / Technical advancement

- Monitoring more than 75 points for produced and transmitted water from SWCC plants.
- More than 8,300 tests were done for the water produced from the six major desalination plants in 2022 (Table 1).
- Scientific paper published.
- Conference papers presented.

Table 6 Statistics of the number of tests that were done for the water produced from the six major desalination plants (Jubail, Khobar, Ras Al Khair, Jeddah, Shoaibah and Yanbu) in 2022

	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
Number of successful tests	2224	2003	1987	2071	8285
Number of failed tests	16	12	14	14	56
Total number of tests	2240	2015	2001	2085	8341
Average of Water Quality Index (Ave. WQI)	98.4 %	99.6 %	98.5 %	98.8 %	98.8 %

A56: Wind Power Generation With High Cf For Areas With Moderate Wind Power Densities

1. Background / History / Initiatives / Needs

- Wind power generation in areas with high wind densities and a high capacity factor (CF) is well-established both technically and economically. However, wind power density in coastal areas of the Kingdom of Saudi Arabia is only moderate. New wind turbine configurations may be economic for these areas, but techno-economic analysis of these technologies is required.

2. Key principle

- The study is considering the specific case of the application of wind-power for future power supply to desalination, green hydrogen production and CO2 emission reduction of Ras Al Khair power plant.

3. Achievement / Economical benefit / Technical advancement

- Techno-economic study is on-going.

DTRI Management

Eng. Tariq Alghaffari

Tariq Ghassan Alghaffari has two different roles at Saline Water Conversion Corporation as the Executive Director of DTRI sector and a General Manger of Local Competencies Projects in TAP sector, where he focuses on research innovation, development, engineering, procurement, and execution of projects for the desalination industry aligning with the vision and goals of 2030 through SWCC's capabilities. During the Pandemic (COVID-19) through innovative solutions one of the projects achieved a world Guinness record "Lowest Energy Consumption in the world for water desalination plant 2.271 KWh per meter cubic". Tariq holds a PMP® , certificate Harvard business school, and many other related professional certificates and a bachelor of chemical engineering from Washington State University USA

Eng. Ali Al-Sahari

Eng. Ali Al-Sahari: Research & Technical Consulting Manager in Desalination Technologies, Innovation & Research Institute (SWCC-DTRI) He has a bachelor's degree in mechanical engineering and a master's degree in materials science and engineering, and experience of more than 12 years at the Desalination Technologies, Innovation & Research Institute (DTRI) worked on several projects related to corrosion and desalination materials as a corrosion engineer. He was a Senior Corrosion Engineer and then a Corrosion Research Assistant and Director of the Central Laboratories at the DTRI through which he worked on advanced systems to support national and international laboratories and accreditations to achieve the highest quality standards. He currently holds the functions of the Research and Consulting Department at the Institute. He participated in different conferences as speaker and delegates.

Eng.Mohammed Al Shaiae

Business Support Manager & Head of the projects and bids examination committee at Desalination Technologies Innovation &Research Institute(DTRI -SWCC) Eng.Mohammed graduated from King Saud University in 2016 with a bachelor's degree in chemical engineering and over 6 years of experience. He worked as a researcher in the Revers Osmosis department for three years before moving into administration as the head of the executive office department for procurement and finance. He is currently in charge of managing and directing the support services department for procurement, finance, human resources, information technology, and logistics, as well as the business development department, which is responsible for DTRI strategy, IP management, projects management, event and conference management, preparing MOUs, agreements & NDAs, KPIs, and business plans

Experts & Researchers biographies

Prof.Sangho Lee

Sangho Lee is a chemical and environmental engineer with a PhD from Seoul National University in Korea. He has been working on advanced water treatment and management since 1999 when he joined Northwestern University in United States. From 2003 to 2011, he was a senior researcher in Korea Institute of Construction Technology (KICT), Korea. He is currently a professor in Civil and Environmental Engineering in Kookmin University, Korea. His current interests are in smart technologies applied to environmental applications and urban water management, with a focus on smart water grid, seawater desalination, and environmental process simulation. He has devoted to practical implementation of emerging desalination technologies, including membrane distillation (MD), forward osmosis (FO), and pressure retarded osmosis (PRO). Since 2018, he has been leading a research group, "DREAMS", focusing on the development of engineering technology for novel desalination ships, which is funded by Korean government. He is also on the Editorial Boards of the Journal of Industrial and Engineering Chemistry, Environmental Engineering Research, and Water Supply.In DTRI, he has worked on process modeling and simulation for various desalination processes including brine concentrators, nanofiltration, membrane distillation, and the like.

Eng. Fritz Alt

He has been involved in the design, development and project execution of thermal desalination plants for more than 40 years and has been holding multiple patents in this field.While he has been working for more than 30 years as an independent engineer he has been also involved in energy saving projects for large industrial plants and in the renewable energy production While working with SWCC-DTRI for the past for years, he reduced the allocated energy consumption of the Ras Al Khair 720,000 m3/day MSF desalination plant by about 20% and introduced concepts for wind power generation with high capacity factors for regions with moderate wind power densities, which can contribute under the 2030 Vision in future reductions of CO2 emissions and in the replacement of fossil fuel power generation capacities.

Dr. Nausha Asrar

Over 30 years' work experience of material selection, applied research and resolution of industrial corrosion and material degradation problems, with 15 years of management and consultation services.
Provided quality services to multinational Oil & Gas companies, power & water desalination and steel industries.
Self-motivated to bring professional enhancement in the team of engineers. Excellent capability of leading innovation projects and technical departments/ laboratories.
Developed and taught courses on metallurgy, industrial corrosion, chemistry and failure management to engineers and technicians of industries and institutions.
Published and presented over 60 technical papers and review articles in international journals and conferences in the areas of materials development, failure management, industrial corrosion and composite materials.

Dr. Byungsung Park

He worked at DOOSAN Water Research & Development Center, Al Khobar as Director General for 3 years and worked in DOOSAN Heavy Industries and Construction, Korea as senior researcher for 11 years.
He is working at DTRI as senior desalination expert of pretreatment systems in SWRO desalination plant.
He specialized in the designs of Dissolved Air Flotation and Dual Media Filter with high loading rate.
He is focusing on the operation and maintenance improvements of SWRO plants to increase water production and cost savings.

Dr. Seungwon Ihm

Dr. Seungwon Ihm received his Ph.D. in Seoul National University, Korea, in Feb. 2009, majored in Mechanical and Aerospace Engineering. As a Senior Research Engineer in Doosan Water R&D Center (2008-2018), he led various R&D projects on Thermal Desalination (MED, MSF), Power-Water Cogeneration, and SWRO Pretreatment. Since joining to SWCC-DTRI in Oct. 2018, his research focuses on Ocean Brine Mining and ZLD (Zero Liquid Discharge) technologies based on membrane separation and brine concentration systems, such as NF (Nano-Filtration) and OARO (Osmotically Assisted Reverse Osmosis). In DTRI, he completed the optimization study of Combined Cycle Power Plant (CCPP) – Desalination (MED and SWRO), the overall mass and ion balances in the FEED (Front End Engineering Design) of the 2mil. tpa NaCl salt and 3,800 tpa production facility, and the Shoaiba NF-Magnesium project as a supervisor general.

Eng. Youngwook Yoo

He is working in a field of renewable energy, carbon footprint of industrial processes and carbon capture and utilization technologies in SWCC-DTRI. Before he joined in SWCC-DTRI, he had been actively involved in many projects as a process engineer, commissioning engineer and construction manager for 15 years in various countries. His former experiences were mostly related to process optimization between thermal power plant and desalination processes, and now he is keen to implement renewable energy sources to desalination plant.

Dr.Christopher Fellows

Dr.Christopher Fellows is a Senior Expert at the Desalination Technologies Research Institute (DTRI) of the Saline Water Conversion Corporation and an Adjunct Professor at the University of New England (Australia). Dr Fellows has a background in polymer chemistry and has numerous research interests in relating to processes occurring at surfaces and interfaces: the main focus of his work at DTRI is the development and testing of novel polymeric inhibitors for inorganic scale formation. However, he is involved in a broad range of current projects relating to physical , analytical, and organic chemistry as related to desalination processes.

Dr. Ghulam Mustafa

Dr. Mustafa worked at Bhabha Atomic Research Centre India as Senior Researcher for 9 years. Then he joined Research & Development Centre, SWCC in 1993 and worked for 9 years as Senior Process Engineer. Later he worked for UNESCO Membrane Science and Technology, CH2M Hill Australia, GE Water Australia as Lead Process Engineer and NJS Consultant Japan as Principal Process Engineer/ Project Manager on the design of wastewater treatment and desalination plants. At present, he is working with DTRI, SWCC as Senior Desalination Expert and focusing on the innovative process design for Brine Mining to extract Minerals and Salts from SWRO Brine and on the overall energy conservation and capacity augmentation in the existi ng SWCC RO desalination plants.Dr. Mustafa is specialized in the process design of commercial water treatment plants including seawater/brackish water desalination and municipal/ industrial wastewater treatment plants.

Dr. Sheng Li

Water expert in Desalination Technology Research Institute (DTRI) of Saline Water Conversion Corporation (SWCC).Dr. Li specialized in water management/ sanitary engineering, with more than 15 years' innovation research experience in membrane-based water treatment technologies (especially in membrane fouling control). Dr. Li received his PhD degree from Delft University of Technology in the Netherlands, and was an associate professor in Chinese Academy of Sciences before joining SWCC in 2021.

Dr. Christopher Paul

Dr.Christopher East received his Ph.D. from the Queensland University of Technology (QUT) in 2013, majoring in Chemistry. After his Ph.D. he worked as instrument scientist at the Central Research and Analytical Facility at QUT specializing in Electron Microscopy. Dr East has a background in polymer chemistry and inorganic fouling of surfaces. His main areas of work at DTRI are the development and testing of novel polymeric inhibitors for inorganic scale formation, analysis of hyper concentrated brines and laboratory instrumentation, research equipment and facilities.

Dr. Mohammed Al- Namazi

Mohammed received his BSc. in Physical Marine Science from King Abdul Aziz University (KAAU), and Ms. in Environmental Sciences from King Fahd University for Petroleum and Minerals (KFUPM) and Ph.D. in Environmental Sciences and Engineering at KAUST with a specialization in Desalination pretreatment at Water Desalination and Reuse Center, WDRC. Dr. Mohammed is working in desalination industry with more than 20 years' experience at Desalination Technologies, Innovation Research Institute, DTRI; the research arm of Saline Water Conversion Corporation (SWCC) locating in Jubail, Saudi Arabia. During these years, he involved in many research projects about the troubleshooting and challenges facing the desalination plants in the kingdom. His current research focuses on AOM concentrations in different seawater RO pretreatment techniques. He is a co-author of 2 patents and several papers on various desalination aspects published in peer-reviewed journals. Currently, He is a Director for Expertise Department at DTRI.

Dr. Ali Al-Hamzah

Research Advisor at DTRI.In 1997, I joined theDesalination Technologies Research Institute (DTRI), Saline Water Conversion Corporation (SWCC) in Al-Jubail City in Saudi Arabia.Areas of Interest:Synthesis, characterization and application of polymeric scale inhibitors. Water quality research. Water treatment for desalination process. Thermodynamics and kinetics studies.Disinfection and disinfection by-products researches.the Awards :The Custodian of the two Holy Mosques' Prize for Honoring Inventors and Talented, 2014.Gold medal in the field of Water in the Innovation Exhibition 2013, Riyadh, Kingdom of Saudi Arabia.Saudi Arabian Cultural Mission (in Australia) Award for Research Excellence, 2010.School of Science and Technology Certificate for Research Excellence, University of New England, Armidale, Australia, 2010.

Mr.Gaheishi Aldowis

He worked at SWCC Duba plant as a chemist for 4 years. He is working at DTRI as Laboratory Manager. Specialized in Laboratories supervision and has responsibility for complex laboratory procedures, interpretation, and application of water quality regulations, writing of comprehensive reports and documentation and maintaining the certification for the laboratory. Manage the operations, services, and activities of the Water Quality Laboratory, including the performance of a variety of chemical, microbiological, and physical tests on raw and treated water.

Eng. Hussain Al Mahji

Hussain Al Mahji More than 18 years of experience at SWCC. He holds a bachelor's degree in chemical engineering from King Saud University. Al-Mahji began his career at Jubail plant as a shift engineer, from 2005 to 2011. Also, he worked at the Desalination Technologies Research & Innovation Institute as head of the operations department from (2011 to 2016). From 2016 to the present, he has been working as the pilot plant manager

Eng. Ahmed Al-Ghamdi

Researcher in DTRI with 13 years' experience, He holds a s BEng degree in chemical Engineering and MSc in water desalination science from the king Saud University located at KSA. Worked in many projects in thermal water desalination and coupling with solar systems. Research Interests in Solar Energy include computational and Experimental Methods in Solar desalination coupling and economics. Participated in publishing so many papers in water and solar desalination.

Eng. Eslam Alwaznani

He has a bachelor's degree in mechanical engineering from King Abdulaziz University, Experience of more than 9 years at the Desalination Technologies, Innovation & Research Institute (DTRI) Worked as a Reverse Osmosis Engineer and Senior Reverse Osmosis Engineer, and then a Researcher and deputy manager in Reverse Osmosis department at the Research DTRI, worked on designing and improving of desalination systems include pretreatment, Reverse Osmosis (RO), Membrane Distillation (MD), Forward Osmosis (FO) and Energy Recovery Devices (ERD). Recently he involved in brine concentration and brine mining projects.

Dr. Fahad Alharthi

He obtained his Ph.D. degree the University of Manchester where he carried out advanced polymerization work. He is working at DTRI as research specialist, focusing on MOFs synthesis, biofouling, and graphene membranes. Dr. Alharthi is also interested in kinetics and thermodynamics studies of chemical reactions.

Dr. Maha Aljuhani

MIT research fellow, PhD in chemical science. Managing SWCC's office at KAUST for research collaboration.Dr. Aljuhani received her Master's degree from KAUST with two publications on atomically-precise metal nano-clusters synthesis under supervision of Prof. Osman Bakr. In 2019 she was awarded a PhD degree, with five publications in highly renown journals focused on catalyst by design using surface organometallic chemistry. Her PhD research was performed under the supervision of Prof Jean-Marie Basset. Dr. Aljuhani awarded a postdoctoral fellowship funded by (Aramco/KACST) 2020, her research at MIT in chemical engineering department is on mixed matrix membrane synthesis.

Mr.Troy N. Green

University of College Park, USA
BSc: Life Sciences Specialization (Synthetic Biology): Cell Molecular Biology and Genetics (CMBG)
Research Assistant: National Cancer Institutes, National Institutes of Health (NIH) Performed tumorigenicity studies and cancer determinations of surgically removed tissues from patientsusing molecular genetic techniques. Investigated cellular genetic mutations in cancer cells.Research Assistant: Institute of Biotechnology, University of Maryland Molecular genetic studies of nitrogen fixation genes in Vibrio cholera species to determine clinically derived infections- using molecular genetic techniques Biology/ Chemistry Teacher and Consultant (Minarat, Riyadh Schools [King Faisal Foundation]) Teacher of Biology and Chemistry and curriculum developer (wrote two scientific books)Sr. Researcher (Current) Saline Water Conversion Corporation (Co-authored and authored over 45 research papers and publications, participated in conferences(presenter, co-chair, and chairman), and active reviewer for scientific journals.

Eng. Faisal Abu Derman

He has 13 year's experience in SWCC. He hold a master degree in Mechanical engineering since from king Sauid University KSU also he Worked in Ras Alkhair plant as maintenance manager during 3 years. He working in so many projects in DTRI in thermal desalination plants coupling with solar system and RO plants. Also working with King Abdulaziz City For Science and Technology (KACST) to build the first world hybrid desalination plant in Rabigh city to, producing 5200 t/day potable water at 30°C and 750 kg/day of salt.

Eng. Basil Alrajhi

He has 11 yrs of experience in SWCC. He holds a BEng degree in chemical engineering from Heriot-Watt University in UK. He worked 6 yrs as a Shift Charge Engineer in Ras Alkhair plant (Combined cycle), in charge of Power side, Desal and RO operations. Also, worked in DTRI: team member of the Minster's initiative Projects enhancement of MSF units in Ras Alkhair plant in 2019, opportunity cost have been applied which resulted in annual saving of SAR 96 million and the local energy cost resulted in annual saving of SAR 13.6 million per year.Done so many evaluations of thermal anti-scalants projects.Now, his projects focused on Solar, Wind and Hydrogen Energy.He has 1 filed patent in desalination application and 1 published paper.

Eng. Ammar A. Alnumani

Ammar received his M.Sc. in Chemical Engineering from the University of Dayton, USA. BSc. in Chemical and Materials Engineering at King Abdul Aziz University (KAU), and Eng. Ammar joined Saline Water Conversion Corporation (SWCC) in June 2020, as a researcher at Desalination Technologies Research Institute (DTRI), the research arm of SWCC, located in Jubail City, Saudi Arabia. Since then, he involved in numerous research projects about troubleshooting and challenges facing the desalination plants in the kingdom. His current work focuses on evaluating newly developed technologies related to the Reverse Osmosis Process, SWRO plant optimization, and brine mining and related technologies.

Eng. Abdulrahman Alenazi

He has 7 years' experience in SWCC. He holds a BEng. Degree in chemical engineering from North Border University in ARAR. He worked so many projects in Corrosion and Materials performants, with material testing lab. Also, he presented a scientific paper at the corrosion conference in King Abdullah Cultural Center Jubail Industrial City 2022. He worked with King Fahd University on a collaborative project and have 1 patent in green corrosion inhibitors for desalination plant.

Eng. Amro Mahmoud

17+ years in the design, process development. MSF, MED & RO, design, operation and troubleshooting of desalination plants (RO, MSF, MED & Solar), thermal calculation, heat and mass balance process engineering and optimization, process modelling & simulation

Dr.Mohamed Ershath

He gets his Doctorate in field of Marine Biology and Ecology in Chennai, India. He specialized in Marine Biology & Ecology, Aquaculture, and Environmental Biology. He worked at the National University of Singapore, Singapore as a Research Assistant in Oceanographic Studies.He is working at EMB, DTRI as a Researcher of Marine Biology and Environment perspectives and focusing on the Environmental and ecology studies on Arabian Gulf and Red Sea. And, interested in the Conservation Program in the vicinity of Desalination and Power Plants Industry.

Eng. Abdulrahman Abutaleb

Engineer Abutaleb is a Researcher in SWRO department at Desalination Technologies Research Institute (DTRI) of the Saline Water Conversion Corporation (SWCC) closely involved in the development and implementation of innovative technologies for improvement of pretreatment and SWRO desalination plant operations. Eng. Abutaleb has M.Sc. Degree in Chemical Engineering from University of Dayton, Ohio, USA.

Eng. Abdullah Albiladi

Chemical Engineer, MASc. specialized membrane separation processes such as reverse osmosis (RO), nano-filtration (NF), membrane distillation (MD), pervaporation (PV)... etc. I am interested in desalination and water/wastewater treatment including various design and operational aspects as well as advanced research capabilities. In addition, I am interested in coupling renewable energy to desalination processes such as solar, wind, geothermal and sea waves energy. My mission is to cnotribute positively to ensure desalination and water treatment are more economical and environmentally friendly.desalination plant.

Ms.Layan A. Alkharboush

She holds a Bachelor's degree in Biological Science and currently pursuinga Master's in Microbiology and Biotechnology from the University of Bahrain. She joined DTRI-SWCC in April, 2021 as a Microbiology Researcher with the Environment and Marine Biology Department (EMB). She specializes in Marine Microbiology, Biotechnology and Environmental Science with focus on the Biological Fouling and Environmental related projects of Desalination and Power Plant.

Eng. Fatima AlRadhi

She holds a Bachelor's Degree of Science in Chemical Engineering from Kuwait University. She began her journey in earning Master's Degree of Science in Chemical Engineering since January, 2023 from King Fahad University of Petroleum & Minerals. She joined DTRI-SWCC since March, 2021. She is working at Materials and Corrosion department as a Chemistry Researcher and gained an experience in Lab Analysis, Metallurgical Studies and Failure Investigation. She is working on research projects to improve productivity and eliminate overall costs

Business Development Team

Mr.Ahmad Husain Daghas

Over 26 years work experience of strategic planning, goal management, performance indicators and monitoring. He is leading & managing agreements (MoU, NDA & Collaboration), Intellectual property and of Enterprise Project Management Office-EPMO.
He is working as Planning and Business Development Manager in DTRI.Intellectual property, PM.

Mr. Salem Al-Qahtani

Mr. Al-Qahtani holds master degree in marketing from Queensland University of Technology in Australia and bachelor's Degree of media (PR & Journalism) from Imam Mohammad Bin Saud University in Riyadh. He has more than 11 years' experience at SWCC – DTRI as communication Head at business development dept. His experience focused on high organized communication and event planning to generate awareness of the DTRI brand and having a high ability to manage any events. Also, he has experience in marketing, event management, quality, and project management as well. He organized tow international conferences and many workshops locally & internationally.

Eng.Omar Alraqibah

his M.Sc in Engineering Management from King Fahd University of Petroleum and Minerals (KFUPM). BCs in Mechanical Engineering from Jubail University College (JUC). he has joined DTRI in 2018. He works in the Business Support department with experience in project management, procurement, planning, and key performance indicators (KPIs).

Ms.Amal Alzeqedi

Project management officer and Experts affairs specialist in DTRI major of management information system Engineering Over 7 Years of experience in Business development (Project management ,Markiting and Human Resources)

Ms.Mona AL Nasser

A certified AS9100 auditor with four years of experience in the business development department as a quality researcher and organization performance analyst. Expert at providing quality assurance. Applying ISO 9001 and 17025 with proficiency.balancing training advances with the management of the HR needs assessment Design and update policies and procedures for many types of agreements (MoU.NDA& Consultant).

المؤسسة العامة لتحلية المياه المالحة
Saline Water Conversion Corporation (SWCC)

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