

# ADVANCING WATER RECYCLING IN RED MEAT PROCESSING WITH NATURAL COAGULANT AND CERAMIC MEMBRANE

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## KEYWORDS

Water recycling, natural coagulant, ceramic membrane, circular economy.

## ABSTRACT

In response to intensified water consumption in red meat processing facilities, a Western Australian red meat plant aiming to recycle water from the final wastewater treatment pond for use in cooling towers and boilers encountered algal-related challenges within its reverse osmosis-based recycling system.

This paper investigates the use of coagulation combined with ceramic membrane filtration as a pre-treatment to reverse osmosis, based on bench-scale testing and an on-site pilot trial. At the bench scale, the natural coagulant Tanfloc provided the most effective clarification at the lowest dosage while also generating the least amount of sludge. Ceramic membrane filtration downstream of coagulation achieved permeate turbidity as low as 0.02 NTU and maintained stable flux and transmembrane pressure across operating cycles. Although dissolved air flotation (DAF) proved effective during testing, it was excluded from the pilot due to existing site infrastructure constraints. Replication of the coagulation-ceramic membrane configuration at pilot scale restored reliable reverse osmosis performance. The integrated double-barrier approach demonstrates a scalable and robust solution for resilient non-potable water reuse across multiple industries.

## INTRODUCTION

Australia's red meat processing sector is among the largest food processing industries in the country, contributing over \$21 billion annually to the economy and supporting approximately 138,000 jobs (AMPC, 2024). Despite its economic significance, the sector has a substantial environmental footprint. In 2024, water intake was recorded at 7.3 kL/tHSCW, of which around 6.5 kL/tHSCW, representing 89% of intake, was discharged as wastewater (AMPC, 2025).

To mitigate this impact, the industry has implemented numerous initiatives aimed at improving water-use efficiency, including the adoption of recycled water for non-food contact operations. A typical non-potable water recycling

plant in a red meat processing facility incorporates multiple treatment stages such as coarse filtration, ultrafiltration, ion exchange, reverse osmosis (RO), and microbial control barriers. However, when the source water originates from open systems such as ponds, algae contamination presents significant challenges that can compromise system performance, necessitating additional treatment measures.

This paper introduces an innovative approach that integrates natural coagulants and ceramic membrane technology to effectively manage algae-laden water within non-potable water recycling systems, based on bench-scale and pilot tests executed at Tessele Consultants and a red meat facility in the Great Southern of Western Australia, respectively.

## METHODOLOGY

This study comprised bench-scale tests and pilot trials. The bench-scale tests aimed to evaluate the efficiency of a natural coagulant compared to conventional options, determine the optimal dosing for algae-laden water, and identify the settling system required for effective on-site coagulation. Insights from these tests guided adjustments to the on-site water recycling system to align with expected outcomes.

A structured approach was adopted for the bench-scale tests, which were executed with the recycling water system inlet stream sample (algae-laden water). The tests were divided into three phases:

### **Phase 1 – Coagulant Comparison**

Jar tests were conducted to compare coagulant performance. Key parameters assessed included turbidity, colour and pH.

### **Phase 2 – Settling, Sludge Generation, and Flotation Assessment**

The settling behaviour of coagulated samples was monitored using graduated cylinders and time-based observations, a standardised procedure to quantify the sludge mass generated post-coagulation and dissolved air flotation (DAF) tests were also

performed, the latter followed by analysis of turbidity, colour and pH.

### Phase 3 – Ceramic Membrane Filtration

Ceramic membrane tests involved clean water and sample permeability experiments. The permeability test used the best-performing coagulant and its optimal dose identified in Phase 1. After coagulation, various liquid–solid separation processes were applied before ceramic membrane filtration. These processes influenced membrane performance and helped determine the most suitable option for pilot-scale implementation between coagulation and ceramic membrane filtration at the studied red meat facility. The scenarios evaluated before ceramic membrane filtration are summarised in Table 1 below.

Table 1: Scenarios evaluated before ceramic membrane filtration.

Scenario	Description
A	Sample without coagulation (baseline)
B	Coagulation followed directly by ceramic membrane filtration
C	DAF before ceramic membrane filtration
D	Gravity settling before ceramic membrane filtration

In assessing membrane performance, the key parameters considered were the transmembrane pressure (TMP) throughout a 15-minute filtration cycle, the initial pressure immediately after backwashing, and the behaviour of these parameters across successive cycles. These quantitative measurements were complemented by qualitative observations made during the experiments. In addition, the permeate flux rate was recorded for each scenario, indicating the maximum capacity achievable by a pilot-scale ceramic membrane system.

During on-site pilot trials, the optimal coagulant dosing and ceramic membrane cycles identified at bench scale were successfully replicated. This allowed the water recycling pilot system, previously compromised by algae growth in the reverse osmosis unit, to operate smoothly without issues.

## RESULTS

### Bench Scale Tests

After testing all coagulants, the optimal dosage (with pH adjustment) was determined for each and compared to identify which coagulant required the lowest concentration while still achieving good turbidity and colour removal. These results are presented in Figure 1 and Table 2.

After coagulation with the optimal dosing (with pH adjustment), the settling behaviour of the coagulated

samples was evaluated over 60 minutes. All coagulants exhibited rapid initial settling within the first 15 minutes, with the metallic coagulants settling more quickly and producing a clearer supernatant than Tanfloc during the early stages. Thereafter, settling gradually stabilised. Final sludge volumes after 60 min were lowest for Ferric Sulphate (120 mL), followed by PAC (130 mL), Ferric Chloride (140 mL) and Tanfloc (140 mL), while ACH stabilised at a slightly higher volume (170 mL). This analysis is shown in Figure 2.

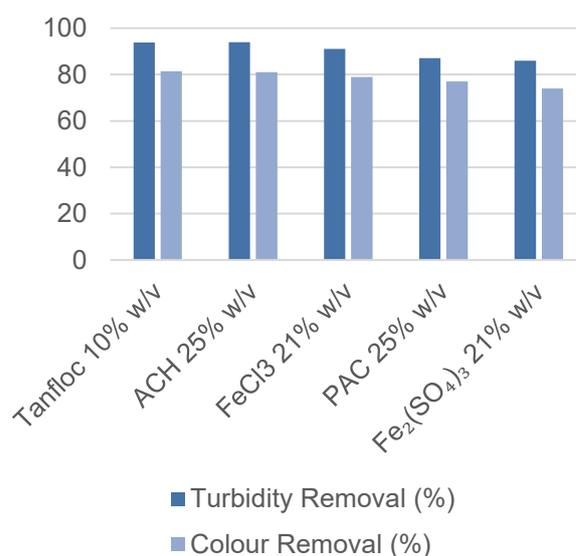


Figure 1: Turbidity and colour removal rates for different coagulants.

The mass of sludge generated per litre of treated water at the pre-determined optimised dosage (with pH adjustment) of each coagulant is shown in Figure 3. Tanfloc produced the lowest sludge yield (0.21 g/L), followed by ACH (0.26 g/L) and PAC (0.28 g/L). In contrast, the ferric coagulants generated considerably more sludge, with Ferric Chloride and Ferric Sulphate producing 0.51 g/L and 0.53 g/L, respectively.

The DAF tests demonstrated that dissolved air flotation is an effective separation technology for all coagulants assessed. In every case, the process successfully floated the coagulated sludge to the surface, leaving a clarified supernatant from which clean water could be obtained, as shown in Figure 4. Tanfloc produced the highest removal efficiencies, achieving 95 % turbidity reduction and 85 % colour reduction, followed by PAC and Ferric Chloride, which both provided more than 80 % turbidity removal and 70–75 % colour removal. Although ACH and Ferric Sulphate were less effective, they still delivered notable improvements compared with raw water. These findings confirm the capability of DAF to efficiently separate coagulated particles and improve water quality. Table 3 summarises ceramic membrane permeability results across different upstream separation processes.

Table 2: Coagulant comparison summary.

Coagulant	Dosage (ppm)	Turbidity Removal (%)	Colour Removal (%)	Final pH
Ferric Chloride	168	91	79	5.8
Ferric Sulphate	168	86	74	5.9
ACH	100	94	81	6.4
PAC	100	87	77	6.5
Tanfloc	80	94	81	6.4

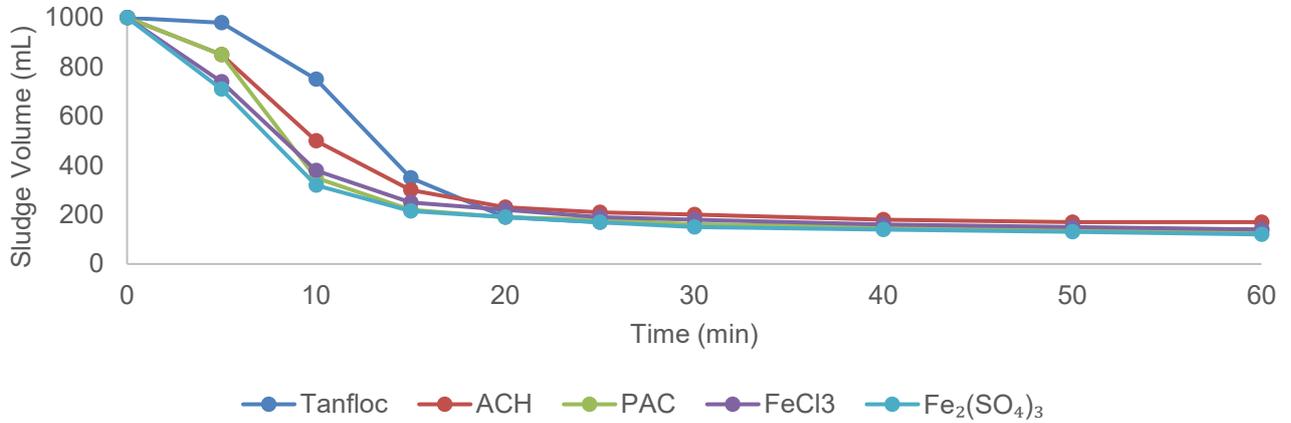


Figure 2: Settling test: sludge volume vs time.

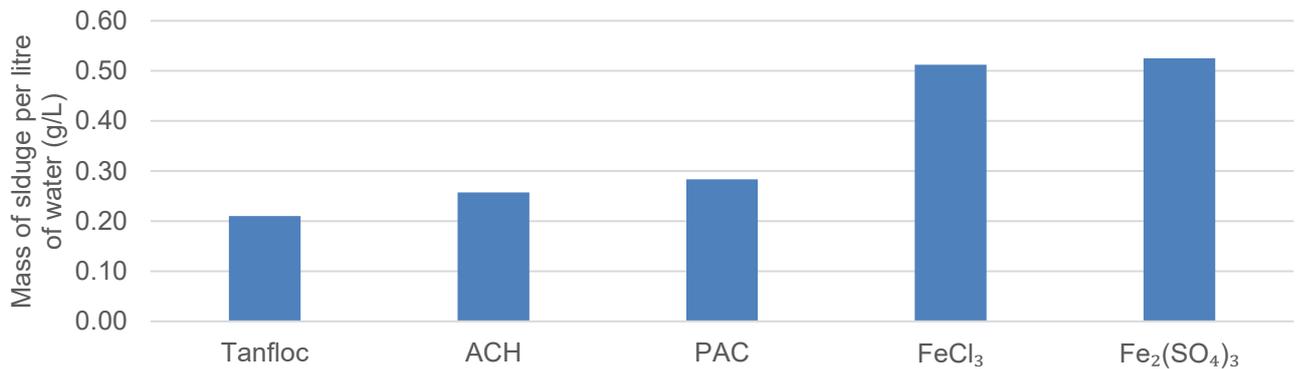


Figure 3: Mass of sludge per litre of sample at the pre-determined optimised dosage of each coagulant.

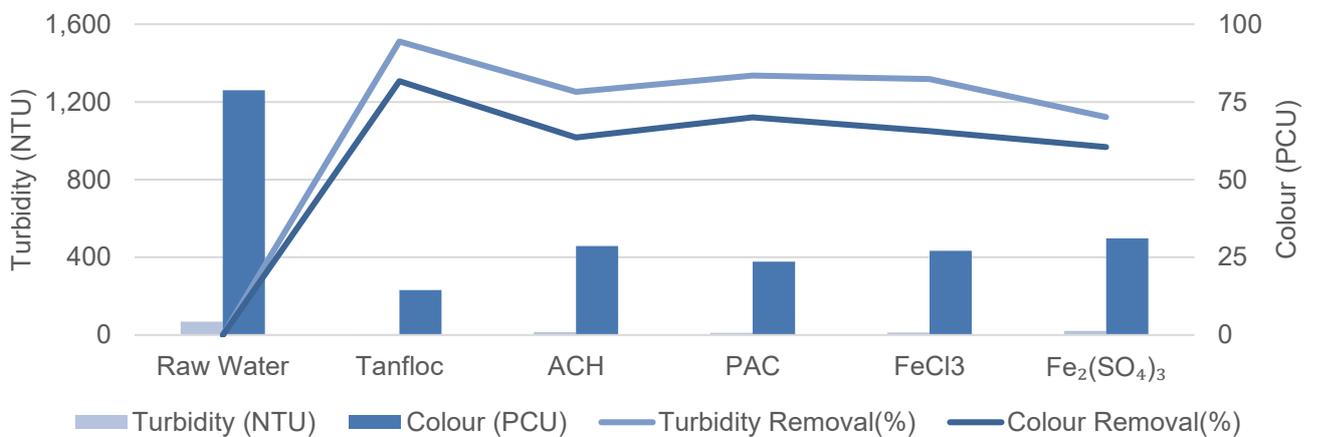


Figure 4: Turbidity and colour results after DAF.

Table 3: Ceramic membrane (CM) bench scale results.

Scenario	Turbidity post CM (NTU)	Colour post CM (PCU)	Permeate Flux (LMH)
A	0.2	309	52.2
B	0.02	83	75.3
C	0.3	83	97
D	0.2	94	60.7

### Pilot System

The recycling water pilot system included level control systems to ensure the process operated according to the design flow rates. In addition, samples were taken from sampling points distributed along the process pipeline to allow easy and continuous validation. Table 4 presents a brief description of each sampling point. Samples were taken for 4 weeks. Figure 5 shows samples collected during week 4. The sampling points results are shown in Table 5 and Table 6. Figure 6 shows the ceramic membrane at a pilot scale used in this project.

Figure 5. Samples collected in week 4, from SP A (left) to SP E (right).



Figure 6. Ceramic membrane pilot skid on site.



Table 4: Sampling point descriptions.

Sampling point	Description
A	Pond water (recycling water system intake stream)
B	Ceramic membrane (CM) permeate (effluent from coagulation with Tanfloc followed by ceramic membrane filtration)
C	Reverse osmosis (RO) permeate
D	CM reject
E	RO reject

Table 5: Sample results from the pilot trial on site (weeks 1 and 2).

Parameter	Unit	Week 1					Week 2				
		SP A	SP B	SP C	SP D	SP E	SP A	SP B	SP C	SP D	SP E
Phosphorus	mg/L	70	55	0.063	58	n/a	75	62	<0.050	61	63
pH	pH units	9.5	8.3	6.1	8.4	n/a	9.8	8.4	6.5	8.3	8.1
Electrical Conductivity	µS/cm	2,800	2,200	28	2,200	n/a	2,800	2,300	25	2,400	3,100

Parameter	Unit	Week 1					Week 2				
		SP A	SP B	SP C	SP D	SP E	SP A	SP B	SP C	SP D	SP E
Total Dissolved Solids	mg/L	1,800	1,300	17	1,500	n/a	1,900	1,600	15	1,600	1,900
Total Suspended Solids	mg/L	66	<5.0	<5.0	43	n/a	140	<5.0	<5.0	25	<5.0
Total Nitrogen	mg/L	14	9.2	<0.50	12	n/a	18	9.3	0.37	12	6.4
Chlorophyll a	mg/m <sup>3</sup>	300	<2.0	2.1	96	n/a	n/a	n/a	n/a	n/a	n/a
BOD	mg/L	7.8	<5.0	<5.0	<5.0	n/a	41	<5.0	<5.0	<5.0	<5.0

Note that SP E was not included in the week 1 sampling due to limited RO purge during the sampling period.

Table 6: Sample results from the pilot trial on site (weeks 3 and 4).

Parameter	Unit	Week 3					Week 4				
		SP A	SP B	SP C	SP D	SP E	SP A	SP B	SP C	SP D	SP E
Phosphorus	mg/L	72	61	<0.050	62	150	71	66	0.056	67	200
pH	pH units	9.7	8.8	6.6	8.4	8.1	9.7	8.7	8.7	8.7	8.2
Electrical Conductivity	µS/cm	2,800	2,400	32	2,400	5,300	2,800	2,600	51.0	2,600	7,600
Total Dissolved Solids	mg/L	1,800	1,600	19	1,500	3,400	1,700	1,500	31.0	1,600	5,200
Total Suspended Solids	mg/L	100	<5.0	<5.0	25	7.5	59.0	<5.0	<5.0	56.0	<5.0
Total Nitrogen	mg/L	15	9.9	0.43	14	14	15.0	11.0	0.7	15.0	23.0
Chlorophyll a	mg/m <sup>3</sup>	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
BOD	mg/L	6.7	<5.0	<5.0	11	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

## DISCUSSION

### Bench Scale Tests

The coagulant that achieved the highest turbidity and colour removal requiring the lowest dosage was Tanfloc, demonstrating its feasibility for the project. It also produced the smallest sludge volume per litre of treated sample. This indicates that this coagulant not only delivers competitive clarification performance but also significantly reduces sludge generation, which is advantageous for downstream handling and disposal on-site. In terms of settling behaviour, Tanfloc exhibited longer settling times compared to other coagulants. However, this was not a limitation for the recycling water pilot system, given the large capacity of the existing settling tank. The DAF (Dissolved Air Flotation) tests showed good turbidity and colour removal across all coagulants tested. However, a DAF system was not considered for the recycling water pilot due to its operational complexity, operator skill requirements, and typical application for suspended solids and oil/grease removal, which is not the case for the pre-treatment before the RO unit at the studied red meat facility.

Ceramic membrane testing confirmed that coagulation combined with settling enhances filtration performance. Increasing pump rotation achieved significant process flux while remaining within the supplier's TMP limits.

### Pilot System

Based on the results obtained from the analysed sample points from the pilot system, a significant reduction in key water quality parameters was observed throughout the water treatment process. This performance is attributed to the implementation of a double-barrier technology upstream of the reverse osmosis stage, consisting of coagulation followed by ceramic membrane. These two processes were the main contributors to solids removal, evidenced by marked decreases in chlorophyll-a (a proxy for algal biomass) and other particulate-associated constituents, including total suspended solids (TSS), biochemical oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP). The reverse osmosis stage provides effective removal of total dissolved solids (TDS), which is directly reflected in the corresponding reduction in electrical conductivity (EC).

## CONCLUSION

The bench-scale tests informed the design and operation of the water recycling pilot system at the studied red meat processing facility. Incorporating a natural coagulant in combination with a ceramic membrane upstream of the reverse osmosis (RO)

unit improved RO permeate quality and prevented maintenance issues associated with membrane fouling, previously caused by algae. Optimisation of the on-site water recycling system enabled water reuse for applications such as the cooling tower and boiler for the system's outlet stream. The process also produced high-quality water after coagulation and after ceramic membrane filtration, suitable for non-critical uses within the facility, including cattle and truck washing. The integration of natural coagulation with ceramic membrane filtration represents a pioneering and sustainable water-recycling treatment method, with strong potential for application across a wide range of industries.

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## REFERENCES

AMPC. 2024. Annual report 2023–2024: The cutting edge of change. Sydney: AMPC.

AMPC. 2025. Environmental performance review 2024. Sydney: AMPC

