

Application Guide 9

SWRO Fouling & Scaling

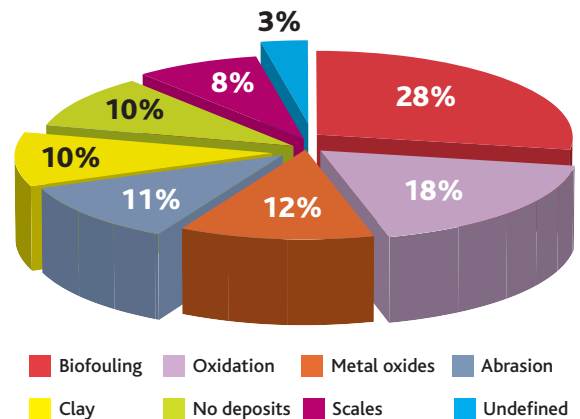
Extract from the paper "Results from 99 seawater RO membrane autopsies", presented at the IDA World Congress on Desalination and Water Reuse, Perth, Australia, September 2011

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A statistical review of the results of 99 sea water RO membrane autopsies, from a variety of systems located all over the world, was conducted in order to identify the most common causes of membrane failure.

These causes of failure were scientifically determined over a 10 year period as: biofouling, oxidation, metal oxide fouling, abrasion, clay & mineral scale (Fig. 1).

Fig 1: Reason for Membrane Fouling



Biofouling

Membrane Biofilms are principally caused by bacteria, but also include fungi, algae and even nematodes.

All membranes have a viable bacterial population. Secretion of a protective polysaccharide layer (known as EPS - Extracellular Polymeric Substances - or TEP - Transparent Exopolymer particles), generally leads to biofilm formation which may adversely affect system performance.

Chlorination is the most commonly practiced control method used in many SWRO systems combined with nutrient restriction through effective filtration.

There are accepted limitations to the use of chlorine:

- ◆ Chlorination efficiency is limited against existing biofilm in pipes and equipment with the EPS providing protection from chlorine in the bulk water
- ◆ Chlorination can promote bacterial growth, with surviving bacteria feeding on the chlorine-degraded assimilable organic carbon (AOC)
- ◆ The biocidal efficiency of chlorine is reduced above pH 7.5 due to the dissociation of hypochlorous acid (HOCl) to hypochlorite (OCl⁻). HOCl is 100 x more effective at killing bacteria than OCl⁻;
 - at pH < 5.0 HOCl – 100%
 - pH 6.5 HOCl – 90%
 - pH 7.5 HOCl – 50%
 - pH > 10 HOCl – 0%
 - most SWRO waters have a pH between 7.5 and 8.3.

Due to the limitations of chlorine, an increasing number of SWRO operators have found that by removing chlorine dosage less nutrients are available for biofilm formation and fouling rates are lower.

Oxidation

With chlorination widespread in SWRO plants, membrane oxidation is the second most common cause of failure. Polyamide membranes are oxidised by free chlorine, eventually resulting in a higher salt passage.

Chlorine is easily removed by dosing sodium meta-bisulphite (SMBS) to the feed water: oxidation is usually the result of SMBS dosing pump failure, underdosing, poor Cl₂ analysis, or human error.

Cellulose Acetate (CA) membranes are resistant to chlorine but are easily degraded by bacteria (which use them as a nutrient source), in addition pH restrictions also make them more challenging to clean. This explains their recent resurgence in the design of some large SWRO systems in the Middle East, where high chlorine dosing is used to control algal blooms.

The rate of membrane oxidation is catalysed by the presence of aluminium and transition metal ions. The detailed results of autopsies demonstrated partial oxidation of the polyamide layer which we think is related to pockets of catalysed oxidation, due to the presence of metal impurities from commodity pre-treatment chemicals.

Metal Oxides

Iron, manganese and aluminium oxides are the third cause of membrane failure (12%). Overdosing of pre-treatment inorganic coagulants, which are mostly based on iron and aluminium salts (ferric chloride, aluminium chloride, etc), is the main source. Iron fouling damages cartridge filters as well as membranes (Figs. 2 & 3).



Fig 2: Iron fouled cartridge filters



Fig 3: Iron fouled membranes

When excess iron is present, the nature of the antiscalant used is critical:

- ◆ phosphonate-based antiscalants sequester iron, thus preventing its deposition on the membrane surface.
- ◆ polymer-based products react with iron to form iron acrylate, causing irreversible membrane damage.

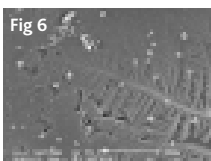
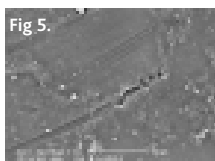
Small quantities of transition metals are often identified on membrane surfaces (titanium, vanadium, chromium, manganese, nickel etc.). They may come from plant corrosion, but they are also present as impurities in lower grade inorganic coagulants. Presence of these impurities has been shown to catalyse oxidation reactions on polyamide membranes, and accelerate the degradation of cellulose acetate membrane by deacetylation*.

Abrasion

With SWRO plants operating at high pressures (50-70 bar), a high incidence of abrasion damage to the membrane surface was detected, resulting in an increased salt passage, lower permeate quality and a higher flux.

Membrane abrasion can be caused by:

- ◆ fouling and/or scaling: pressure may cause spacer material to push into the membrane surface causing physical damage (Fig. 4), which may only become apparent once the scale has been removed (Fig. 6).
- ◆ particulate abrasion caused by filtration media (Fig. 5) or metallic particles (abrasion by-products or welding residues).
- ◆ algae: some species have calcite or silicon exoskeletons which have been identified on the membrane surface.



Alumino-silicates (clays)

Alumino-silicates were present on one third of the membranes, and are directly responsible for 10% of all membrane failures.



Fig 7: Clay fouling on a membrane

Clay is the by-product of chemically weathered rocks and is ubiquitous in all waters around the world. Clay minerals have a sheet-like structure, giving them their unique soft, compressible nature (Fig.8).

During fouling, clay deposits are compressed against the membrane causing a flux reduction and a differential pressure increase, resulting in further deposit compression making clays difficult to remove without a specialist cleaning approach.

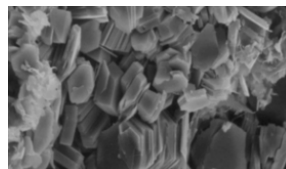


Fig 8: Tetrahedron clay rings

Clay particles can also contribute to abrasion.

Clay fouling can be minimized through improved pre-treatment and appropriate flocculant selection. However, regular cleans with speciality chemicals are still necessary.

Mineral Scale

Mineral scales (mainly calcium carbonate, calcium sulphate and silica) were present in 21% of the membranes but are only directly responsible for 8% of failures. This low occurrence is attributed to the use of antiscalants in SWRO systems. Feed water acidification can be significantly reduced or even stopped without impacting the effectiveness of iron coagulants and antiscalant performance [NB : approx. 5 tons/day of 95% H₂SO₄ are required to lower the pH from 8.0 to 7.0 on a 100 MLD SWRO plant].

In many cases, first pass SWRO plants operate at natural sea water pH with a phosphonate-based antiscalant and no acid dose requirement.

In addition, the higher pH of the first pass aids boron rejection in a second pass BWRO system.

CONCLUSION

Causes of membrane failure were identified in decreasing order: biofouling, oxidation, metal oxide fouling, abrasion, clay and mineral scale.

Commodity chemicals are widely used but can have adverse effects:

- ◆ chlorination can increase system biofouling and cause membrane oxidation
- ◆ iron and aluminium coagulants foul membranes
- ◆ metal impurities in low grade sulphuric acid and coagulants can catalyse membrane oxidation, increasing membrane damage

The preferred method of treatment is the use of phosphonate-based antiscalants which sequester a large range of metals, preventing deposition on the membrane surfaces and disabling the potential for catalysing oxidation reactions on the membrane.

*Reference SWRO Drinking Water Project in Shuqaiq: Advanced BWRO, Membrane Oxidation, and Scaling

Nabil Nada, Tony Attenborough, Yoshiaki Ito, Yasushi Maeda, Kiichi Tokunaga, and Hideo Iwahashi IDA Journal Volume 3 No. 4

Genesys sea water Antiscalants

Genesys LF	for use with 2 pass sea water plants with partial recycling where a common antiscalant is required. Highly effective at sequestering metal impurities, protecting the membrane from spot catalysed oxidation
Genesys LF 60	for use with single pass SWRO plants. Sequesters metal impurities from pre-treatment chemicals preventing catalysed membrane oxidation
Genesys LS	seawater antiscalant with low metal content in feed water and no recycling
Genesys SW	polymer based antiscalant where phosphonate antiscalant is prohibited
Genesys HR	acidified sea water antiscalant