Replacing membrane CIP by Direct Osmosis cleaning

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Editor's note
Is there an alternative to the current cleaning-in-place (CIP) to remove the fouling and scaling that has traditionally affection membrane desalination processes? The authors are advocating the Direct Osmosis cleaning system using a High Salinity solution (the DO-HS system) as an innovative online technique that does not interrupt the operational process.

Membrane desalination technology has been a proven process for the last four decades, though it still has several operational problems. One of the major problems is membrane fouling and scaling, which require periodical membranes Cleaning-in-Place (CIP) procedure. That has low effectiveness, high cost and adds significant environmental issues related to the CIP solutions disposal.

The Direct Osmosis cleaning by the High Salinity solution (DO-HS) presented in this article could be the answer to the main operational problem caused by the fouling and scaling of Reverse Osmosis membranes. The DO-HS cleaning method offers a novel approach for the RO membrane reliable operation. DO-HS process is the on-line technique without interruption of the operational process.

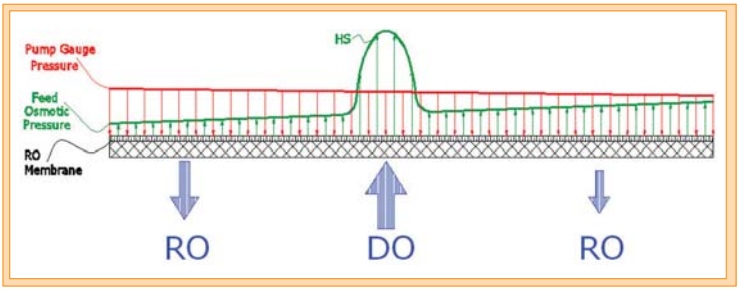
How DO-HS works (physics)

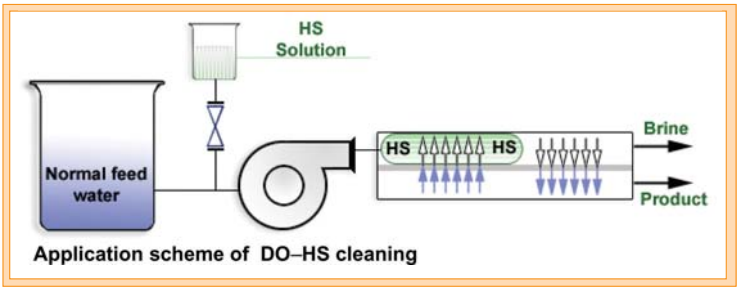
In the RO process, the high-pressure pump (HPP) supplies gauge pressure (red line) to feed water which overcomes its osmotic pressure (green line). A short injection of high salinity (HS) solution into the feedwater provides a wave of process changes from the Reverse to the Direct Osmosis, and, as a result, a wave of permeate backwash streams through the membrane.

In the wave of HS solution, its osmotic pressure overcomes the pump gauge pressure. The force required for DO-HS cleaning process can be provided by non-super saturated, 25% concentrated, activated, NaCl solution, with 194 Bar Osmotic Pressure.

Practical Implementation

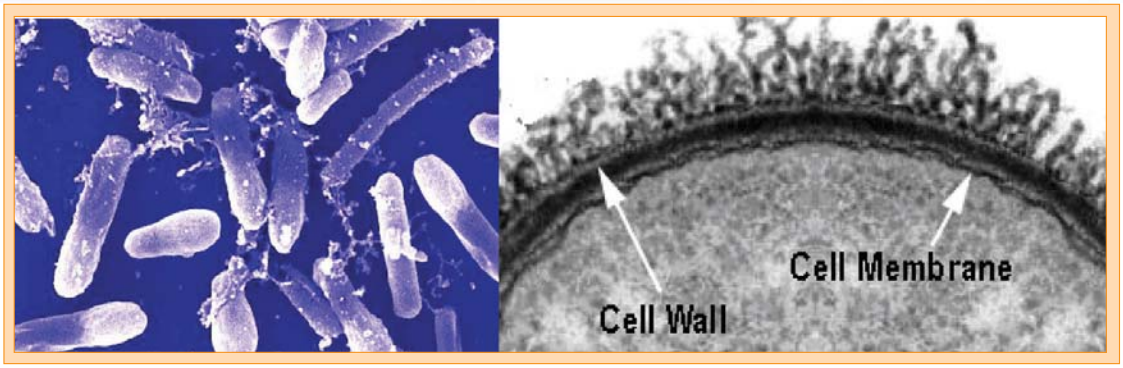
Simple mechanical changes are required for implementation of the DO-HS cleaning method into the RO train.





Application scheme of DO–HS cleaning

RO membrane cleaning



Usually, the existing cleaning pump, tank and micronic filter of the CIP system are sufficient for the DO-HS cleaning process.

Application scheme of DO–HS cleaning

Four synergetic cleaning effects take place within a few second of HS injection:

1. Fouling lifting
2. Fouling sweeping
3. Bio-osmotic shock
4. Salt dissolve shock

1. Fouling Lifting

During the DO-HS cleaning, HS solution is injected online into the feedwater, upstream of the HPP, for a few seconds, without changing the operational parameters of the HPP or the RO train. The HS solution is moving into the feed-brine membrane space like a wave and occupies one or two membranes in each pressure vessel.

In the section where HS solution contacts the membrane, the permeate changes its direction and moves against the gauge pressure gradient from the low-pressure permeate channel to the high-pressure feed channel, lifting up the fouling and/or scaling components from the membrane feed surface.

The high-salinity solution with foulants lifted from the membrane surface, moves in the membrane feed-brine spacer in the direction towards the brine outlet. The osmotic pressure of the high-salinity solution decreases on its way, but remains strong enough to create back permeate flow and lift foulants until it reaches the end of the pressure vessel.

2. Fouling Sweeping

The HS solution, like a cleaning wave, moves in the membrane feed-brine channel with speeding up velocity.

Stripping and sweeping effects take place due to the permeate "up" suction in those places where the HS solution moves. Such increased velocity of the HS solution mechanically removes foulants from the feed spacer and from the membrane surface, reducing the pressure drop in the pressure vessel.

3. Bio-Osmotic Shock.

A semi-permeable cell membrane similar to the Reverse Osmosis membrane covers cytoplasm of such organisms as bacteria, algae and fungi.

The HS solution sucks up water from the bacteria cytoplasm and dehydrates it as well as from the permeate channel of the RO membrane. The cell membrane shrinks and detaches from the cell wall, which is rigid and does not shrink. Separation of the cell membrane from the cell wall is fatal for bacteria, algae and fungi.

4. Salt Dissolve Shock

The HS solution utilized in the DO-HS cleaning has high ionic strength and is able to dissolve microcrystals growing on the membrane and feed brine spacer.

Membrane Integrity

Leading membrane manufactures DOW, Hydranautics, and Toray tested DO-HS membrane cleaning technology and approved it for implementation.

One of the four containerized BWRO trains, Dshanim Factory, Israel.

RO membrane cleaning

Before and after cleaning

Flow, concentration and duration of the High Salinity (HS) solution injection have to be well calculated in compliance with feed water chemistry, configuration of the existing RO train and pumps' curves. DO-HS is a highly powerful instrument that can supply more than 100 bar of the cleaning force, but improper implementation of the technique can damage the membrane element. At the same time, properly designed DO-HS is a very gentle cleaning instrument suitable for old, scaled and damaged RO membranes.

DO-HS Cleaning Successfully Implemented

Two brackish water RO (BWRO) plants employ DO-HS cleaning in commercial operation of six RO trains.

Dshanim Factory, Israel applies DO-HS cleaning in four containerized BWRO trains. The RO plant operates a combination of the Koch, Hydranautics, and Dow membranes. Each RO train is designed with three stages. Three out of four RO trains operate an old, silica-scaled RO membrane damaged by chlorination. Within 50 days, 35 DO-HS cleaning injections were made, once a day, five times a week with intervals for the holidays.

Since DO–HS has been implemented, a significant decrease in the pressure drop between feed and brine stream, and a decrease in the product conductivity were achieved. Sixteen membranes have being weighed before and after DO-HS cleaning. Their weight decreased from 20-23 kg before cleaning to about 17 kg after it. About 4-5kg of fouling debris was removed from each membrane (see above).

The graph (below, Fig 1) presents the dynamics of the pressure drop and product conductivity decrease during the DO-HS cleaning in RO train 3.

RO train #2 operates old Dow Filmtec membranes. Each RO train is designed with two stages. The raw feed comes from heavy fouled shallow wells including 0.06 ppm oil. Pretreatment involves a 5 micron cartridge filter only. Before implementation of DO-HS treatment, the plant was cleaned by conventional CIP procedure every week.

Within two weeks of DO-HS cleaning made four times a day, DP has decreased from 6.5 to 3.4 bar. Conductivity has decreased from 815 µS to 437µS. No conventional CIP was conducted during DO-HS treatment.

RO train #1 operates new Dow Filmtec membranes. This train is treated by DO-HS once a day. Its conductivity and pressure drop stay stable: 170 µS, and 2.5 bar respectively. No conventional CIP was conducted during DO-HS treatment.

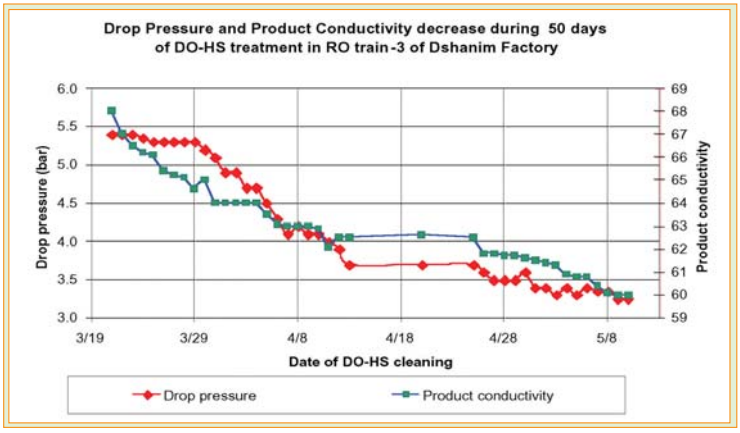
The graph below presents the dynamics of the pressure drop and product conductivity decrease during the DO-HS cleaning in the Blue $ Green Plant, RO train #2.

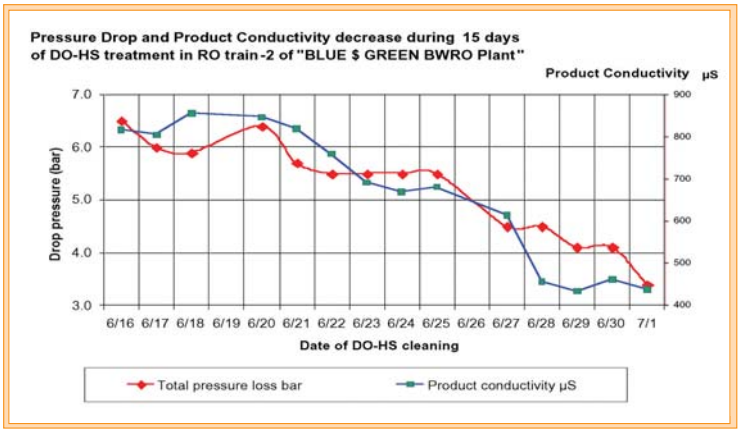
New Treatment Scenario

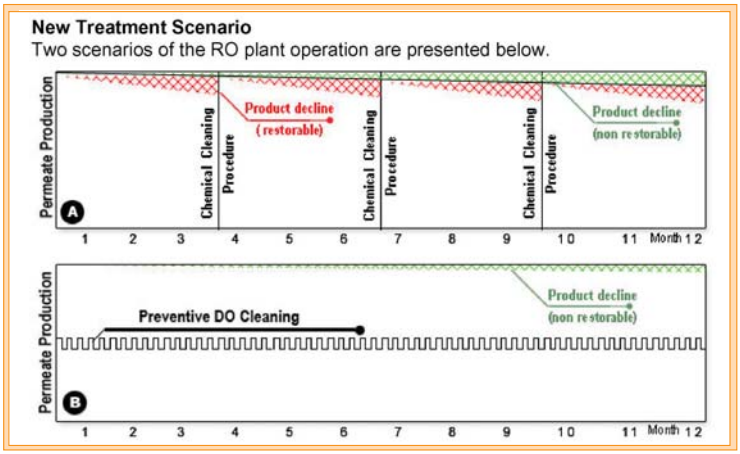
Two scenarios of the RO plant operation are presented over the page.

A. - Conventional Scenario of the Membrane Fouling and Cleaning

B. – DO-HS Membrane Cleaning Scenario







A. - Conventional Scenario of the Membrane Fouling and Cleaning
B. – DO-HS Membrane Cleaning Scenario

The conventional "A" scenario of the RO plant operation includes:

- Operation with decline in the water production;
- Increase in power consumption, pressure drop, product conductivity, and membrane replacement rate;
- Several conventional cleanings per year, with the expense of the cleaning chemicals, production losses during cleaning time, and losses related to the disposal of the cleaning solutions.

The novel "B" scenario of the RO plant operation includes:

- One or several automatic preventive DO-HS cleanings a day;
- Productivity, power consumption, product quality kept at a designed point;
- Membrane replacement rate is low.

Summary

DO-HS process has been successfully implemented at two commercial RO plants. It has significantly improved the membrane performance, reduced the pressure drop, and increased the membrane salt rejection.

The DO-HS is an environmentally friendly preventive technique, which is performed on-line, at low cost, without interruption of the process, continuously producing water and bringing significant benefits to the overall Reverse Osmosis system performance.

The process can be easily applied to an operational facility as well as to be designed for a new project.

This DO-HS membrane cleaning process is patent pending. For more details see: www.membrane-recovery.com

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5. *Figures made by Dogma Design & Technology http://www.dogma.co.il.*

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