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Water Arabia

SUCCESSFUL LONG-TERM OPERATION RESULTS OF SEAWATER RO PLANT BY USING HOLLOW FIBER TYPE CTA-RO MEMBRANE MODULES

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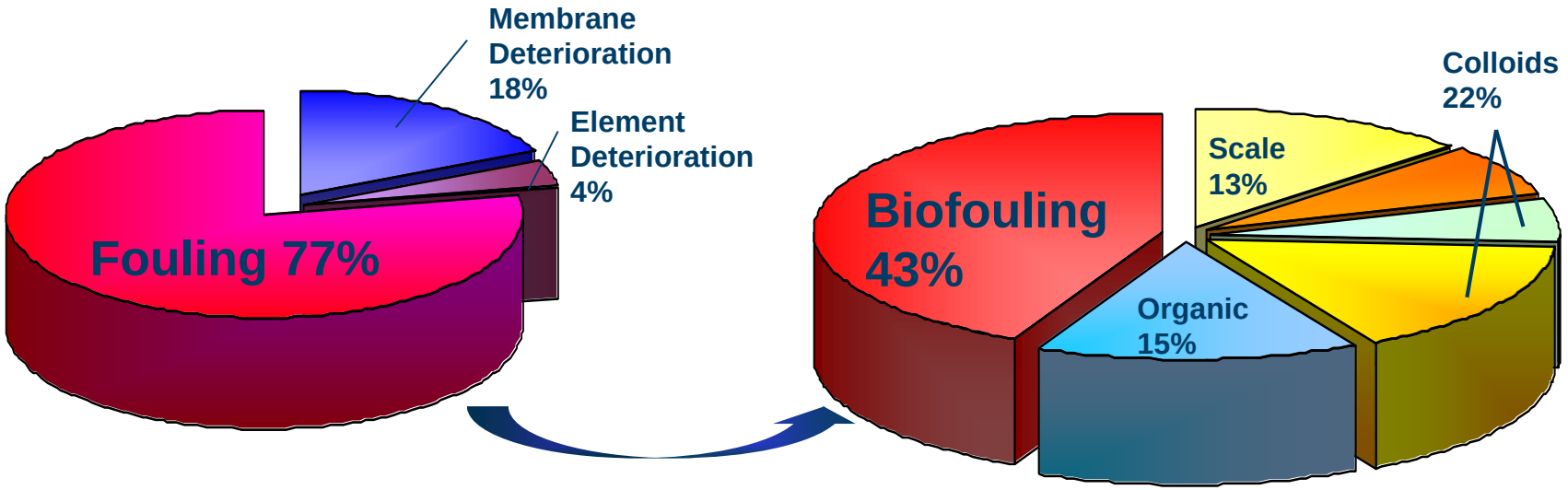
Background

Serious water-shortage

Demand for desalinated water is increasing.

Seawater RO membrane desalination plants

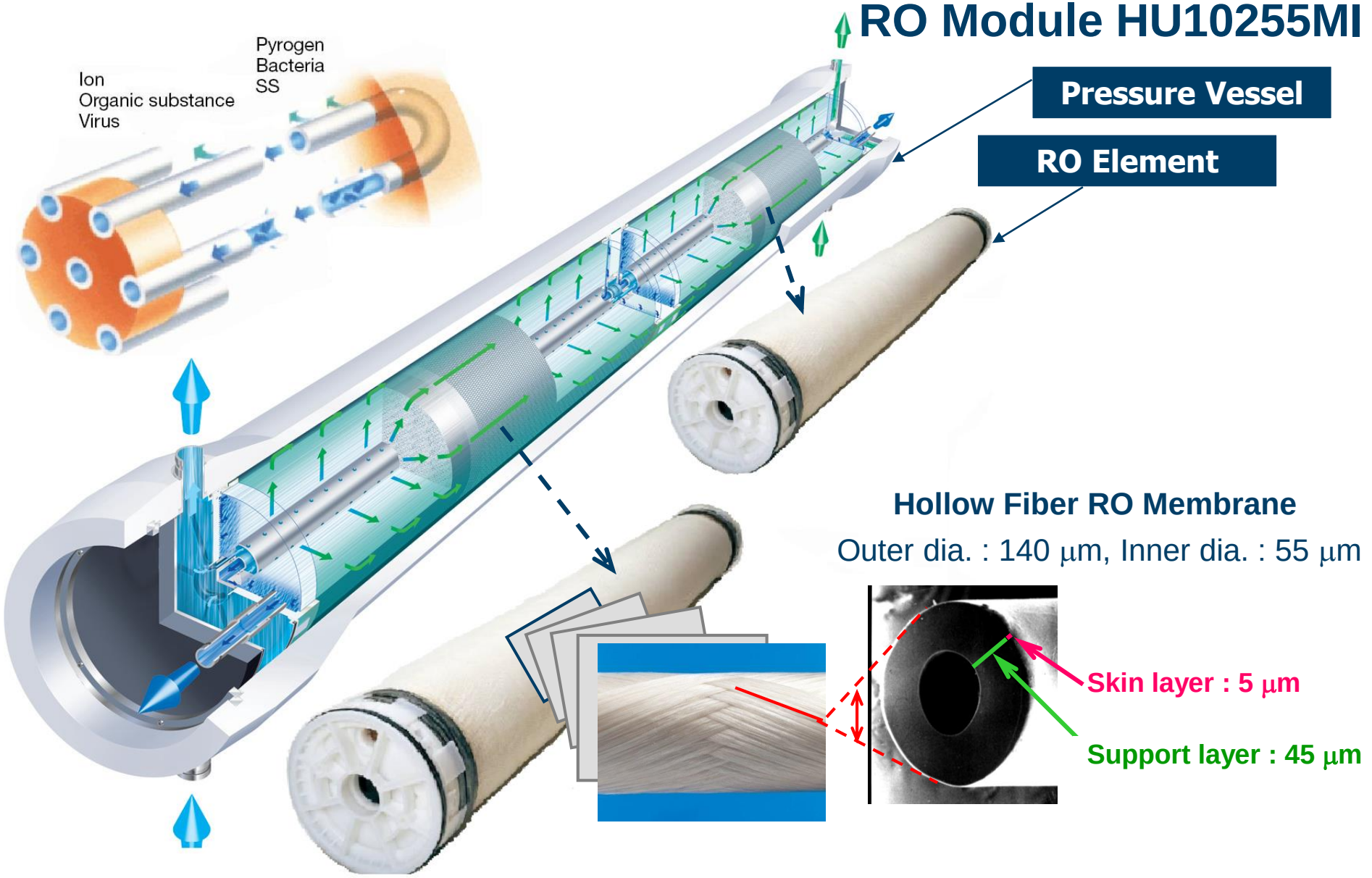
- **Advantage: Saving energy**
- **Problem: Fouling (biological fouling)**



Khedr, Desalination & Water Reuse, 10/3 (2000) 8-17

Features of CTA Hollow-Fiber RO Module

RO Module HU10255MI

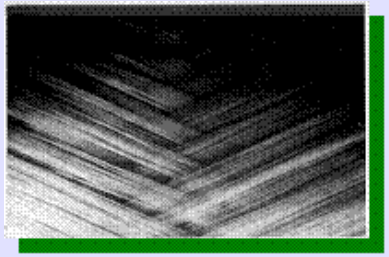


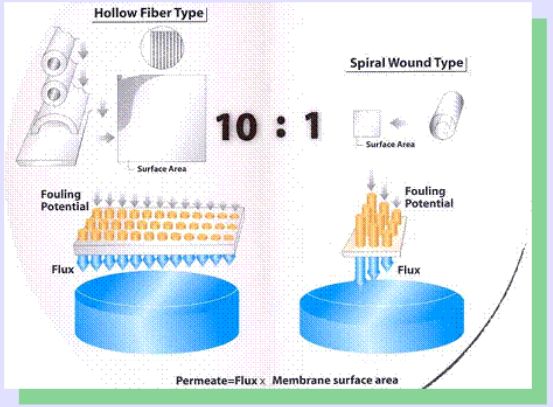
Hollow Fiber RO Membrane

Outer dia. : 140 μm, Inner dia. : 55 μm

Features of CTA Hollow-Fiber RO Module

Structural Advantage	
Cross winding arrangement	Cross winding arrangement of hollow fiber bundles can minimize pressure loss and uniform water flow. Space between hollow fibers is remarkably large, so fouling matter can pass through very easily
Large membrane surface area	Millions of hollow-fibers are wound into element configuration. Compared to spiral wound membrane element, hollow-fiber membrane element has about 10 times larger surface area. Much larger surface area allows much less surface fouling.





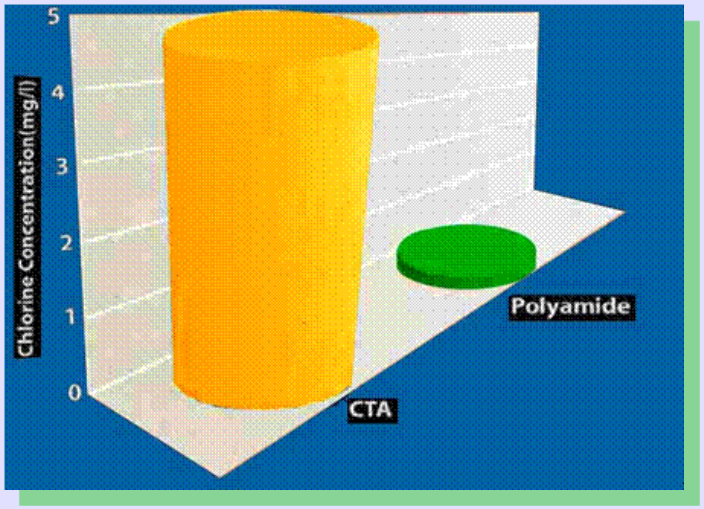
Features of CTA Hollow-Fiber RO Module

Material Advantage

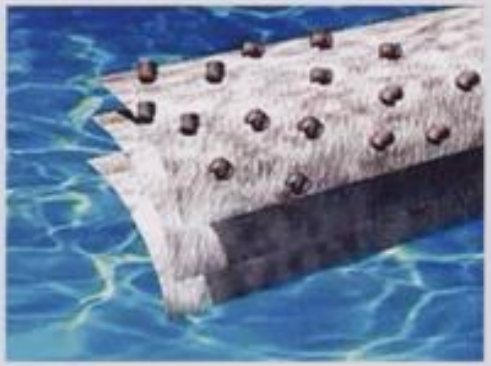
“Control biological fouling with chlorine disinfectant”

Hollow-fiber RO membrane made from CTA has a superior chlorine tolerance compared to Polyamide membranes, and it enables direct injection of chlorine disinfectant to RO modules.

The disinfection operation mode can also be optimized by continuous chlorine injection (CCI) or intermittent chlorine injection (ICI).



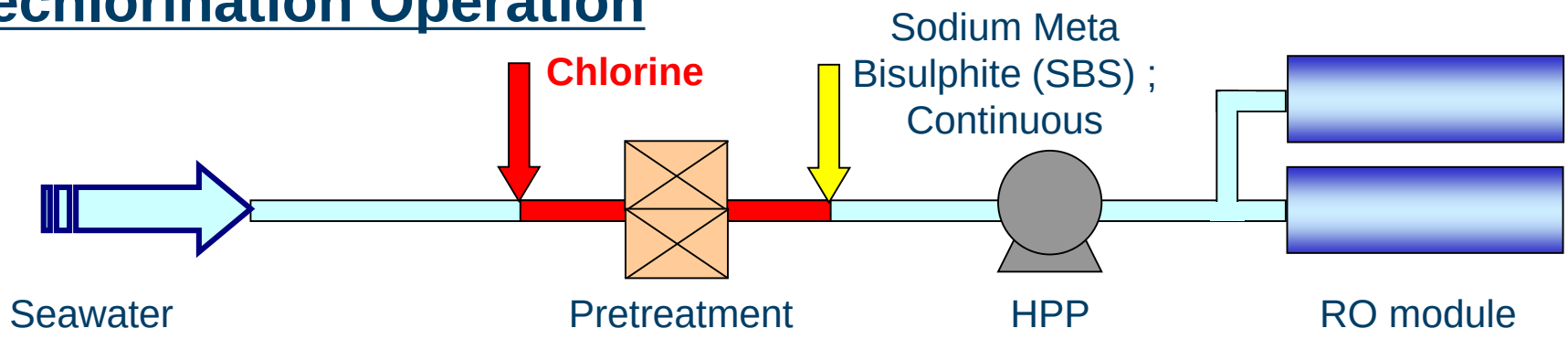
CTA Hollow-Fiber RO Membrane



Fouled Membrane

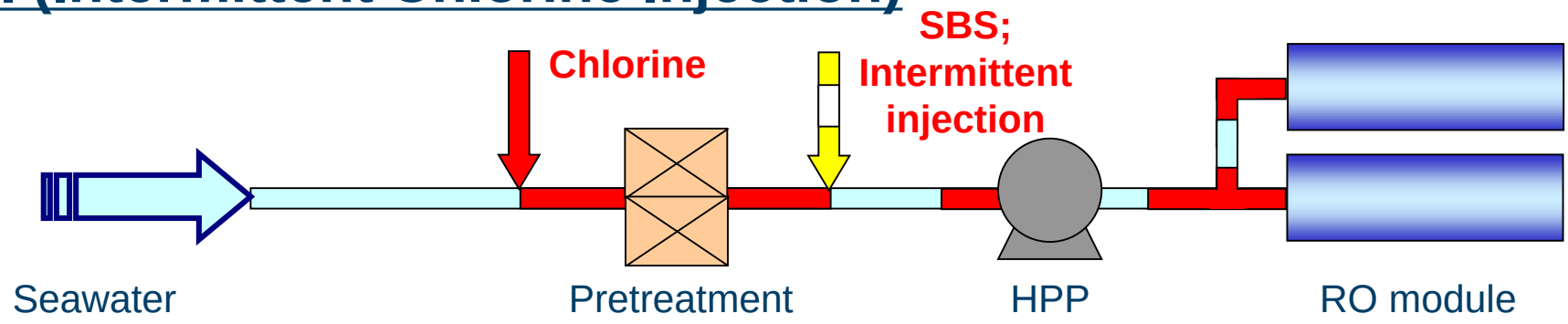
Chlorine Injection to RO Membrane

Dechlorination Operation



1. **Dechlorination before RO inlet to prevent deterioration of the membranes from happening due to oxidation.**
2. **AOC (Assimilable Organic Carbon) problem has been reported.**

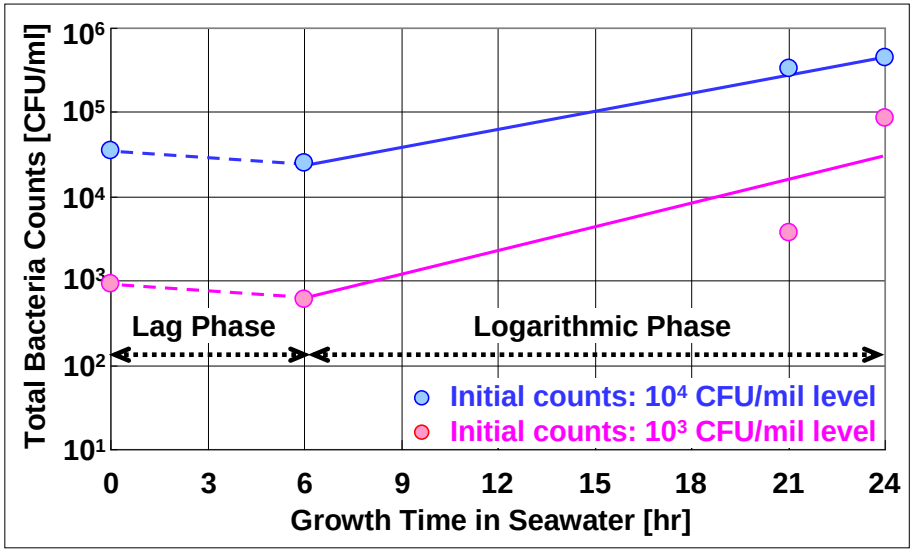
ICI (Intermittent Chlorine Injection)



1. **Intermittent chlorine injection directly injects chlorine disinfectant to RO modules in order to prevent biological fouling on the membrane.**
2. **Membranes have to be resistant to chlorine.**

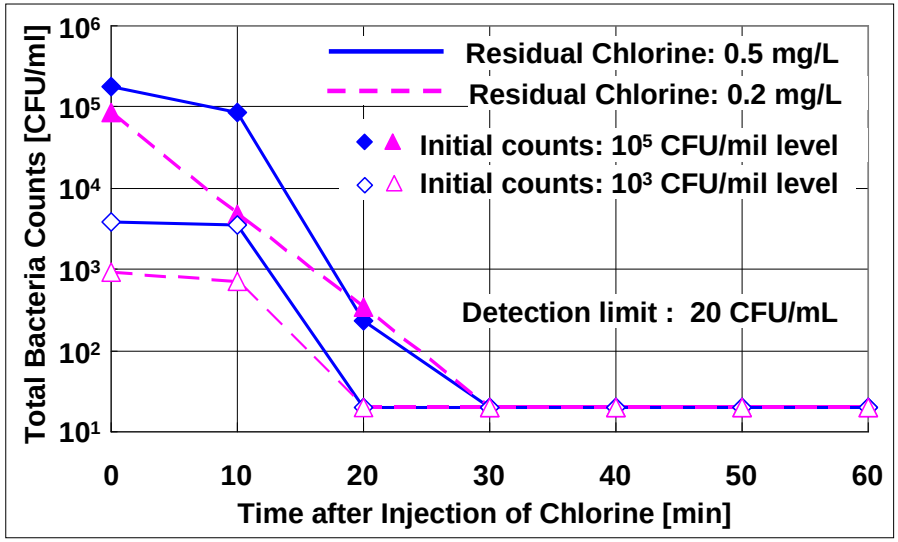
Investigation on the Optimization of ICI Condition

Result of growth rate of bacteria in the seawater from the Red Sea



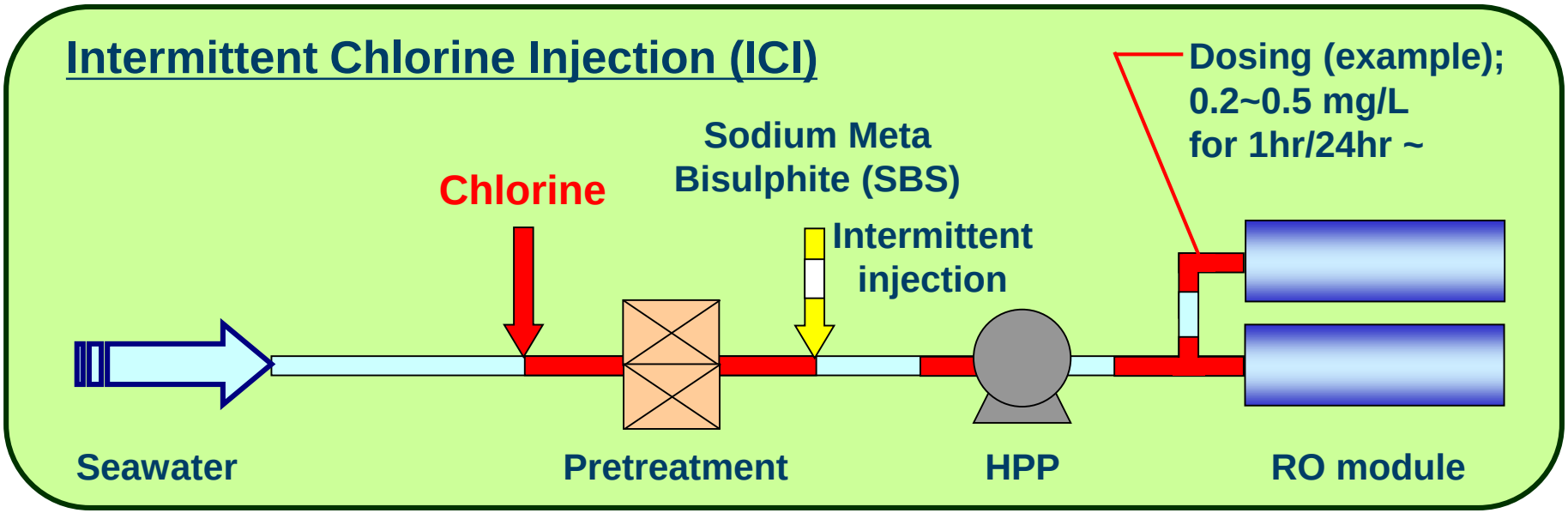
Lag phase is for at least 6 hours from the incubation start

Result of sterilization of bacteria by chlorine



Bacteria counts of 10^5 CFU/ml level became below the detection limit in 30 minutes after chlorine injection.

Summary of Bacteria Count Test



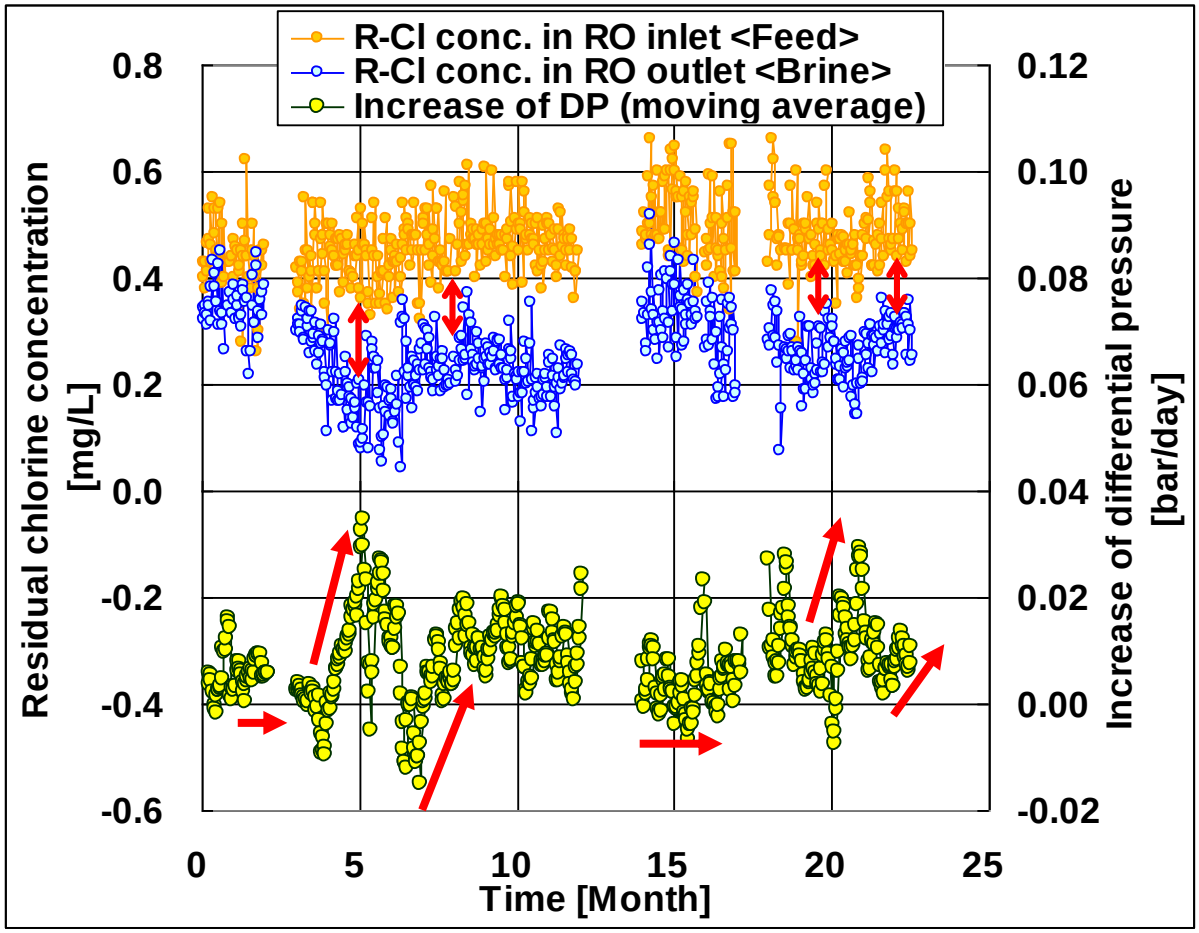
1. 10^4 to10^5 level of total bacteria counts became under the detection level when the bacteria were exposed to 0.2 to 0.5 mg/l of residual chlorine for 30 minutes or more.

2. The number of bacteria stayed the same during “Lag phase” for at least 6 hours, after that, the number of bacteria increased exponentially. Even if bacteria increased during “Logarithmic Phase" , 1-hour chlorine injection every 24 hour could constrict the biofouling.

Chlorine Consumption during ICI

Result at actual SWRO plant

ICI condition : about 0.5 mg/L (target value) for 1hr/24hr



Chlorine consumption*1 during ICI was high

➡ **Fouling potential became high**

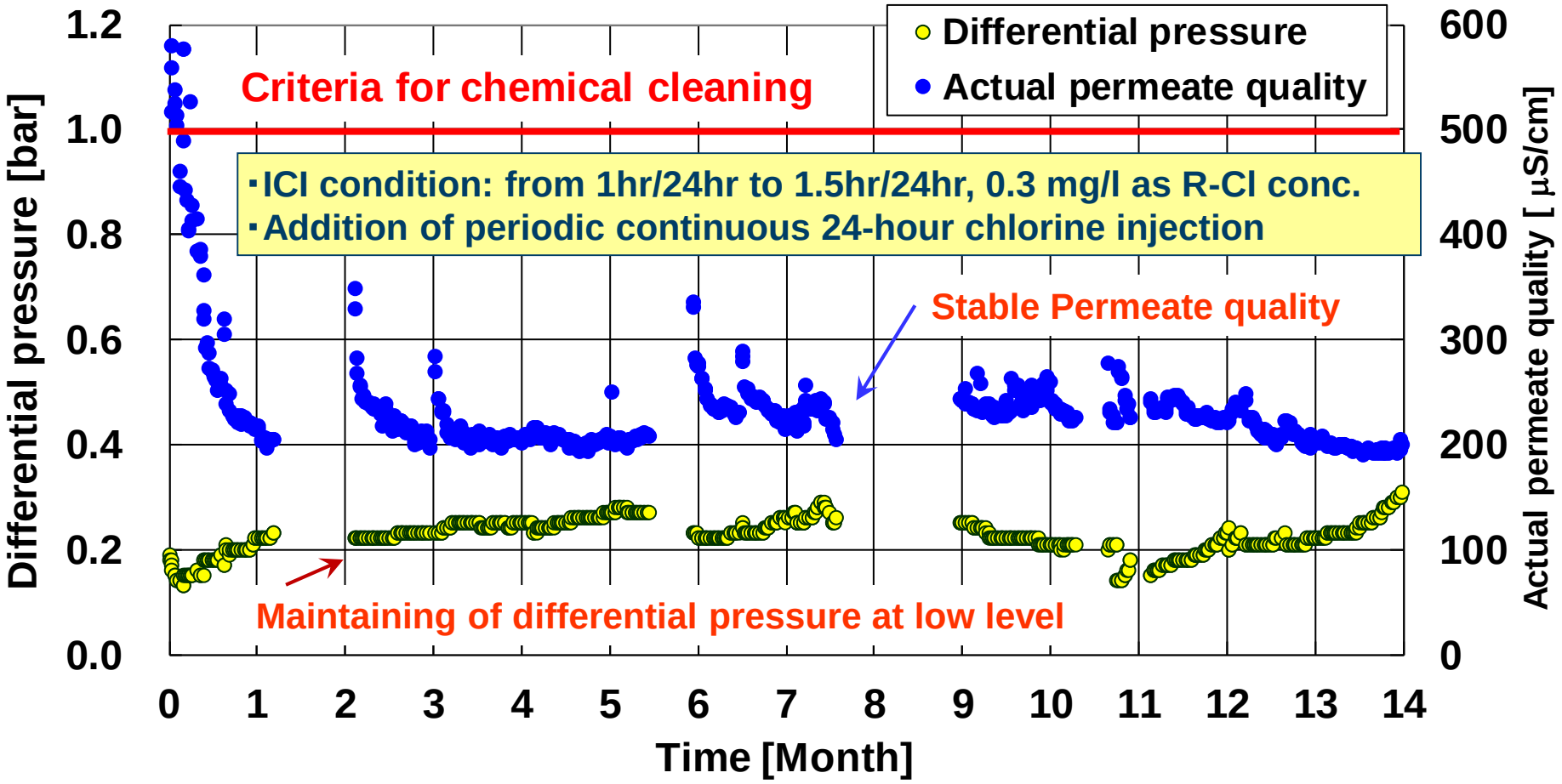
*1 Chlorine consumption means the difference between R-Cl conc.*2 of RO inlet and R-Cl conc. of RO outlet

*2 R-Cl conc. means “Residual chlorine concentration”.

Operation Result of ICI

Result of Site Test at Addur SWRO Plant in Bahrain (Arabian Gulf)

Initial ICI condition: about 0.3 mg/L (target value) for 1hr/24hr

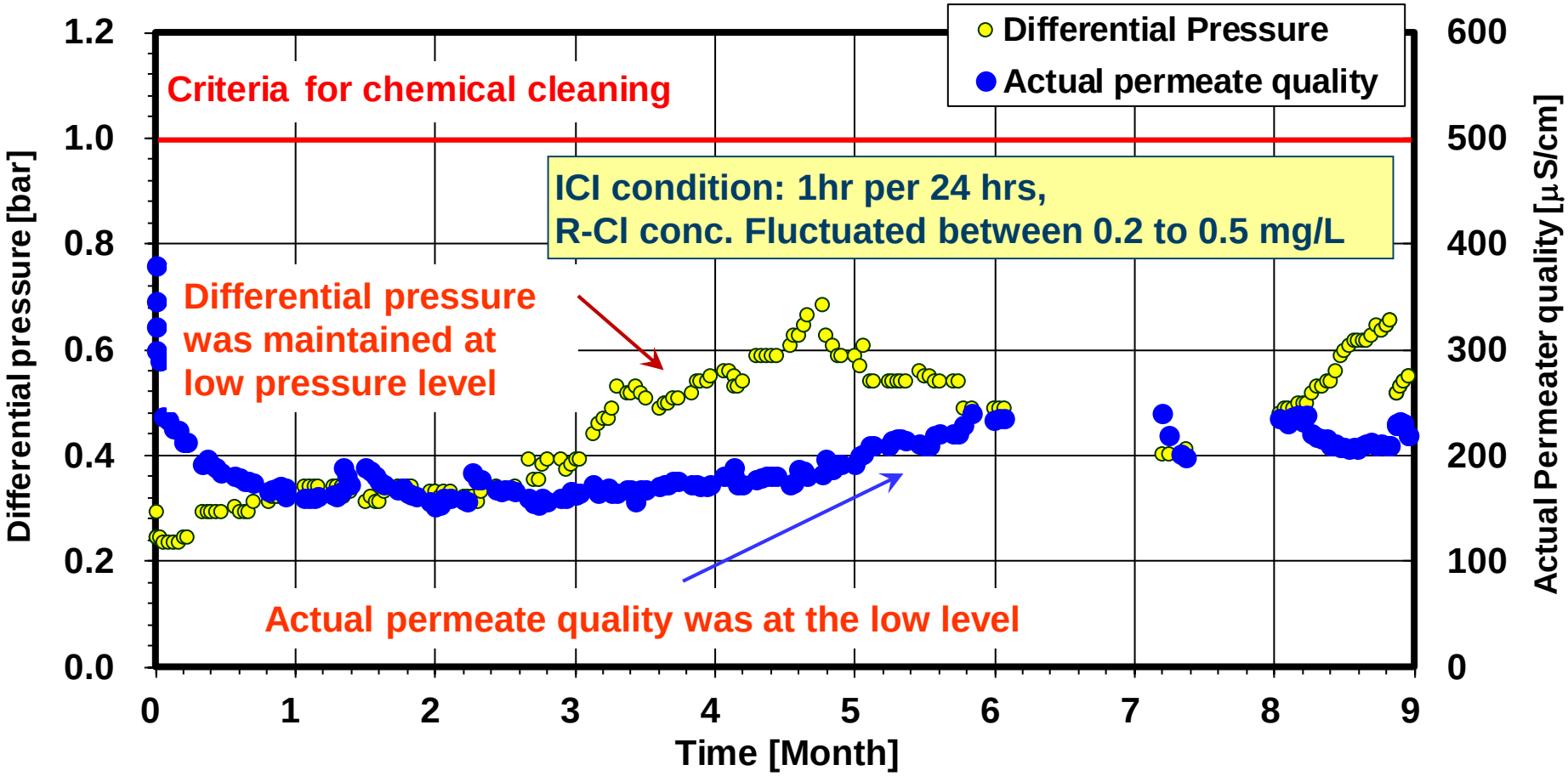


ICI can effectively prevent biological fouling

Operation Result of ICI

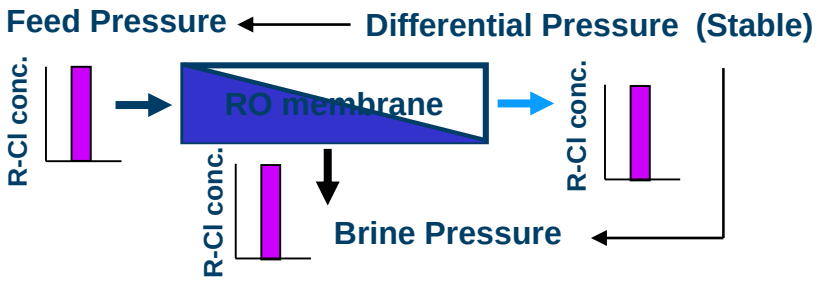
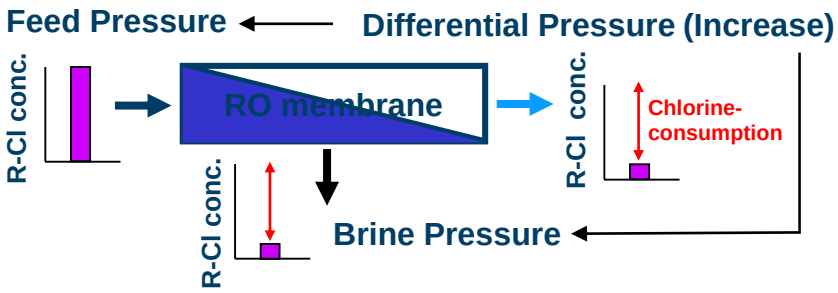
Results of site test at Al-Jubail SWRO plant in Saudi Arabia (Arabian Gulf)

Initial ICI condition: about 0.3 mg/L (target value) for 1hr/24hr



ICI is effective against biological fouling

Optimization of ICI

Condition during ICI	Assumption	Countermeasure
	A small amount of chlorine-consuming matters was in RO module	No need to change the ICI condition
	A great amount of chlorine-consuming matters was present in RO module or RO inlet.	Required

*1 R-Cl conc. means “Residual Chlorine concentration”.

*2 During ICI, it is desirable R-Cl conc. of RO brine/permeate is more than 0.05 mg/L (less than 0.10 mg/L).

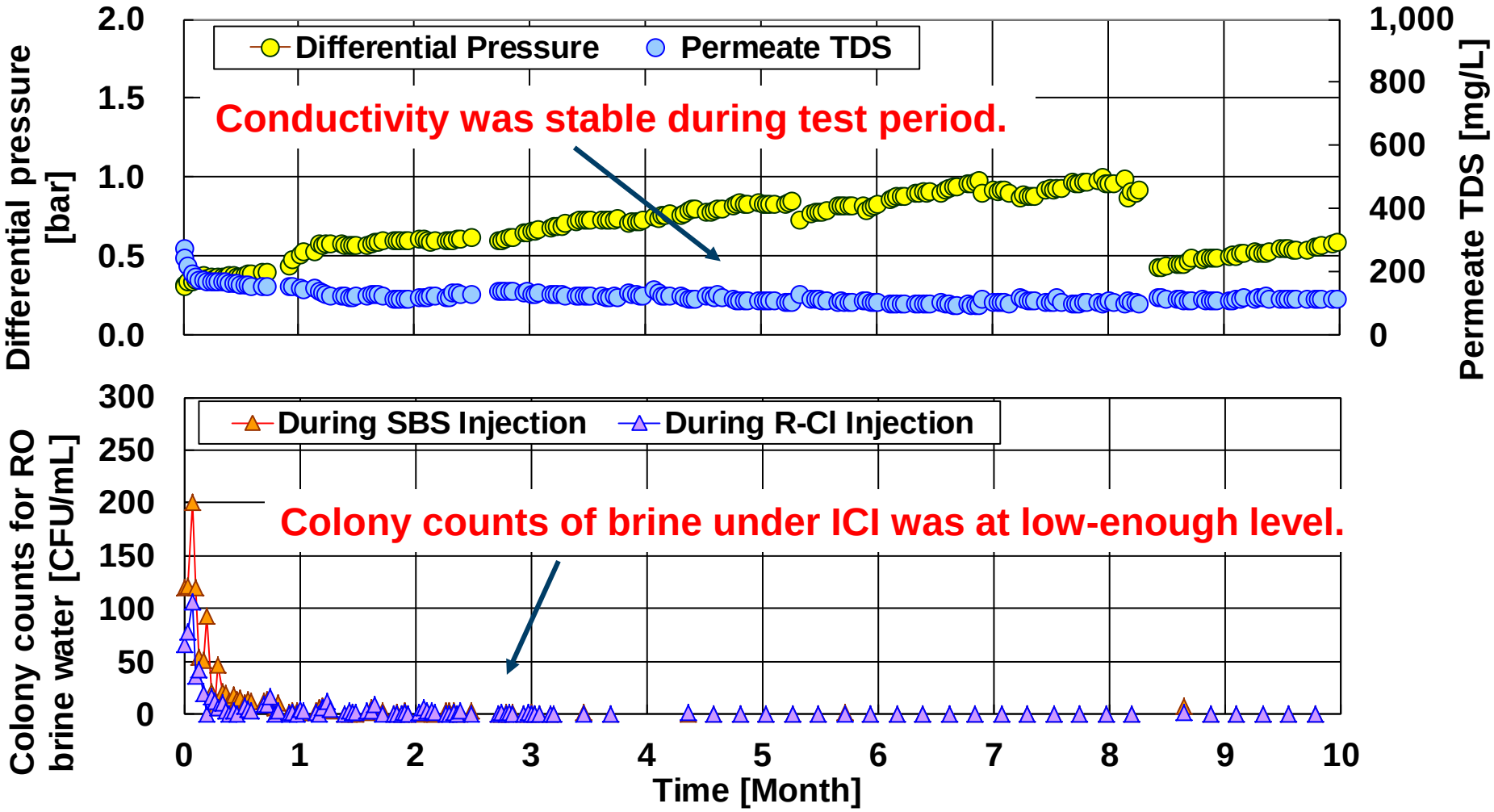
Improvement method

- Change of chlorine injection frequency
- Addition of periodic continuous 24-hour chlorine injection

Operation Result of ICI

Results of Site Test at Jeddah SWRO Plant (Red Sea)

ICI condition: 0.2~0.4 mg/L for 1hr/8hr

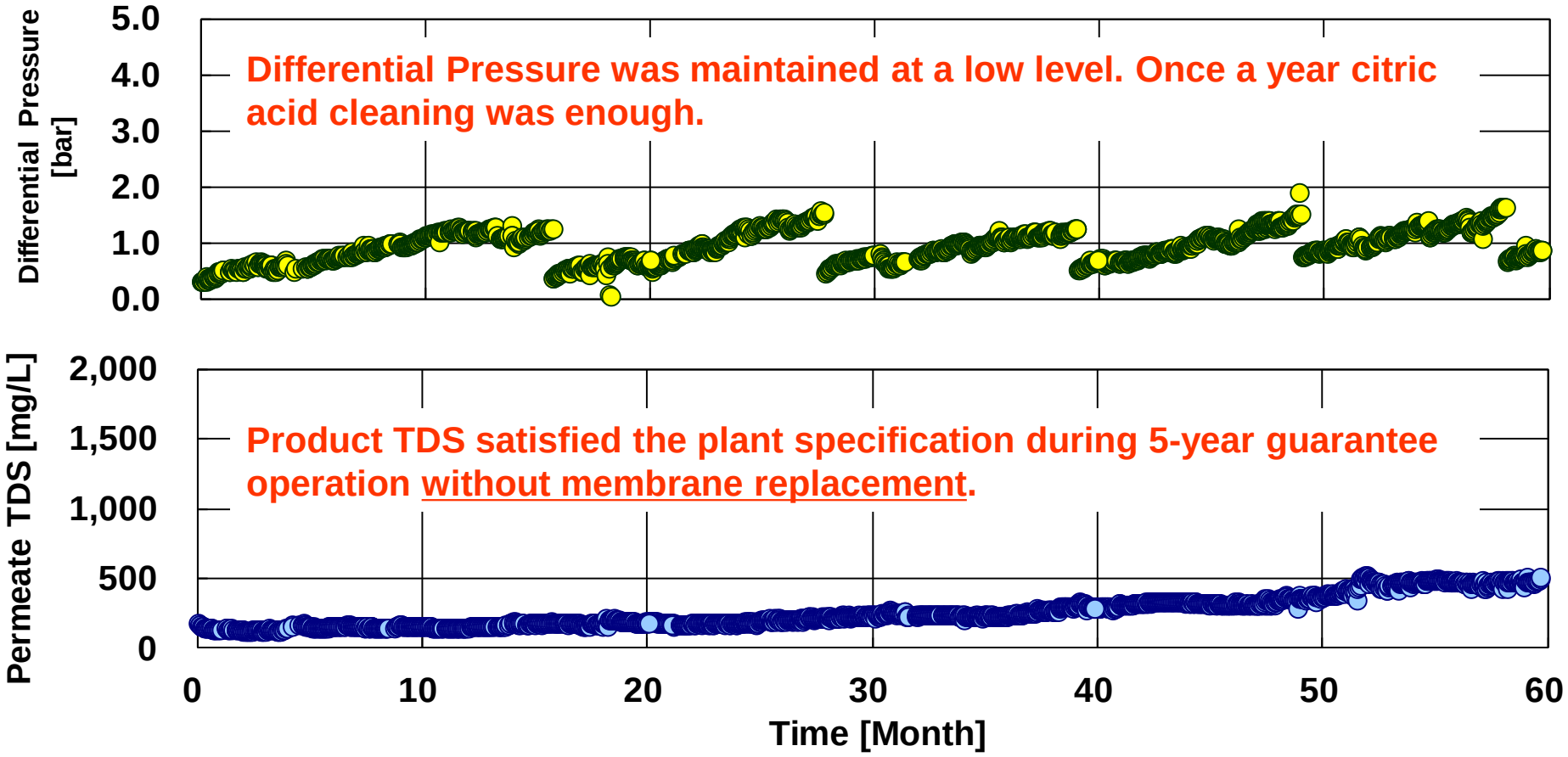


ICI is a very effective disinfection method

Operation Result of ICI

Jeddah Phase-2 SWRO Plant for 5-Year Operation (Red Sea)

ICI condition: 0.2~0.4 mg/L for 1hr/8hr

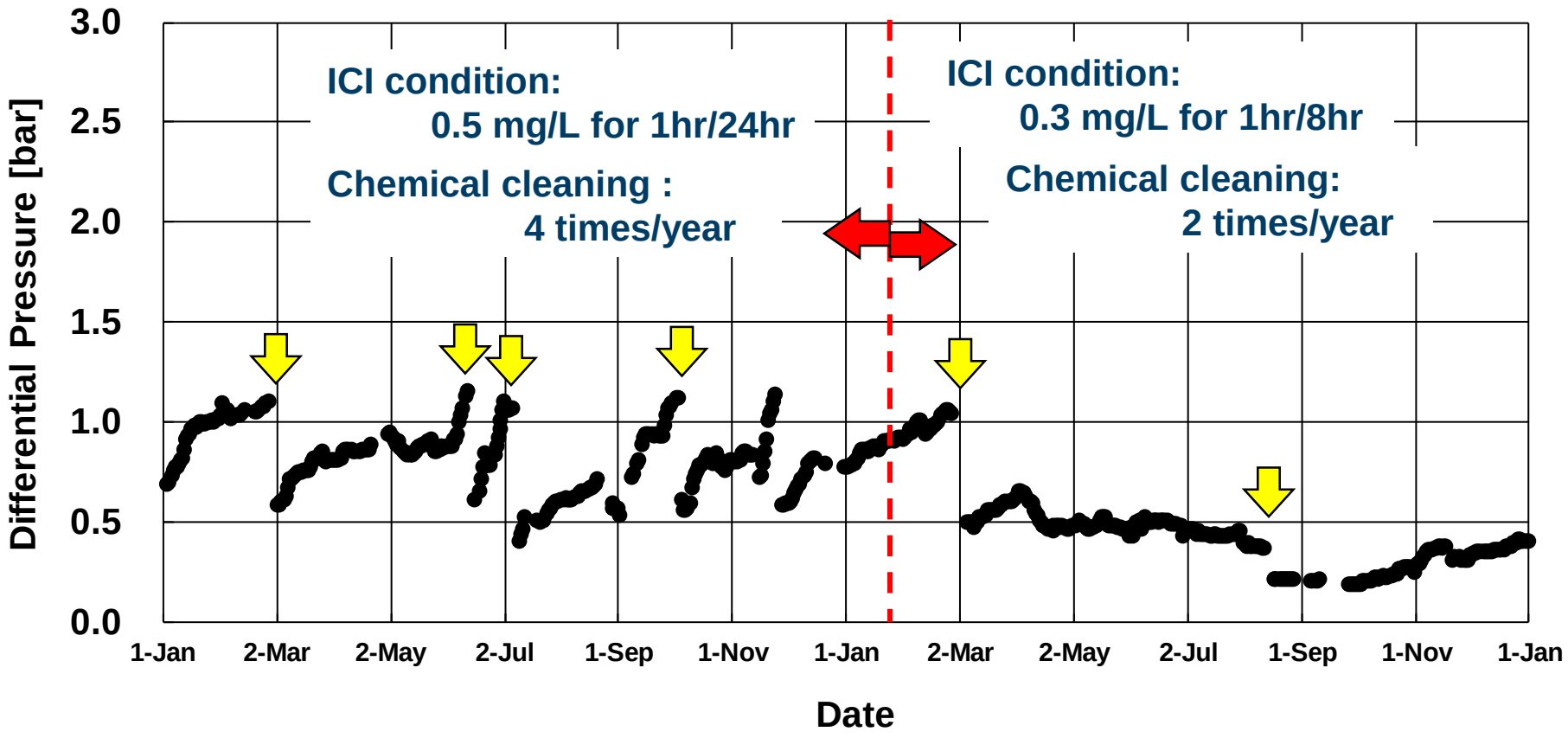


ICI is applied as a basic disinfection method to all SWRO plants using hollow fiber CTA based RO membranes.

Operation Result of optimization of ICI condition

The stable RO operation has been achieved by appropriately adjusting the ICI condition depending on the quality of RO feed water.

Result at an actual SWRO plant in Saudi Arabia (Arabian Gulf)



TOYOBO RO Membrane for Seawater Desalination

Haql (SWCC)
- 4,400m³/d (1989)

Duba (SWCC)
- 4,400m³/d (1989)

Yanbu (SWCC)
- 128,000m³/d (1998)

Yanbu (MARAFIQ)
- 50,400m³/d (2006)

Rabigh (RAWEC)
- 218,000m³/d (2008)
- 109,000m3/d (2015)

Jeddah (SWCC)
(RO1) 56,800m³/d (1989)
(RO2) 56,800m3/d (1994)
(RO3) 260,000m3/d (2012)

Al Birk (SWCC)
- 2,200m³/d (2001)

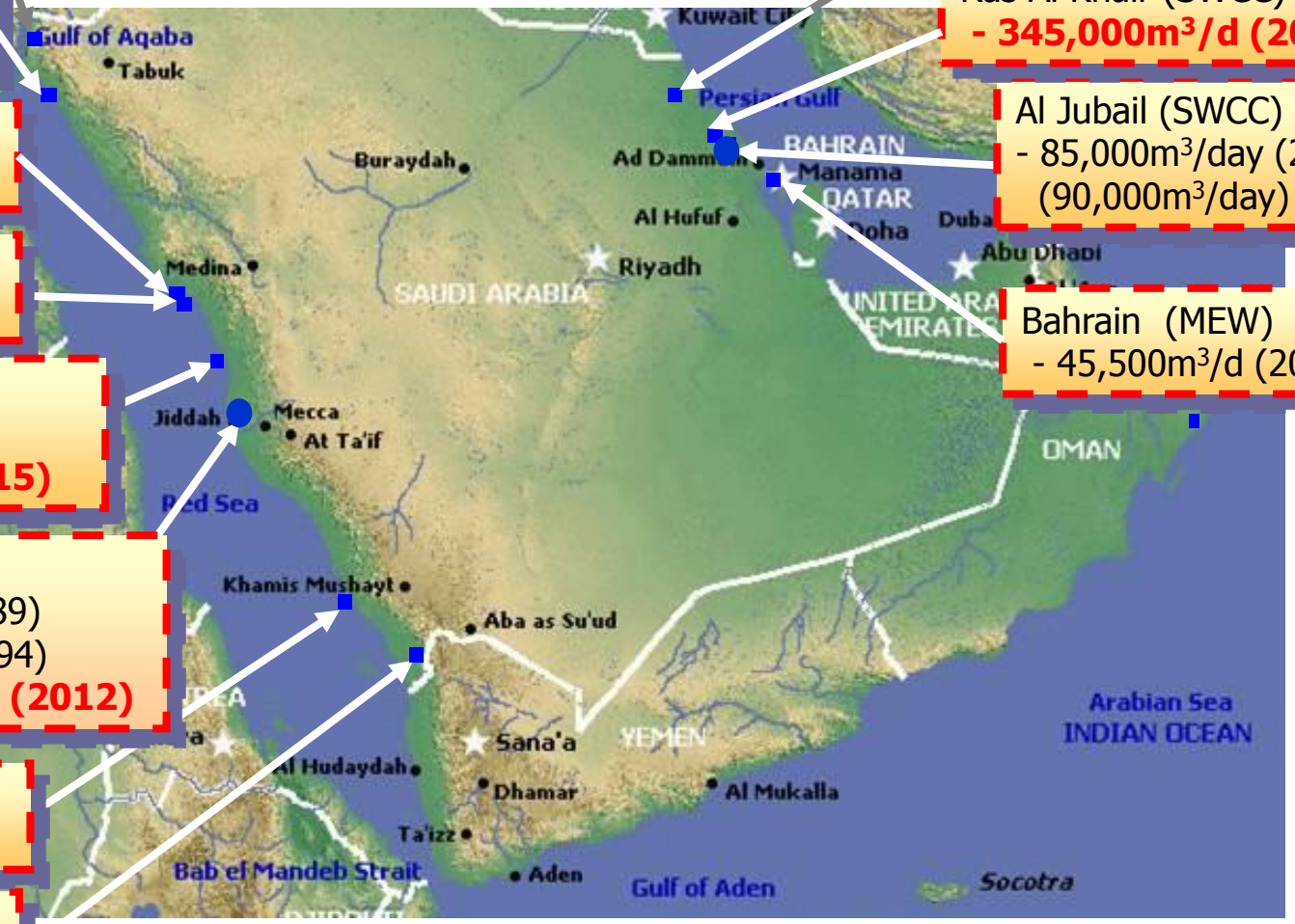
Shuqaiq (SqWEC)
- 240,000m³/d (2010)

Manifa (Aramco)
- 27,000m³/d (2012)

Ras Al Khair (SWCC)
- 345,000m³/d (2013)

Al Jubail (SWCC)
- 85,000m³/day (2007)
(90,000m³/day)

Bahrain (MEW)
- 45,500m³/d (2005)



SWRO plant that applies ICI

Conclusions

1. It was demonstrated that ICI (Intermittent chlorine Injection) was an effective method for preventing biological fouling and it has already been proved practically in the regions of both Red Sea and Arabian Gulf.
2. CTA based RO membranes and ICI is a good combination for a long-term operation of SWRO desalination plant.
3. Even with the seawater of the Middle East, ICI can ensure the stable operation of RO modules by adjusting its condition to the followings.

   - Concentration: 0.2 to 0.4 mg/l as residual chlorine
   - Injection time: 1 to 3 hour per 24 hours

Thank you for your kind attention.