BEYOND ORGANIC FOULING: INVESTIGATING INORGANIC SCALING AND RO MEMBRANE PERFORMANCE DECLINE AT HAWKER WTP.

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ABSTRACT

A water treatment plant supplying the rural township of Hawker (South Australia) experienced accelerated reverse osmosis (RO) membrane performance degradation, resulting in premature membrane replacement and increased operational costs. Further performance degradation prompted an investigation into the root cause. A fouled membrane was removed and subjected to detailed laboratory analysis and testing. While organic fouling was initially suspected, microscopy identified deposits of non-biological material within globular structures on the membrane surface. Comprehensive analysis of membrane foulant revealed elevated concentrations of calcium, magnesium, sulphate, and silica, confirming inorganic scaling as a major contributor to the membrane fouling.

Cutouts of the Hawker RO membrane were evaluated in a purpose-built cross-flow unit to simulate operating conditions at Hawker Water Treatment Plant (WTP) and the role of antiscalant dosing on the membranes. Results indicated that the antiscalant may have contributed to the observed scaling behaviour under site-specific conditions, consistent with findings reported in the literature. Subsequent cleaning trials demonstrated that acidic cleaning successfully restored permeate production following experimentally induced fouling. The findings improve understanding of membrane fouling mechanisms and provide practical strategies to extend membrane life, reduce operating costs, and maintain reliable, cost-effective treatment of a challenging groundwater source.

1.0 INTRODUCTION

Hawker Water Treatment Plant (WTP) was established in 2014 to provide drinking water to the rural township of Hawker, as well as surrounding tourist and farming areas. The plant has a treatment capacity of approximately 400 kL/day, with raw water sourced from two bores located nearby. The source water presents several significant water quality challenges, most notably the raw water hardness, which exceeds 800 mg/L as $CaCO_3$. Other key water quality considerations include elevated concentrations of iron and manganese, high salinity, and elevated sulphate.

Hawker WTP is an iron removal and brackish water reverse osmosis (RO) treatment plant. Chlorine gas is dosed into the bore water to facilitate the oxidation of iron and manganese, followed by treatment through three greensand media filters. Antiscalant and sodium metabisulfite (SBS) are dosed upstream of the 1-micron cartridge filter and RO vessels, which comprise a three-stage RO system.

Following the recent transition of the plant to SA Water, ongoing challenges with RO membrane performance were identified. Despite regular backwashing and Clean-in-Place (CIP) chemical cleaning, maintaining consistent membrane performance remained difficult. Accelerated and irreversible fouling necessitated operator intervention and premature membrane replacement in October 2025 (Figure 1), significantly increasing operating costs. Following membrane replacement, similar accelerated fouling was observed until an in-situ clean was conducted in March 2026, indicating that the underlying cause had not been resolved. This prompted a detailed investigation into the fouling mechanism and strategies to improve membrane performance.

Figure 1: ***Normalised differential pressure of the RO membranes at Hawker WTP.***

2.0 DISCUSSION

The study aimed to identify the cause of accelerated RO membrane fouling at Hawker WTP and develop practical strategies to improve long-term membrane performance. The investigation included membrane autopsy and foulant characterisation, laboratory and cross-flow cleaning trials, and assessment of potential contributions from antiscalant and sodium metabisulfite (SBS).

2.1 MEMBRANE AUTOPSY

Fouled Hawker RO membranes were subjected to microscopic examination and inductively coupled plasma mass spectrometry (ICP-MS) metals analysis. Microscopy identified predominantly non-biological material as globular/spherical structures. Metals analysis identified high concentrations of calcium (337,000 mg/kg) and magnesium (104,000 mg/kg), together with sulphate, silica, sodium and iron (Table 1). These findings confirmed that inorganic scaling was a major contributor to membrane performance decline, rather than the initially suspected organic fouling.

<u>Table 1:</u> ***Metals analysis results for foulant collected from Hawker WTP membrane.***

Parameter	Result (mg/kg)
Calcium	337000
Iron	2990
Magnesium	104000
Manganese	74.4
Silica	2770
Sodium	14100
Sulphate	16000
Total Solids: 11.3%	

2.2 LAB-SCALE CLEANING TRIALS

Following identification of predominantly inorganic fouling, a range of acidic and alkaline cleaning solutions were screened for their ability to remove accumulated deposits. The best performing solutions were subsequently tested on fouled membrane sections, with foulant removal assessed visually and through analysis of calcium, iron, magnesium, silica and sulphate in the spent cleaning solutions (Table 2).

Citric acid and sodium tripolyphosphate (STPP) + ethylenediaminetetraacetic acid (EDTA) removed substantial deposits, while sulfamic acid achieved partial visible removal. STPP + EDTA produced the greatest overall removal of calcium, iron, magnesium and silica. Although deionised (DI) water also removed some material, chemical cleaning was generally more effective.

<u>Table 2:</u> ***Metals analysis of the cleaning solutions post membrane cleaning.***

Parameter	Control (DI) (mg/L)		Citric Acid (mg/L)		Sulfamic Acid (mg/L)		STPP + EDTA (mg/L)	
	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble
Calcium	0.89	0.49	2.24	2.3	2.45	2.48	3.12	2.83
Iron	0.054	0.0027	0.13	0.13	0.10	0.093	0.52	0.50
Magnesium	0.37	0.21	0.65	0.66	0.65	0.65	1.48	1.56
Silica	0.4	<0.1	0.3	0.4	0.2	0.2	10.5	10.4

2.3 PILOT SCALE CLEANING TRIALS

The selected cleaning solutions from section 2.2, with the addition of Memguard 61 which is the currently utilised high pH cleaning chemical at Hawker, were subsequently evaluated using 140cm^2 sections of fouled Hawker membrane in a purpose-built cross-flow membrane unit (GE Sepa CF II Membrane Cell System). Clean-water flux was measured before and after cleaning to assess membrane performance recovery (Figure 2).

Despite visible removal of foulant during the laboratory trials, cleaning did not consistently restore membrane permeability, with post-clean flux remaining below pre-clean levels, except for the STPP + EDTA clean (Figure 2b). The recovered Hawker membranes remained heavily fouled and became increasingly fragile during testing. Therefore, the reduced post-clean flux was interpreted as an inability to restore membrane performance rather than evidence of cleaning-induced membrane damage. The results suggest that a component of the accumulated fouling was irreversible.

This finding also demonstrated that visible removal of deposits did not necessarily correspond to recovery of membrane permeability. Due to the compromised condition of the recovered membranes, subsequent investigation of potential fouling contributors was undertaken using new RO membranes (Sterlitech Flat Sheet RO Membrane SEPA)

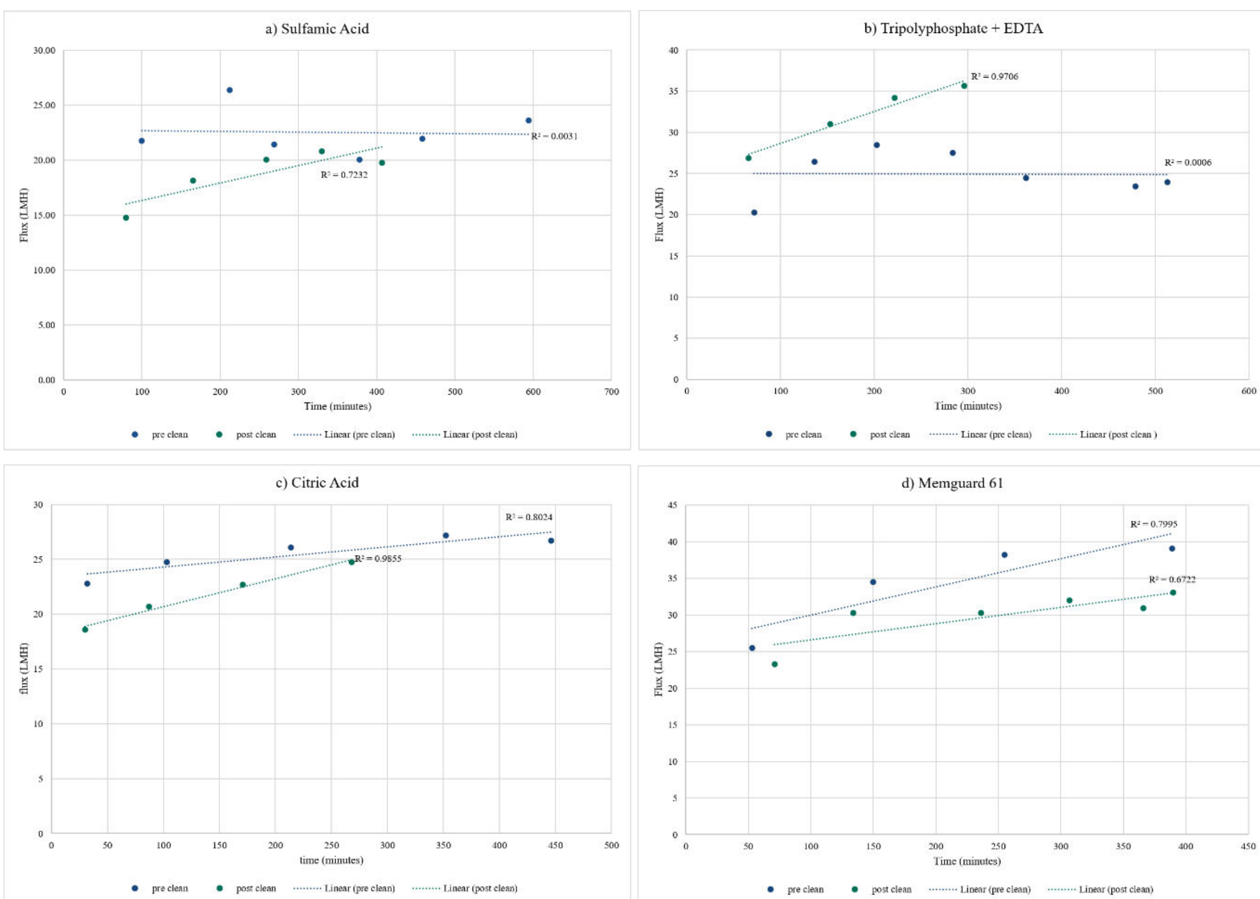

Figure 2: ***Permeate flux of membranes pre- and post- chemical clean.***

2.4 TESTING OF HAWKER CHEMICALS

A new RO membrane was initially operated with Hawker feedwater for six hours, with no significant flux variation or observable fouling, indicating that the feedwater alone did not produce measurable short-term fouling under the experimental conditions. Cross-flow testing was subsequently undertaken to assess the potential contribution of an antiscalant (Memguard 102) and sodium metabisulfite (SBS) which were dosed at Hawker WTP prior to RO vessels.

The testing of SBS alone, up to 16 mg/L, produced no significant change in membrane performance. However, subsequent addition of Memguard 102 up to 250 mg/L to the SBS-treated feedwater resulted in increased pressure and visible fouling. The testing of antiscalant alone, at a total Memguard 102 concentration of 12 mg/L, contributed a slight increase in operating pressure and decrease in flux. To induce accelerated fouling under controlled conditions, concentrations up to 500 mg/L were tested, with pressure progressively increasing while flux and permeate production declined, ultimately resulting in automatic shutdown of the unit and visible membrane fouling.

Cleaning of the membrane fouled with 500 mg/L antiscalant was subsequently evaluated using the previously tested cleaning chemicals. Although STPP + EDTA demonstrated the greatest foulant removal during the laboratory-scale trials, it did not restore membrane performance in the cross-flow trial. Subsequent sulfamic acid cleaning successfully restored permeate production. Figure 3 demonstrates the decrease and restoration of flux for the 500 mg/L antiscalant trial. Citric acid similarly restored permeate production following the combined antiscalant/SBS trial. These results indicate that Memguard 102 may contribute to membrane performance decline under the water quality conditions tested and further support the presence of acid-responsive inorganic deposits.[1] The successful recovery following low-pH cleaning is consistent with literature demonstrating the effectiveness of acidic cleaning for the removal of inorganic scale.[2]

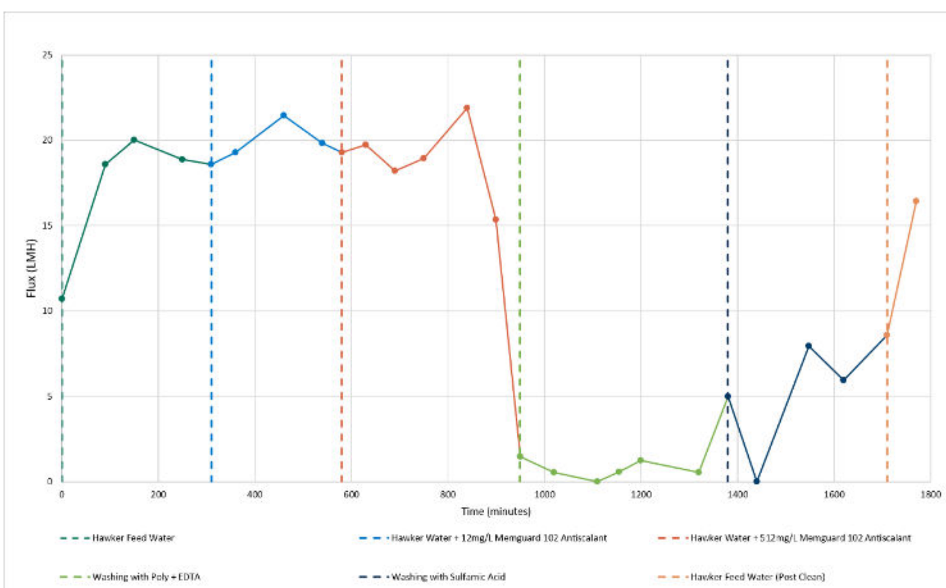

Figure 3: ***Flux of cross-flow membrane unit for trial of Antiscalant Memguard 102.***

3.0 CONCLUSION

The investigation identified inorganic scaling as a major contributor to accelerated RO membrane performance decline at Hawker WTP. Membrane autopsy identified substantial calcium and magnesium deposits, together with sulphate and silica. Cross-flow testing demonstrated that Memguard 102 could contribute to membrane fouling under the tested conditions, suggesting that interactions between antiscalant dosing and the high-hardness feedwater may contribute to the observed full-scale fouling.

Although laboratory cleaning removed components of the inorganic foulant, cleaning of the recovered Hawker membranes did not consistently restore membrane permeability. Controlled testing using new membrane material subsequently demonstrated successful recovery of permeate production using acidic cleaning following experimentally induced fouling. These findings support a revised cleaning approach whereby, when inorganic scaling is identified as the dominant fouling mechanism, low-pH cleaning is undertaken before high-pH cleaning, subject to the limitations of the approved proprietary cleaning products.

Longer-term recommendations include optimising antiscalant selection and dosing to improve compatibility with the feedwater chemistry and investigating upstream softening to reduce the exceptionally high hardness of the Hawker RO feedwater. These measures provide a practical pathway to reduce scaling, extend membrane service life and improve the reliability and cost-effectiveness of the Hawker RO system.

4.0 ACKNOWLEDGEMENTS

We gratefully acknowledge the Water Science Analyst team, Con Kapralos, Edith Kozlik, Miriam Nedic, and Elloise Trotta, for their considerable time and effort in sample preparation and analysis. We also recognise the foundational work undertaken by Ben Drew, which contributed significantly to this project. In addition, we thank Hawker WTP Operator Brad Alcorn and Treatment Specialist Elizabeth Quarrell for their assistance with sample collection.

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