# A Clean Slate: Novel Chemical Cleaning to Recover Water Filtration Membranes

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## ABSTRACT

The Tea Gardens water supply scheme sources water from the Viney Creek aquifer. The aquifer water source is considered good quality with low turbidity, pathogens and chemical contaminants of health concern. The aquifer, however, naturally contains elevated levels of soluble iron. Iron is removed at Tea Gardens Water Treatment Plant (WTP) through a combination of pH adjustment, aeration and membrane filtration.

The membranes at Tea Gardens WTP have been operating since 2013. Regular backwashing with citric acid through extended flux maintenance and Clean in Place (CIPs) have been relatively effective at maintaining membrane performance measures, such as specific flux and transmembrane pressure. In 2023 however, a notable drop specific flux was observed, with several adjustments to CIP cleans unable to recover performance.

Council undertook a membrane autopsy, including thermogravimetric analysis and Fourier transform infrared with energy-dispersive spectroscopy. The autopsy identified significant fouling caused by iron compounds on membrane fibres. Subsequently, a cleaning study was commissioned with Avista Membrane Treatment Solutions which identified a proprietary cleaning chemical effective at targeting iron-based fouling, marketed as Avista127.

This paper presents the processes taken by Council, including the outcomes of onsite cleaning studies to successfully recover membrane performance at Tea Gardens WTP.

## 1.0 INTRODUCTION

The Tea Gardens water supply scheme services the townships of Hawks Nest and Tea Gardens with water extracted from the Viney Creek aquifer. The scheme was established in the 1960s and in 2013, a new 8 ML/day Water Treatment Plant (WTP) was constructed. The plant's primary treatment units include lime and aluminium chlorohydrate dosing for pH correction and coagulation, forced aeration for iron and hydrogen sulphide removal, arkal screening, membrane microfiltration, chlorine disinfection and fluoridation.

The membranes at Tea Gardens have been operating for over 10 years. Operational parameters such as backwash intervals, Clean In Place (CIP) and Extended Flux Maintenance (EFM) (type, strength and frequency) have been optimised in the early years of operation and have remained relatively consistent over the life of the membranes. The rate of irreversible membrane fouling accumulation has likewise been consistent and linear with respect to time for the most part. A slow decline in specific flux performance is shown in in Figure 1 up until early 2023, where a more rapid decline can be observed.

Review into the accelerated fouling found no operational changes or raw water quality indicators that could account for the enhanced loss in flux. An optimisation study was conducted to improve CIP and EFM recovery. The study included extending CIP runtimes, strength and adjusting the sequence (caustic into acid or acid into caustic). The study identified little to no improvement when compared to the existing settings. The loss in flux was affecting the ability of the plant to operate at design flow conditions. Council decided both explore membrane replacement options and investigate the type and cause of the fouling leading to performance loss.

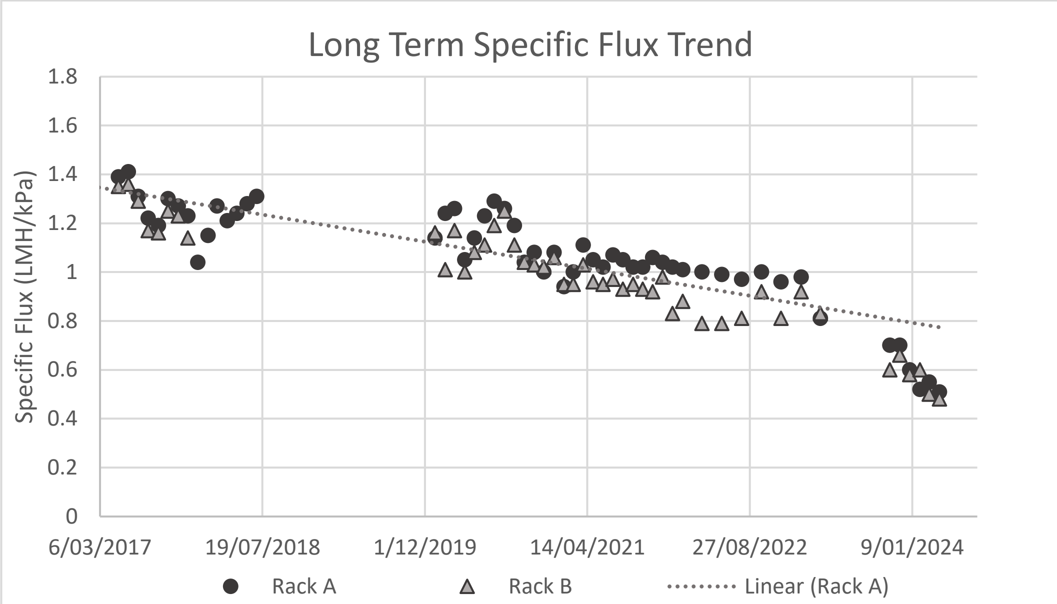



**Figure 1:** ***Tea Gardens WTP long term specific flux trend***

## 2.0 DISCUSSION

### 2.1 Membrane Autopsy

A membrane autopsy was organised to improve Councils understanding on the cause of the accelerated fouling. A membrane autopsy is similar to a regular autopsy, it involves cutting open a membrane module to examine the condition of the internal membrane fibres and enables various types of analysis to be undertaken. Laboratory analysis is utilised to assess the structural condition of the membrane fibres as well as determine the type and degree of fouling. The analysis included carbonate and metals testing, Loss on Ignition (LOI) and Thermogravimetric Analysis (TGA), Fourier Transform Infrared (FTIR) and Energy Dispersive (EDS) Spectroscopy, as well as Scanning Electron Microscope (SEM) imaging.

The key findings include:

- Carbonate and metals testing indicated the presence of metals, but not carbonates, confirming the foulant observed was likely metallic in nature.
- LOI and TGA analysis confirmed the presence of inorganic foulant on the membrane fibres.
- Both FTIR and EDS spectroscopy confirmed the presence of foulant layers coating the membrane fibres. Fibres taken from the centre of the module were coated with a uniform foulant layer, composed largely of iron and iron oxides/hydroxides.
- EDS of the interior and exterior of a membrane fibre revealed the presence of foulant on both the feed and filtrate sides of the membrane. Weight percentage (w/w %) found iron to be the primary foulant at 25.3% weight, with aluminium the second highest foulant at 2.1% weight.
- SEM imaging showed the membrane fibres to be free from perforations or damage. The central fibre sample showed a uniform coating of foulant, covering a large portion of the fibre interior and exterior.

In summary, the structural condition of the membrane fibres was fair to good, however, heavy fouling caused primarily by iron was identified as the cause of performance deterioration.

## 2.1 Membrane Cleaning Study

Following the membrane autopsy, a laboratory cleaning study was commissioned and carried out by Avista Membrane Treatment Solutions. The study was carried out on fibres from the "inner" and "outer" areas of the membrane module. The cleaning study tested a range of chemical cleaners to determine the most effective product and cleaning regime for overall improvement in permeability. Normalised permeability was calculated pre- and post-clean to determine the percentage of change, and the low pH membrane cleaner called Avista127 provided the best results, as shown in the table below:

**Table 1:** ***Membrane Cleaning Permeability Results***

| Cleaner | Permeability (LMH/kPa) | | Percentage Change |
|---|---|---|---|
| | Pre-Clean | Post-Clean | |
| Avista127 Outer fibre | 0.73 | 1.66 | +228% |
| Avista127 Inner fibre | 0.73 | 1.46 | +200% |

Tensile strength was measured pre- and post-clean to determine if there was any deterioration in membrane fibre strength. Table 2 shows no loss in fibre strength for a 2% cleaning solution over an 8 hour clean.

**Table 2:** ***Membrane Cleaning Tensile Strength Results***

| Fiber Sample | Tensile Strength (N) | |
|---|---|---|
| | Pre-Clean | Post-Clean |
| Avista127 Outer fibre | 8.5 N | 8.5 N |
| Avista127 Inner fibre | 8.5 N | 8.5 N |

The figure below shows the visual foulant removal of an inner membrane fibre before and cleaning.

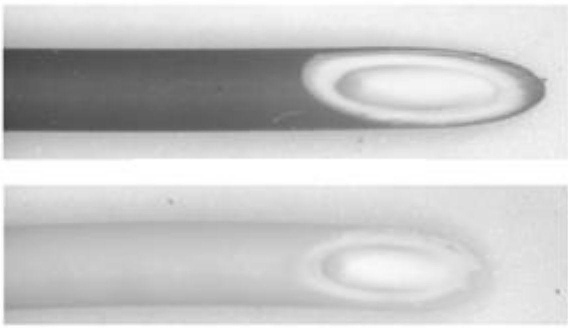


**Figure 2:** ***Upper – membrane fibre pre-clean, Lower – membrane fibre post-clean.***

## 2.1 Membrane Cleaning Results

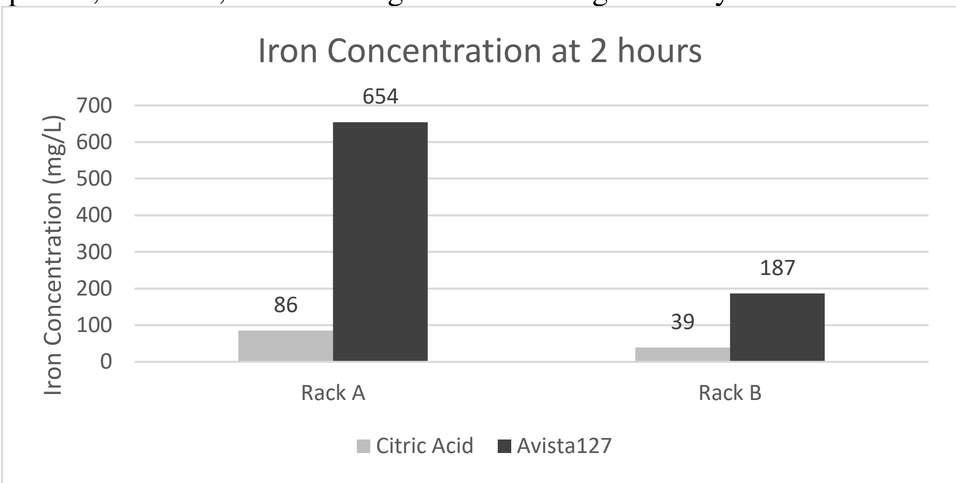
An onsite membrane cleaning study was carried out on the Tea Gardens WTP membranes. The study was undertaken over two trial periods to test the chemical cleaning effectiveness under two configurations. The first trial established the performance of Avista127 and its ability to clean both membrane racks with the same batch of chemical. The second trial tested the effectiveness of cleaning a single rack with increased chemical recirculation time. Details of each trial are provided below.

### Trial One

The first trial included cleaning both membrane racks with citric acid and Avista127 to compare performance. Both chemicals were circulated for 2 hours and maintained at 38°C for the duration of the clean. Avista127 and citric acid were batched at a strength of 2%

and 3% by weight respectively. Rack A and B were cleaned in order with the same chemical solution, with the citric clean occurring the day before the Avista127 clean. Intermittent sampling was undertaken on the CIP solution to measure the iron concentration as an indicator of removal effectiveness.

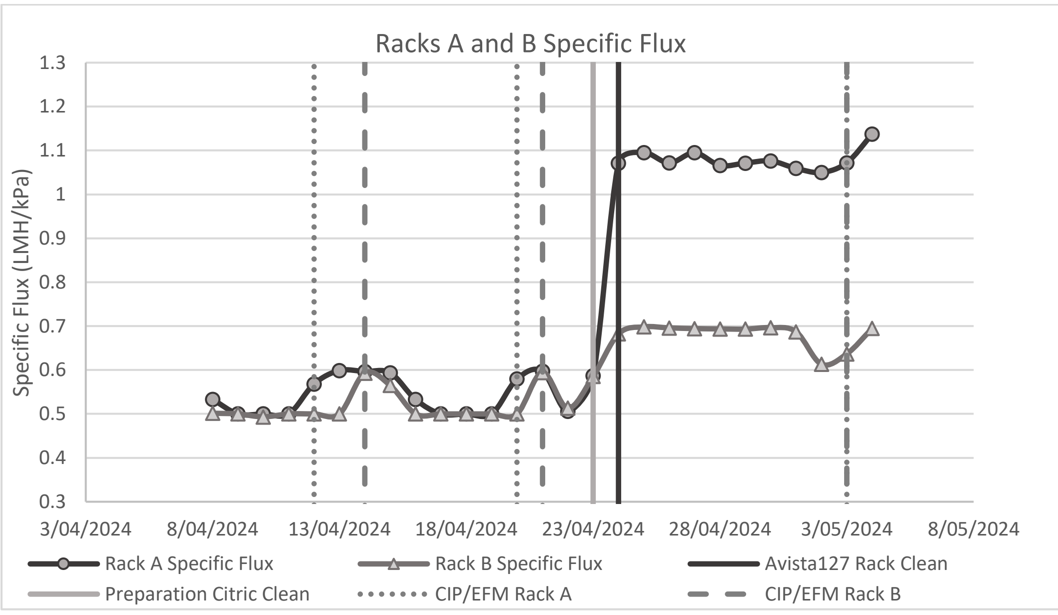
As shown in Figure 3 below, the Avista127 chemical achieved significantly higher iron removal when compared to conventional citric acid. At the 2-hour mark in Rack A, Avista127 removed approximately 8x more iron (654 mg/L to 86 mg/L) than citric acid. Rack B received the spent solution for both cleans and the removal effectiveness is shown to be impacted, however, Avista127 again removed significantly more iron.




**<u>Figure 3:</u>** ***CIP solution iron concentration at 2 hours of circulation***

Figure 4 shows the Avista127 clean provided improvements in specific flux recovery when compared to citric cleans that were conducted in the days and weeks prior. The specific flux recovery in Rack A and B was 0.6 and 0.2 LMH/kPa respectively, from their baseline of 0.5 LMH/kPa. The recovery in Rack A represents a 220% improvement in specific flux. Operation of the plant for the following week showed minimal loss in specific flux, with a recent citric clean recovering flux back to the new baseline for each rack.

Transmembrane Pressure (TMP), feed pressure and rack flow likewise presented improvements following the Avista127 clean. Rack A feed pressure and TMP reduced by 30 kPa or 25%, while rack flow increased by 30 m3/hr.

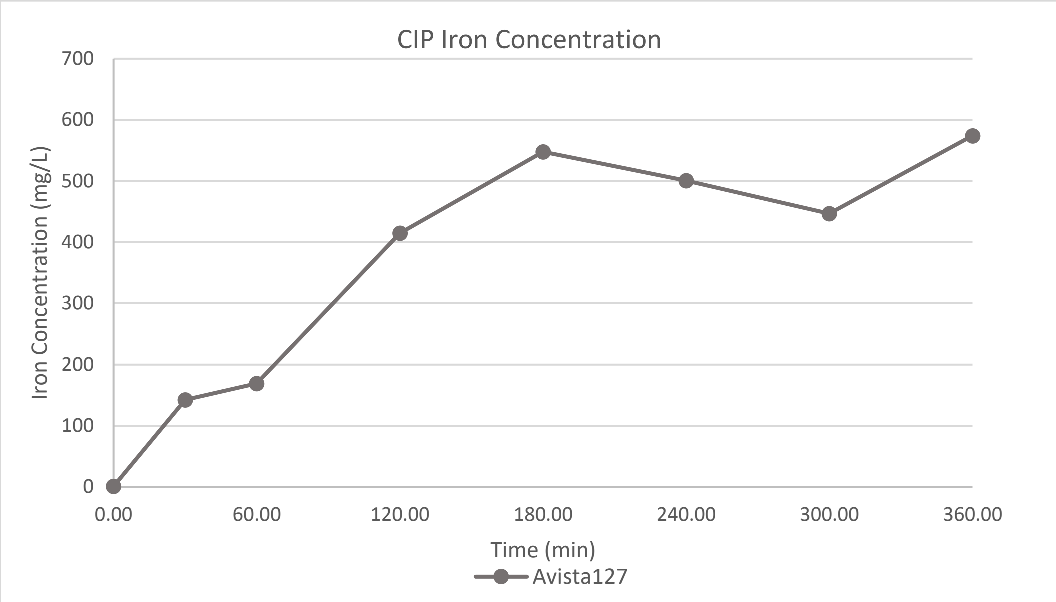



**<u>Figure 4:</u>** ***Trial One membrane specific flux recovery***

**Trial Two**

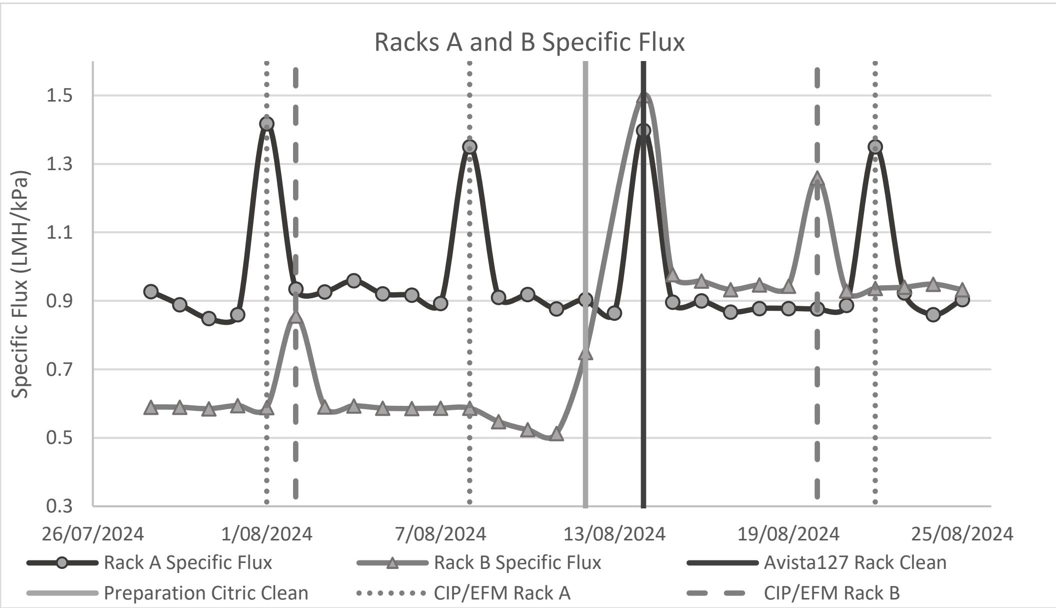
The second trial extended the Avista127 chemical clean duration from 2 hours to 6 hours to determine if further performance improvements could be achieved with increased contact time. Similar to Trial One, Avista127 was batched at 2% and maintained at 38°C for the duration of the clean. A citric acid clean was carried out the day prior.

Figure 5 presents the iron concentration over the duration of the chemical clean. The rate of removal is linear up until the 3-hour mark, in which the concentration began to peak. A slight decline in iron concentration is seen in several results after the 3 hour mark, however it is thought that these results that may be caused by analysis or sampling error.




**<u>Figure 5:</u>** ***CIP solution iron concentration over time***

Figure 6 presents the specific flux recovery for the second trial. Similar to the first trial, the Avista127 clean provided significant improvements in specific flux compared to citric cleans. Rack B recovered 0.4 LMH/kPa, from the baseline of 0.6 LMH/kPa, representing a 165% improvement in specific flux.




**<u>Figure 6:</u>** ***Trial Two membrane specific flux recovery***

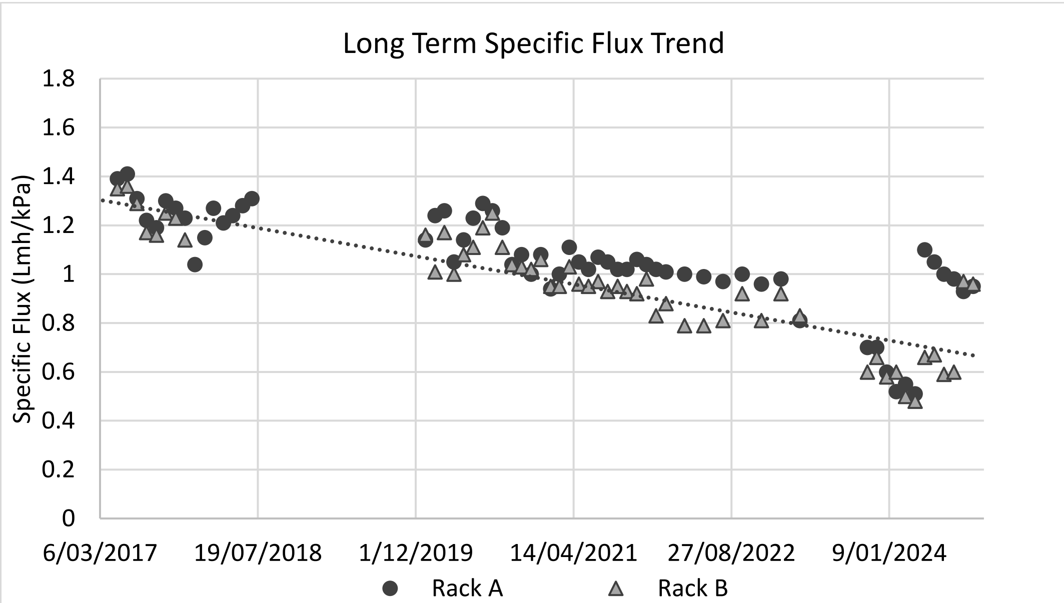
## 3.0 CONCLUSION

### 3.1 Outcomes of the Project

The cleaning study with Avista127 low pH membrane cleaner was successful. The recovery in membrane flux and reduction in TMP has allowed Council to reliably continue operation of membranes at design treatment flows without the risk of accelerated membrane failure due to high feed pressures. The outcomes from the membrane autopsy and cleaning study have given the operations team confidence in the continued operation of membranes well outside their warranty period given the good structural condition of the membrane fibres and recovery of specific flux performance.

Reviewing the financial aspects of the project, two key areas are considered; reduced power usage and prolonged membrane life. The power assessment found an annual saving of ~$28,000/yr due to reduced feed pressures and pumping costs. Assuming useful membrane life of 11 years (2013-2024), each year of continued operation represents a saving of ~$29,000/yr in membrane replacement costs. The cost of Avista127 chemical totalled $7,000 to clean both racks.

Ongoing review of Rack A performance 6 months after the chemical clean has had specific flux stabilise between 0.90-0.95 LMH/kPa, up from the original 0.5 LMH/kPa. It is Councils intention to repeat the Avista127 clean on a 12 month basis to maintain specific flux targets. Figure 7 presents the ongoing specific flux trend.




**<u>Figure 7:</u>** ***Tea Gardens WTP long term specific flux trend***

## 4.0 ACKNOWLEDGEMENTS

A special thanks to Shannon Doherty, Corey Bates and the MidCoast Council Water staff who played a critical role in carrying out and analysing the performance of the membrane cleans.