Under the Patronage of His Excellency **Eng. Abdulrahman bin Abdulmohsen AlFadley**
Minister of Environment, Water & Agriculture

منتدى المياه السعودي
saudi water forum SWF 2024

# Current Status of K-water's Seawater Desalination

Dr. Jihye Kim (K-water, Korea)

29 April – 01 May 2024

Hilton Riyadh Hotel & Residences
Riyadh, Saudi Arabia

Organized by

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Ministry of Environment Water & Agriculture

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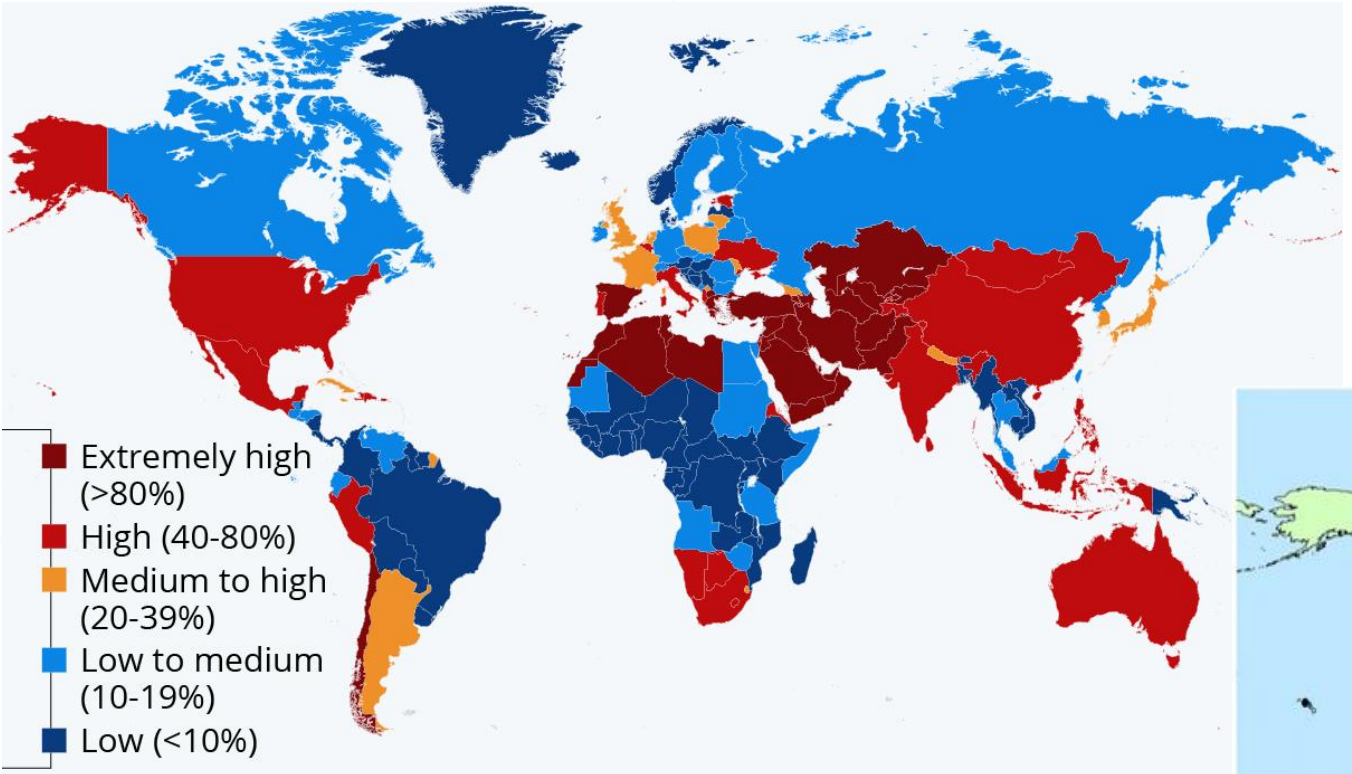
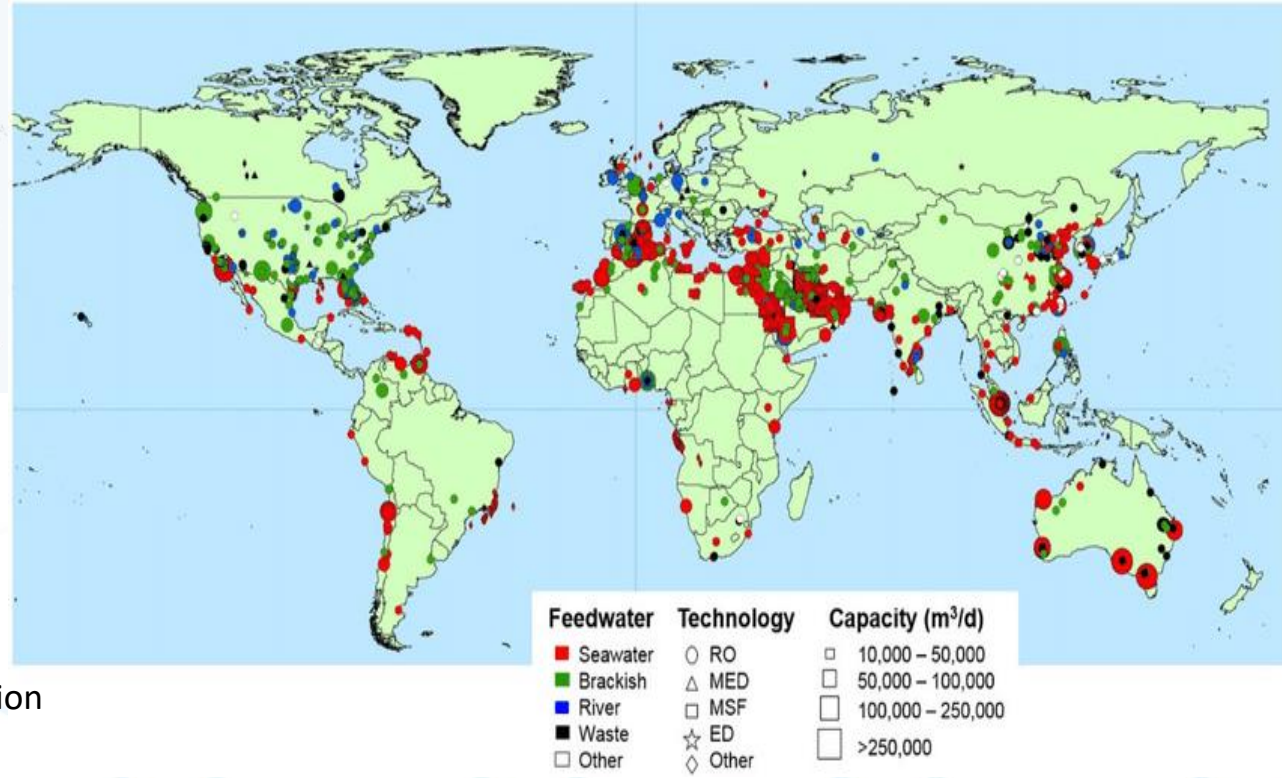
# Global Water Stress



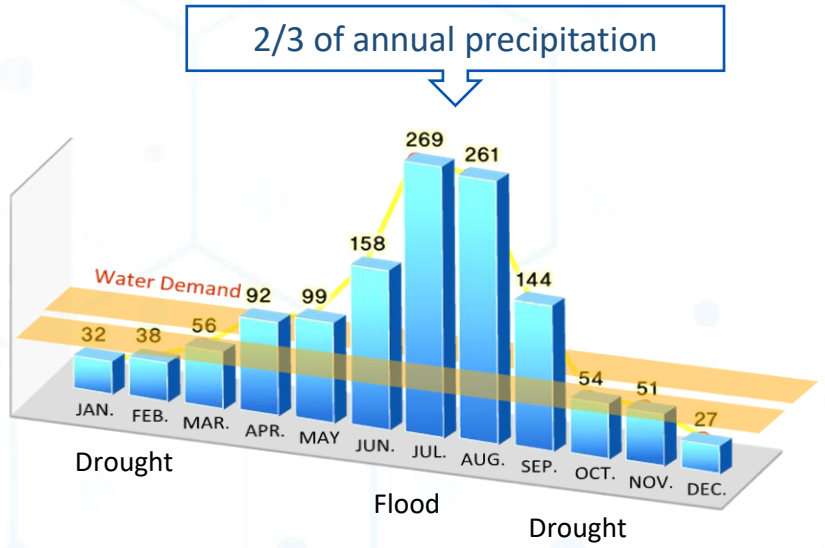

Source: World Resources Institute
via The Economist Intelligence Unit




Source: A Review of the Water Desalination
Technologies, Applied Sciences (2021)

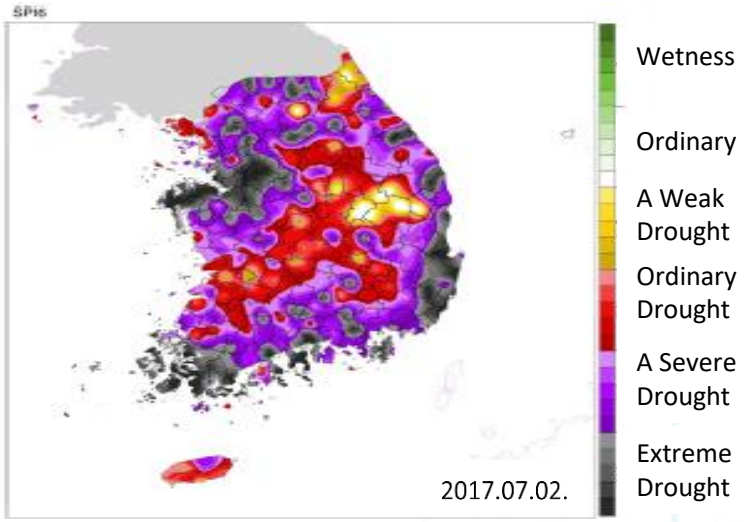
# Water Management Condition of Korea

## Challenges in Water Management




- Precipitation is not balanced across seasons

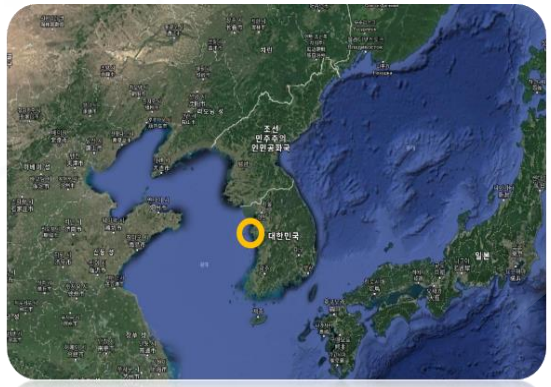
### Recurring flooding & droughts

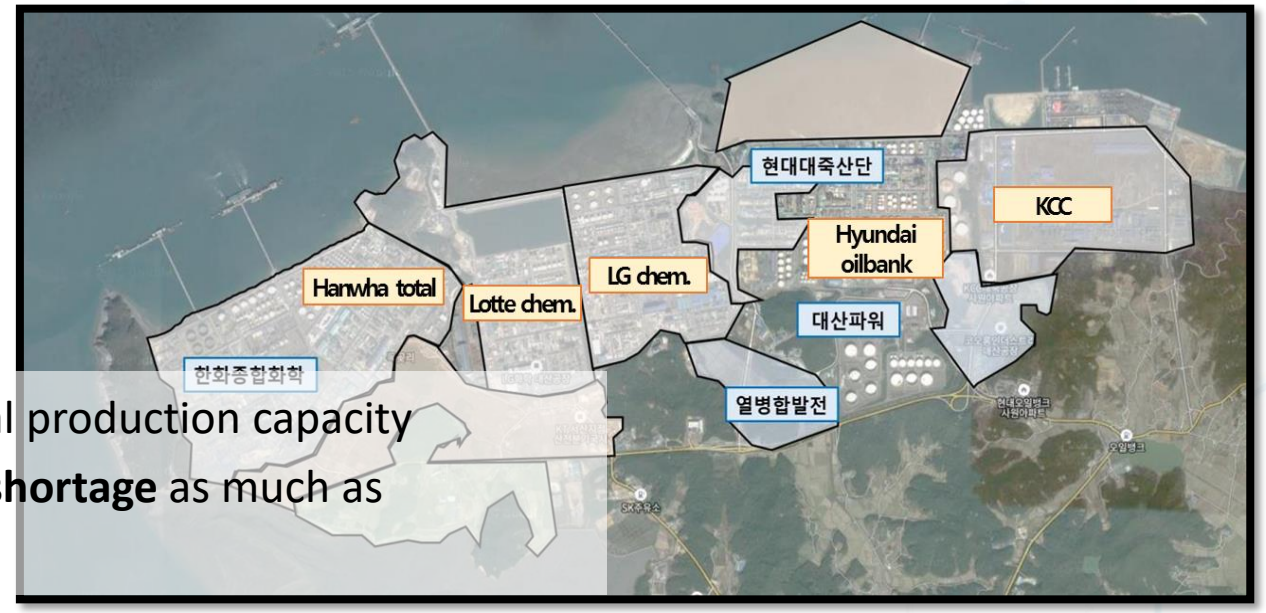



- High max/min discharge rate
- High flooding risk index
  (Korea 6.85, UK 0.23)
- The worst drought in 124 years (Chungnam, ’15)

# Overview of Daesan Industrial Complex

## Daesan Industrial Complex






- Korea's 2nd largest petrochemical production capacity
- Estimated to experience **water shortage** as much as **100,000m³/d in 2026**

**Daesan 5 Major Companies**

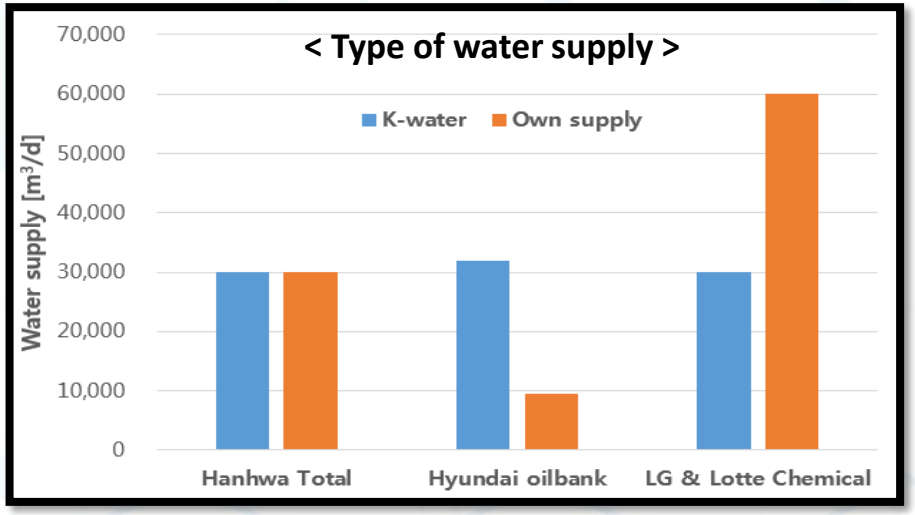
| Company | Product |
|---|---|
| **Hyundai Oil Bank** | Gasoline, Petroleum, Kerosene, Lubricant, Naphtha |
| **Hanwha Total** | Ethylene, Propylene, SM/EO/EG, HDPE/PP etc. |
| **Lotte Chemical** | Poly-ethylene, Poly-propylene/EO, EG/SM etc. |
| **LG Chemical** | Ethylene, Propylene, Synthetic rubber, SM/EG/PP/PE/PVC etc. |
| **KCC** | Gypsum board, Silicon |

# Current Water Supply for Daesan Complex

## (Current Water Supply) ❶ K-water's Daesan BWRO plant

- **Demanders** : Hyundai Oil Bank, KCC, Hanhwa Total, Lotte Chemicals, LG Chemicals
- **Facility Capacity** : Industrial Water 119,000m³/day(RO), Wastewater 11,000m³/day
- **Business Period** : 2012.8 ~ 2037.8 (25yr)
- **Water Processing Procedure :** MF, RO

## (Current Water Supply) ❷ Company's Own BWRO plant




# Overview of Daesan SWRO Project

## Insufficient Lake Water Capacity

- **Repeated drought and factory expansion** cause weak supply stability of existing freshwater resources.


## Overview of K-water's Daesan Seawater Desalination Plant

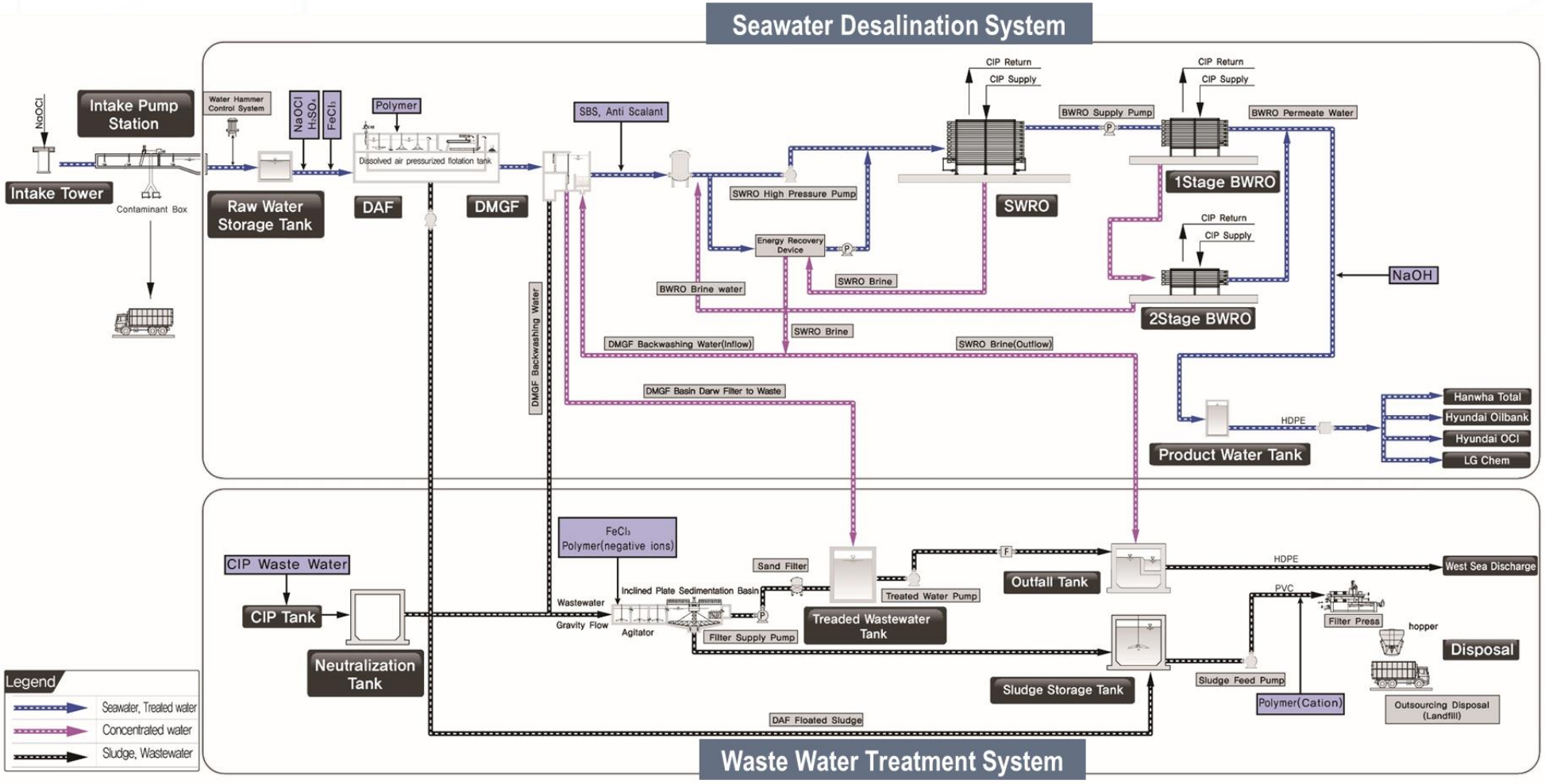
- **Supply Capacity :** 100,000 $m^3/d$
- **Required Permeate Water Quality**

| $Cl^-$ (mg/L) | Conductivity(us/cm) | TDS(mg/L) | Total hardness(mg/L) | pH |
|---|---|---|---|---|
| **20 ↓** | 150 ↓ | 65 ↓ | 2.5 ↓ | 6.5~7.5 |

- **Successful Bidder :** GS E&C
  - Operation Cost : \$0.5/$m^3$
- **Time Schedule**
  - '22.05 : Contract & commencement of main construction
  - '25.03 : Commissioning & performance test
  - '25.06 : Completion & water supply

# Overview of Daesan SWRO Project

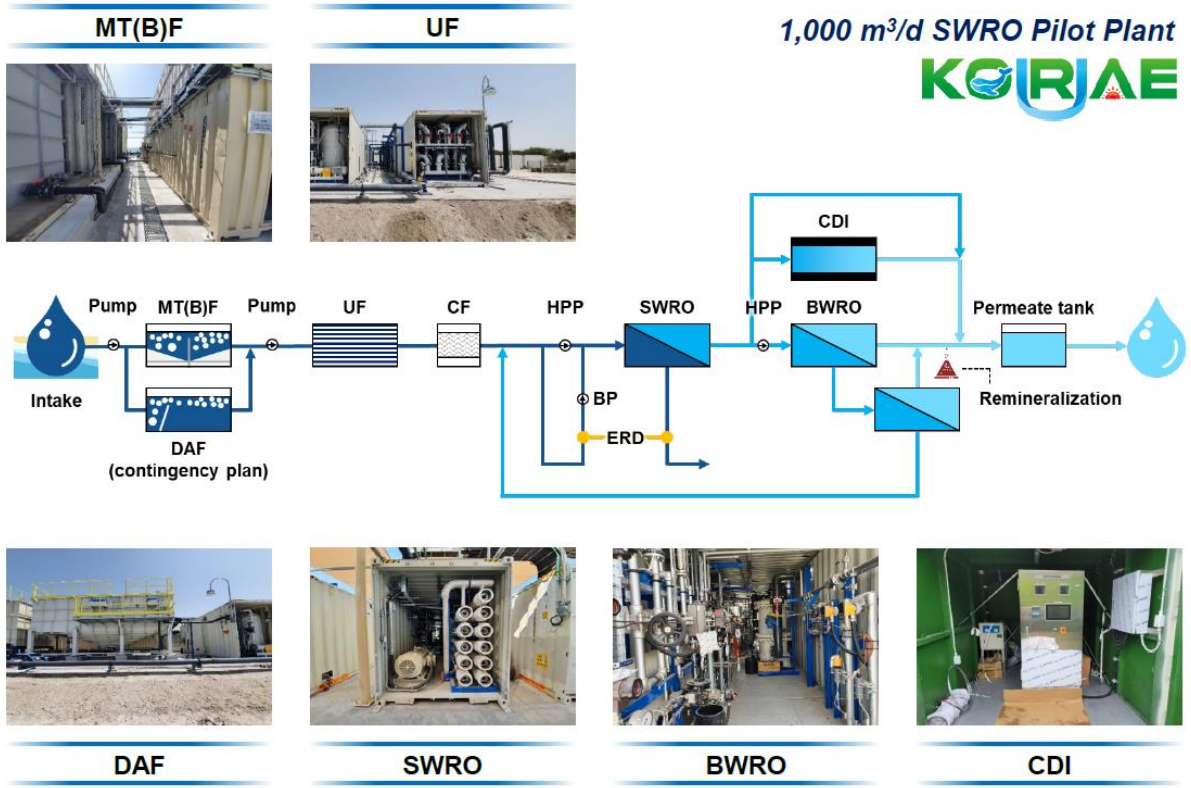
## Process Flow Diagram



# K-water's Research Outcomes('~22)

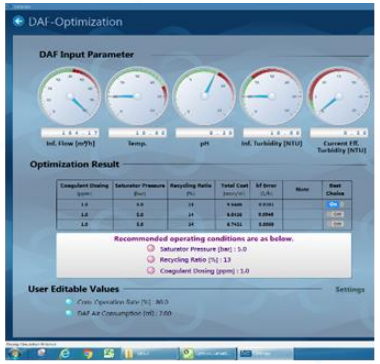
## Operation Experience of 1,000 m³/d Pilot Plant in UAE

- **Commission & Operation :** May '22 ~ December, '22
- **Performance evaluation** with Masdar(UAE counterpart)
- **Parameter validation** of **K-water's operation optimization program**



# K-water's Research Outcomes('~22)

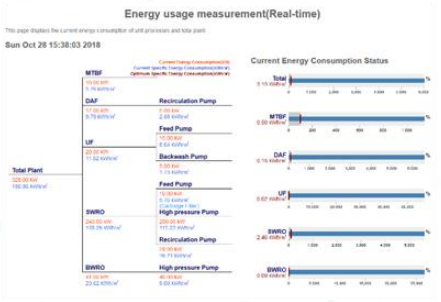
## Development of Plant Operation Optimization Program



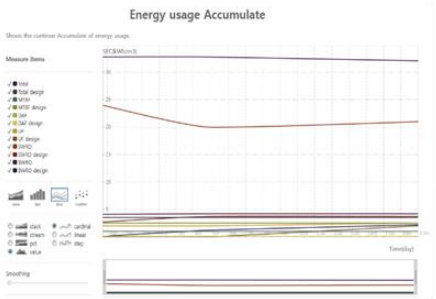

**DAF optimization**
: Suggestion of optimal operation condition


**UF optimization**
: Estimation of CIP timing based on operation data

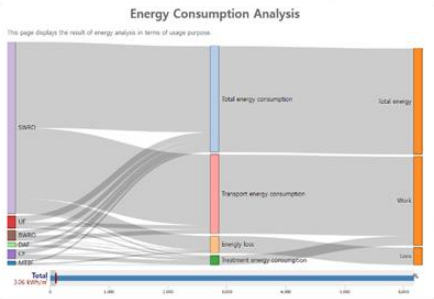

**RO optimization**
: Model-based suggestion of CIP timing




**Real-time monitoring of energy consumption**




**Time-series monitoring of energy consumption**




**Analysis of energy consumption**

Source: S/W# C-2019-016095

# K-water's Research Outcomes('~22)

## DAF Operation Optimization

**DAF optimization**
Suggestion of optimal

**Input**

Influent turbidity($x_i$), flow rate($Q_i$), temperature(T), Target effluent turbidity($x_o$),

**Setting**

DAF tank size, pump efficiency, Compressor power, Daily air generation of compressor, Daily DAF air consumption, power cost, Coagulant dosing range, Saturator pressure range, Recycle ratio range

1) Mathematical eqn. for solid removal

$$k_{f1} = \frac{Q(1+\frac{R}{100})}{V}\left[\frac{X_i}{X_o} - 1\right]$$

2) Empirical eqn. from experimental data

$$k_{f2} = a + b * T + c * X_i + d * C_i + e * S_p + f * R_r$$

Calculation of error between $k_{f1}$ & $k_{f2}$

Pick the lowest error data set

Calculation of chemical and energy costs

Pick the lowest cost data set

**Suggestion of optimal operation conditions**
**: coagulant dosing, saturator pressure, recycling ratio**

- **Function**
  : To determine the optimal DAF operation conditions according to the change of raw water conditions
- **Principle**
  : To minimize the error between the 'floc floatation constant' values from two different equations and energy costs

# K-water's Research Outcomes('~22)

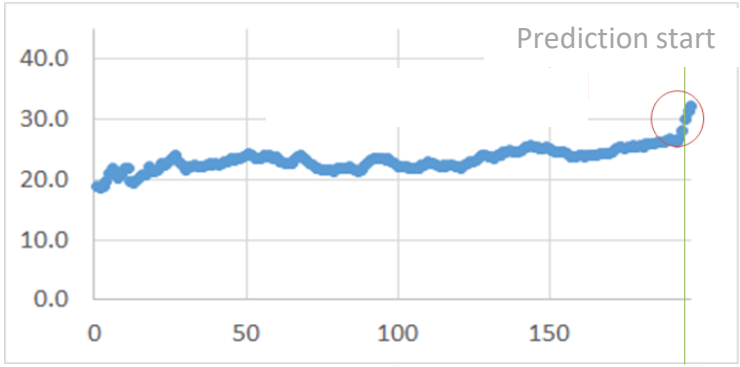
## Prediction of CIP Timing in UF

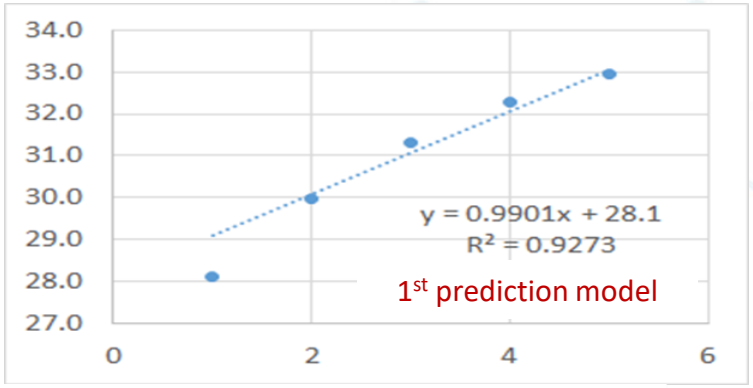
**UF optimization**
: Estimation of CIP timing based on operation data

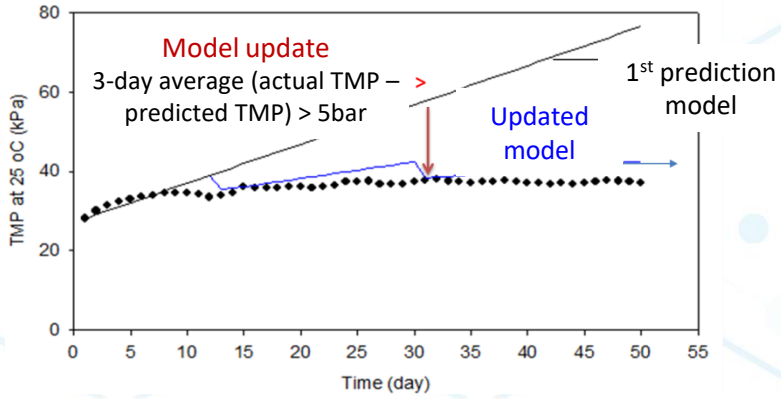
- **Function**
  : To determine the optimal CIP timing by data-based TMP prediction
- **Principle**
  - Use of temperature & flowrate corrected TMP data(moving average applied)
  - Start TMP prediction if either condition is satisfied by using the latest 5-days data

| Condition 1 | Condition 2 |
|---|---|
| Average TMP of 2 days > 10 kPa | Accumulation of TMP difference > 14 kPa<br>+<br>Constant increase of TMP over 5 days<br>+<br>Average of accumulation of TMP difference > 1.1 kPa |

- Compare the prediction and real TMP values and update the fitting equation if required



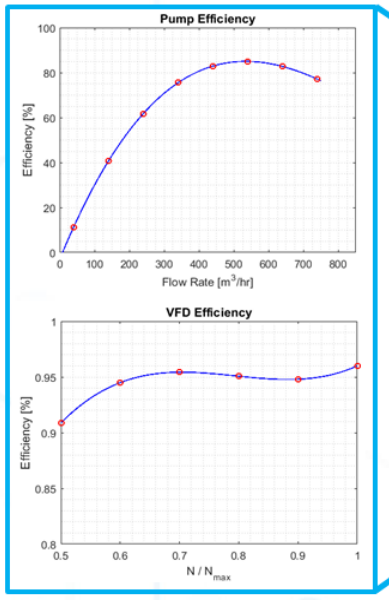
# K-water's Research Outcomes('~22)

## Model-based Prediction of RO CIP Timing

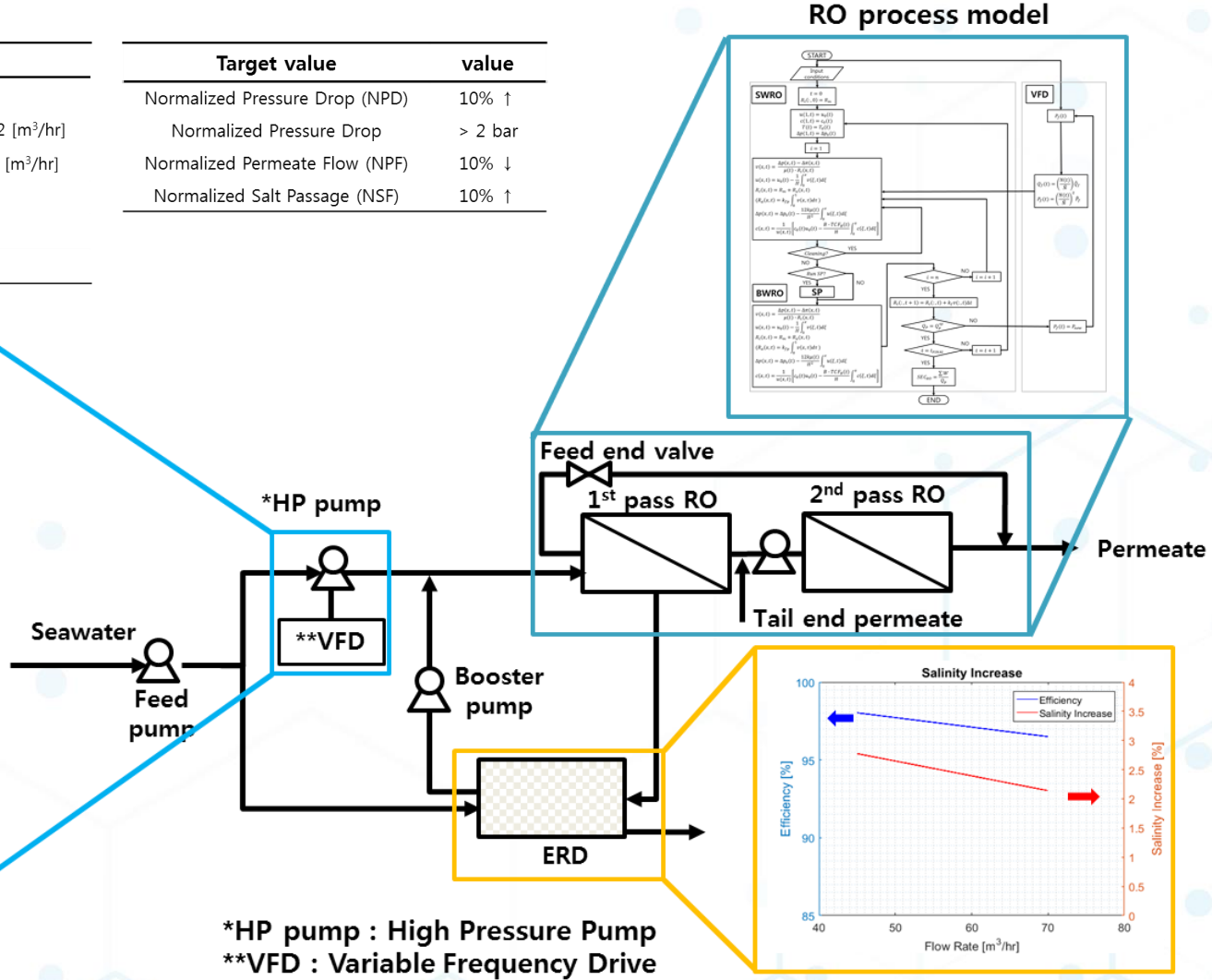
**RO optimization**
: Model-based suggestion of CIP timing

| Parameter | Value | |
|---|---|---|
| Temperature [°C] | 25 | |
| Feed flow rate [$m^3$/day] | 25,000 | 1,042 [$m^3$/hr] |
| Permeate flow rate [$m^3$/day] | 10,000 | 416 [$m^3$/hr] |
| Feed concentration [mg/L] | 32,000 | |
| Pressure Vessel [ea] | 91 | |
| ERD [ea] | 10 | |

| Target value | value |
|---|---|
| Normalized Pressure Drop (NPD) | 10% ↑ |
| Normalized Pressure Drop | > 2 bar |
| Normalized Permeate Flow (NPF) | 10% ↓ |
| Normalized Salt Passage (NSF) | 10% ↑ |




Efficiency variation of pump and VFD based on the feed water condition




*HP pump : High Pressure Pump
**VFD : Variable Frequency Drive

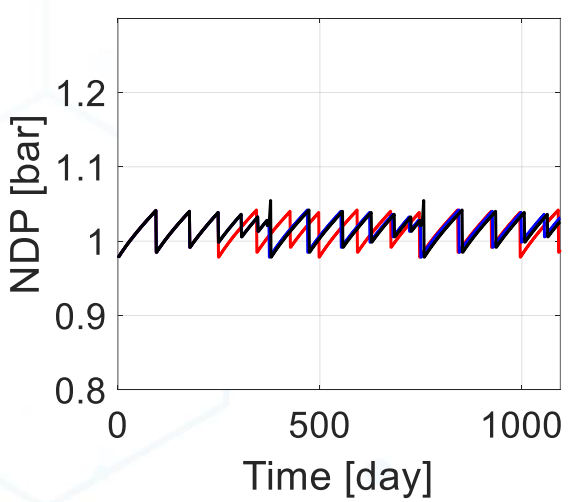


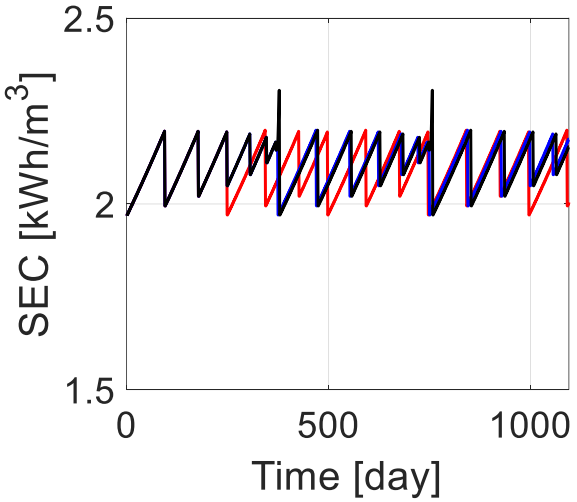

ERD efficiency variation and mixing ratio

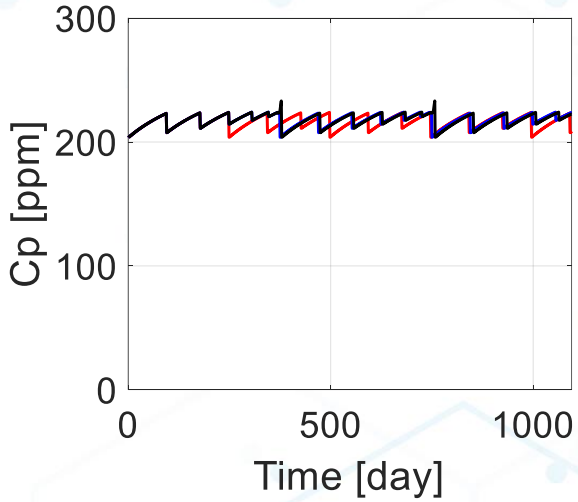
# K-water's Research Outcomes('~22)

## Model-based Prediction of RO CIP Timing

**RO optimization**
: Model-based suggestion of CIP timing



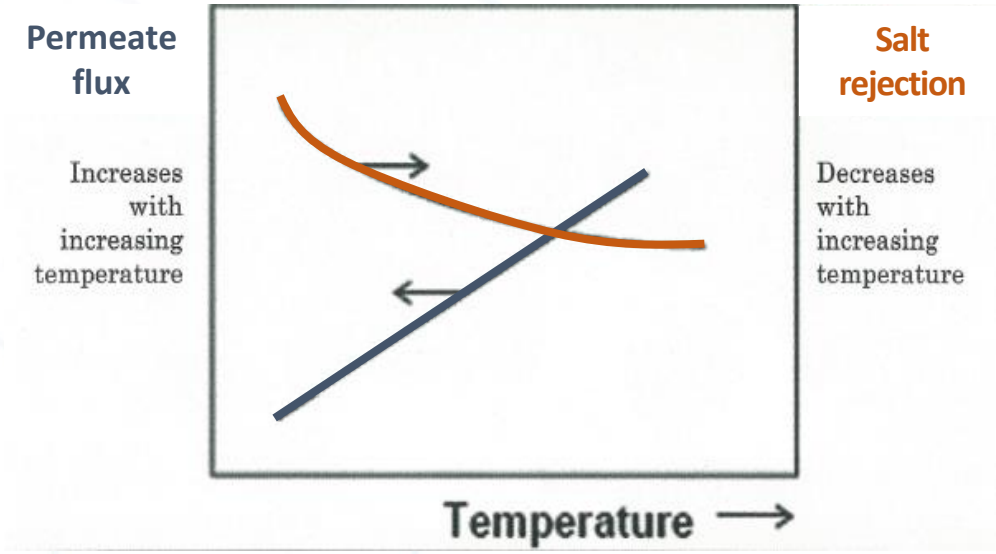




| Contents \ Cost Item | | Annual Cost [KRW] | | | |
|---|---|---|---|---|---|
| | | Energy | Cleaning | Replacement of membranes | Total |
| **CASE 1** | [USD/yr] | 747,114.5 | 1,082,629.2 | 509,600 | 2,339,343.8 |
| | **[USD/m³]** | **0.209** | **0.303** | **0.143** | **0.654** |
| **CASE 5** | [USD/yr] | 747,724,334 | 1,924,674,267 | 245,800,000 | 2,927,198,601 |
| | **[USD/m³]** | **0.21** | **0.541** | **0.072** | **0.822** |
| **CASE 9** | [USD/yr] | 742,002,101 | 2,887,011,400 | 254,800,000 | 3,883,813,501 |
| | **[USD/m³]** | **0.21** | **0.818** | **0.072** | **1.099** |

# K-water's On-going Research

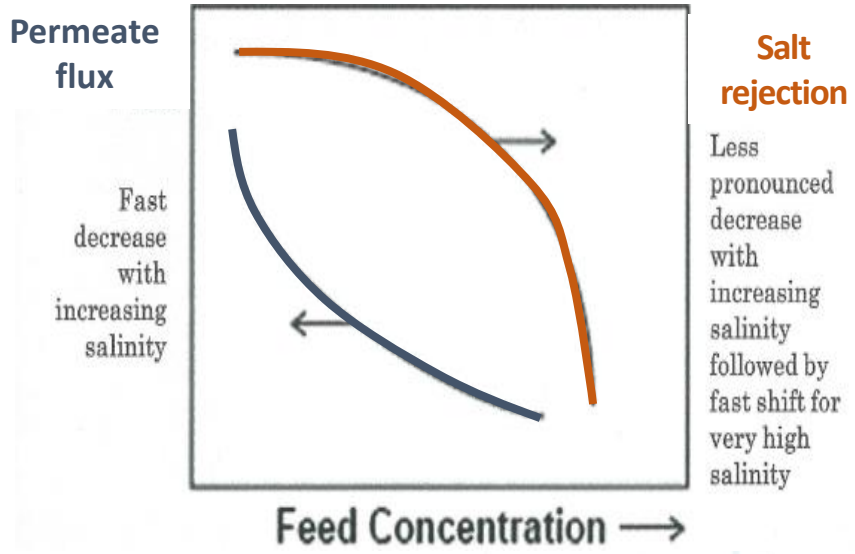
## Critical Parameters for RO Performance

- **Temperature**




- Higher energy at low temperature for constant water production
- Temperature 14 ℃ → 20 ℃
  : Energy saving 0.05 kWh/m³

- **Feed Concentration**

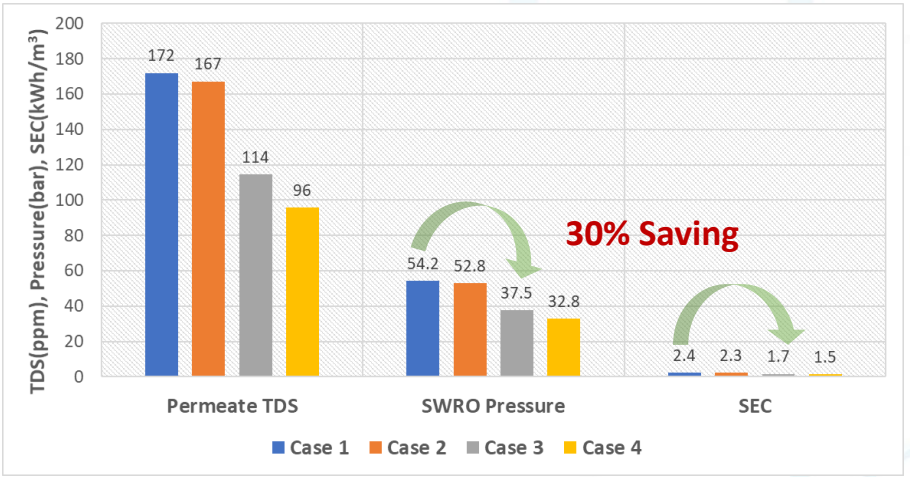


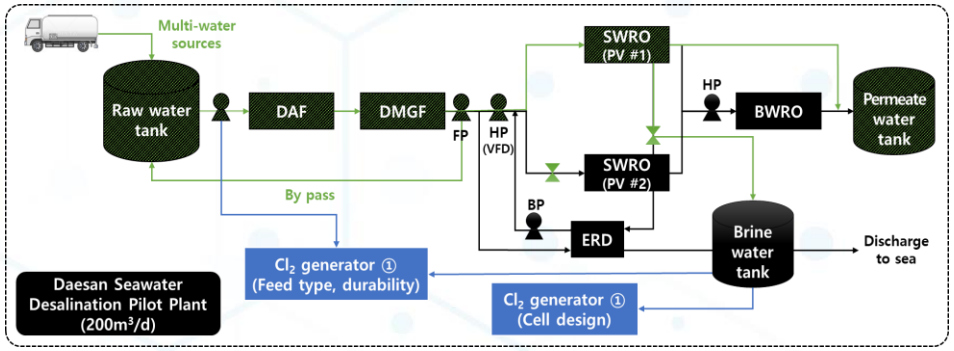

- Higher energy at high feed conc. for constant water production
- TDS 31,000 ppm → 28,000 ppm
  : Energy saving 0.18 kWh/m³

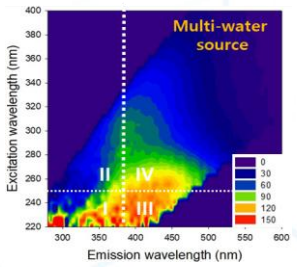
# [Ongoing] Blending of Multiple Water Sources

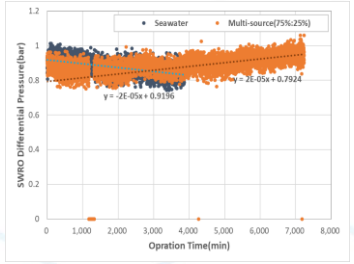
## Performance Analysis : Simulation & Experimental Approach

- **Performance simulation of 200m³/d Daesan SWRO pilot plant**
  - Case 1 : Seawater 100%
  - Case 2 : Seawater 96%, Wastewater 4%
  - Case 3 : Seawater 50%, Wastewater 50%
  - Case 4 : Seawater 50%, Lake water 10%, Wastewater 20%, Sedimented water 20%



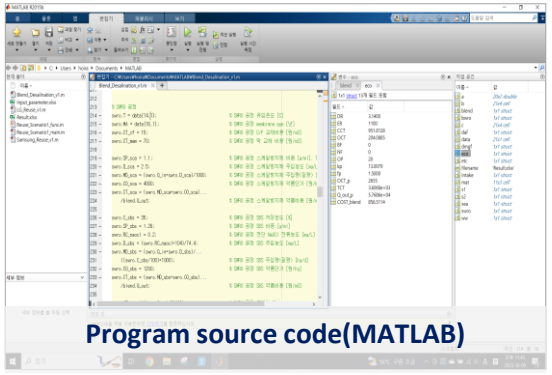




- **Long-term operation based performance analysis of 200m³/d Daesan SWRO pilot plant to evaluate energy-saving effect and membrane fouling tendency**
  - Sources: Seawater, Wastewater(BWRO brine)
  - Variable: blending ratio

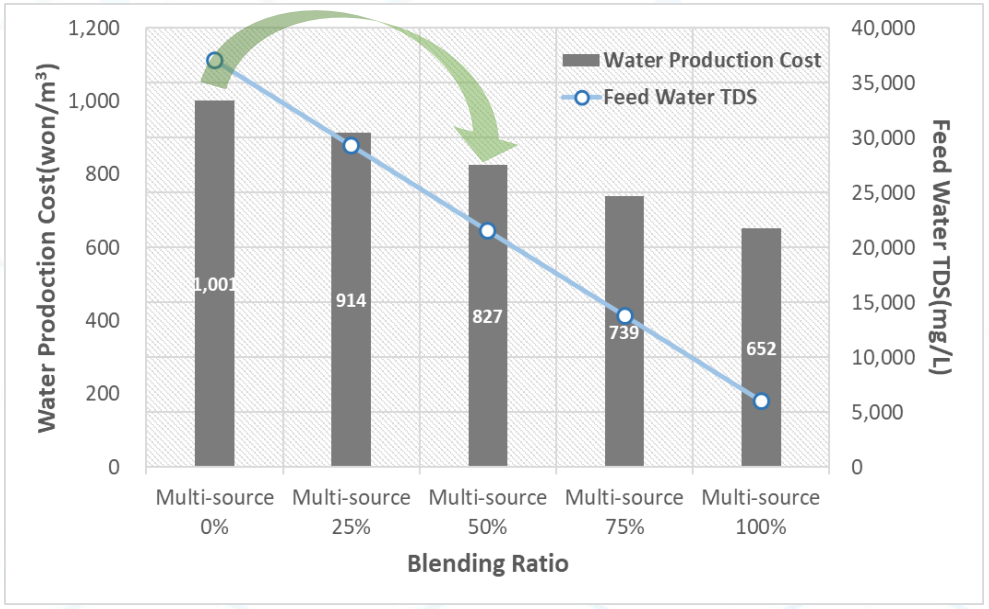
# [Ongoing] Blending of Multiple Water Sources

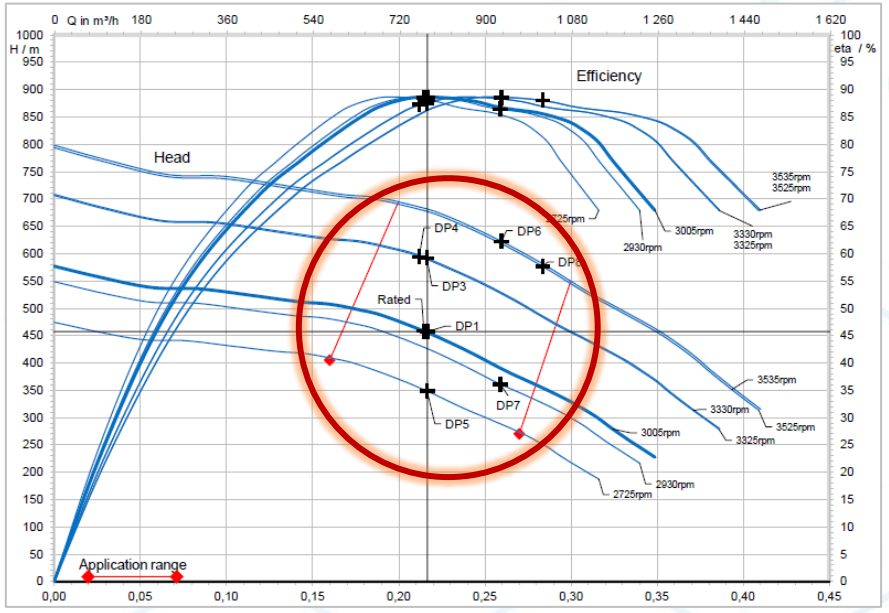
## Application : Feasibility Analysis S/W and Operation Guideline

- **(S/W) Analyze the performance and feasibility of multi-water source SWRO desalination plant**
  - Feed water quality, membrane characteristic, etc.
- **(Guideline/Manual) Suggestion of optimal operation condition when utilizing the multi-water sources**
  - High-pressure pump spec.(35~68bar)



Program source code(MATLAB)



# [Ongoing] NaOCl Generation from SWRO brine

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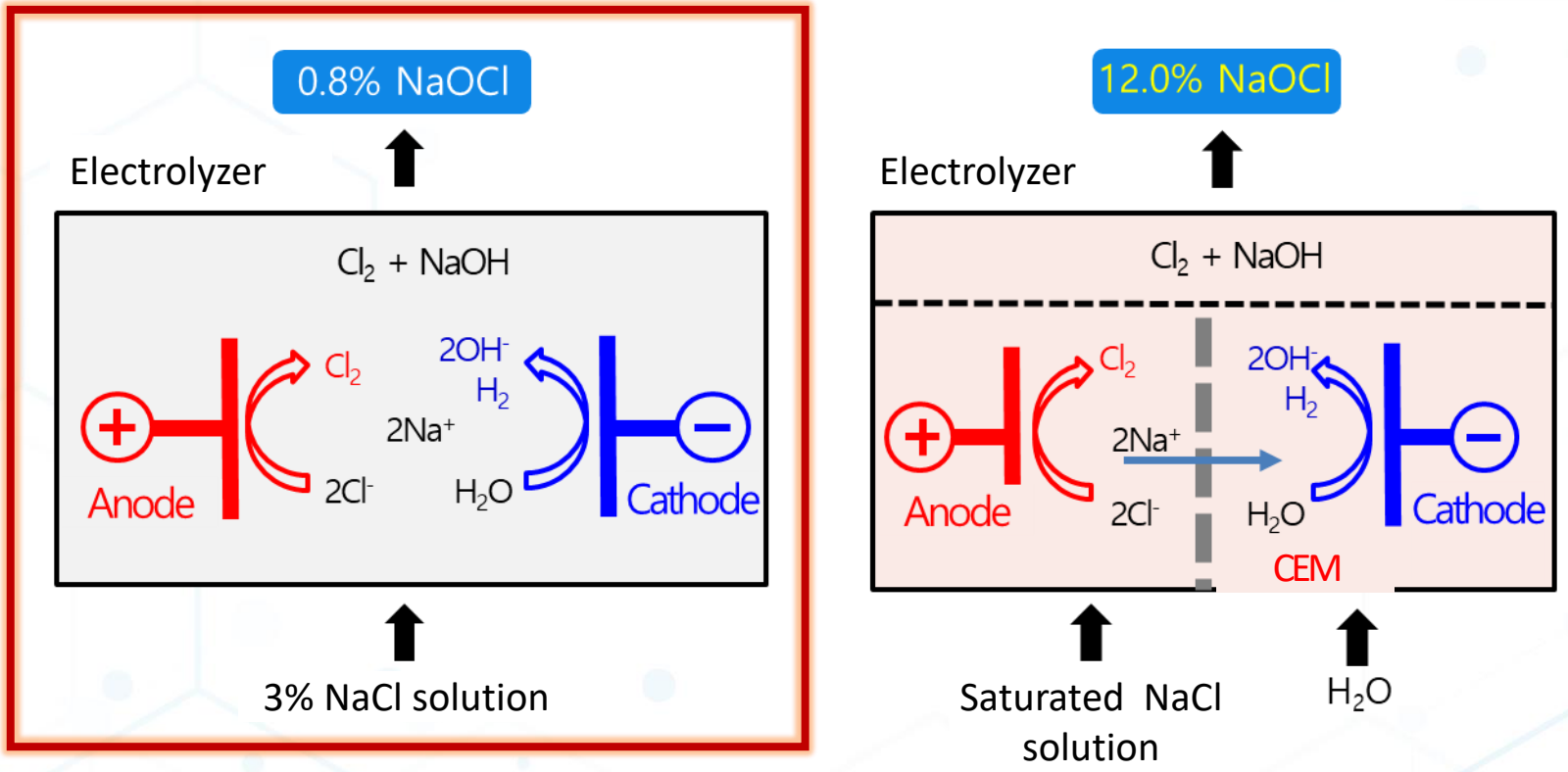
saudi water forum SWF 2024

Techwin 테크윈

## High & Low Sodium Hypochlorite Generation




■ **Electro-chemical reaction**

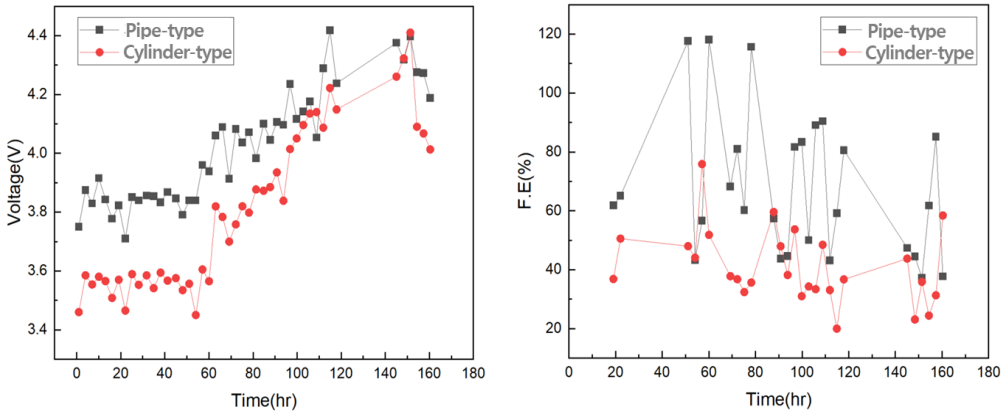
Anode $2Cl^- \rightarrow Cl_2 + 2e^-$

Cathode $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

# [Ongoing] NaOCl Generation from SWRO brine

## Performance Evaluation of Electrolyzer using brine

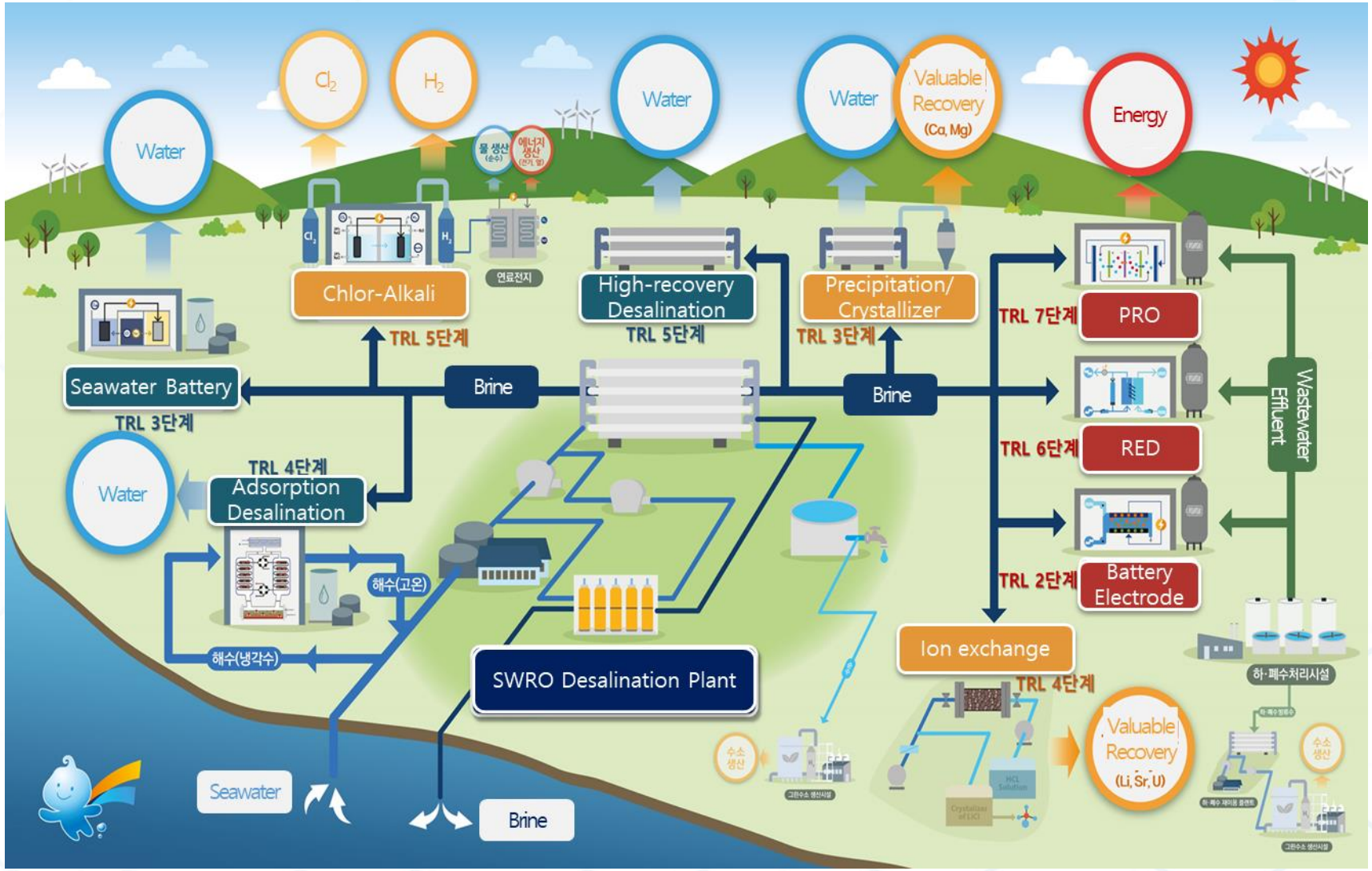
- **(Electrolyzer Type) Performance(Voltage increase, Efficiency difference) comparison of pipe type and cylinder type**
  - Voltage increase due to scale accumulation
  - Lower initial voltage observed in cylinder type
  - Average F.E.: Pipe(67.5%) and Cylinder(40.8%)

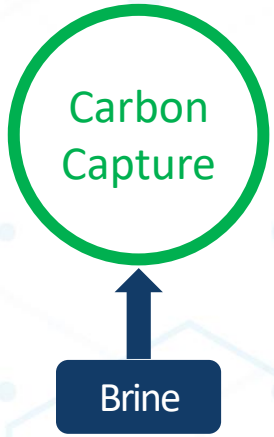



- **(Duration) Long-term operation test to compare the electrode duration when utilizing seawater or SWRO brine**
  - 3.9 times accelerating duration test

# Concluding Remarks

## Some ideas for Sustainable Future with Seawater Desalination




- Direct Air Capture(DAC)
- Carbon Mineralization
- ETC.

Under the Patronage of His Excellency **Eng. Abdulrahman bin Abdulmohsen AlFadley**
Minister of Environment, Water & Agriculture

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# THANK YOU!

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