CITRIC ACID CLEANING: IMPROVING ROUGHING FILTER PERFORMANCE AT NEPEAN WFP

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ABSTRACT

Nepean Dam supplies raw water to the Nepean Water Filtration Plant (WFP), where quality fluctuates significantly due to rainfall-driven inflows and catchment runoff. These variations often elevate colour and turbidity, requiring precise chemical dosing to maintain effective coagulation. The roughing filter beds at Nepean WFP serve as key pretreatment units and are packed with polypropylene beads that improve debris retention but progressively accumulate gunk, scale, and fouling.

Over time, the roughing filter polypropylene media accumulate scaling and particulate fouling, including lime scale, ferric deposits, and residual polymers, which reduces particulate capture, limits hydraulic capacity, and restricts airflow. Lime buildup also reduces the media's surface charge, further decreasing effectiveness. To restore performance, the Nepean WFP team trialled several cleaning agents and selected food-grade citric acid at 2.5 % as the safest and most effective option.
Samples collected before and during the citric wash showed substantial increases in scale-forming cations, with calcium up ~61 %, magnesium ~18%, strontium ~37 %, and barium ~179 % relative to baseline. Indicating active dissolution of carbonate and lime deposits. After flushing, metal levels returned to or below pre-wash values, confirming effective fouling removal with no residual impacts. Airflow to the roughing filter improved by about 122 %, significantly enhancing backwash efficiency.

1.0 INTRODUCTION

Nepean Dam is the sole raw water source for the Nepean WFP, which supplies potable water to approximately 30,000 people across the Wollondilly Shire of New South Wales. Raw water from Nepean Dam is pumped to the treatment plant, where ferric chloride ($FeCl_3$), cationic polymer, chlorine and non-ionic polymer are dosed to facilitate coagulation and flocculation. Most solids generated during the coagulation and flocculation process are subsequently removed in adsorption clarifiers (roughing filters) containing buoyant polypropylene media. Water leaving the roughing filters is then treated through dual media gravity filters before being supplied to customers **(Figure 1).**

As a surface water source, Nepean Dam is subject to significant variability in raw water quality driven by rainfall, catchment runoff and seasonal conditions. High rainfall events typically increase turbidity and solids loading, whereas lower runoff conditions are often associated with elevated colour from dissolved organic matter. These fluctuations influence treatment performance, chemical demand and filter run times, creating ongoing operational challenges that require adaptive management strategies (1). The treatment challenges associated with varying source water conditions are summarised in **Table 1.**

However, additional operational challenges emerged prior to the 2025-26 peak demand season. With only one raw water pump in service, maintaining treatment capacity while minimising internal plant water consumption became critical to meeting projected demand.

Table 1: Impact of raw water quality on adsorption clarifier performance

Raw water condition	**Impact on roughing filters**
High turbidity, low colour	Increased solids loading, higher head loss, frequent backwashing and shorter filter run times.
Low turbidity, high colour	Increased coagulation optimisation requirements to maintain colour removal, filter run times and minimise downstream filter breakthrough.
High turbidity, high colour	Maximum fouling risk and operational complexity, with increased chemical demand, greater headloss development and a higher risk of downstream filter breakthrough.

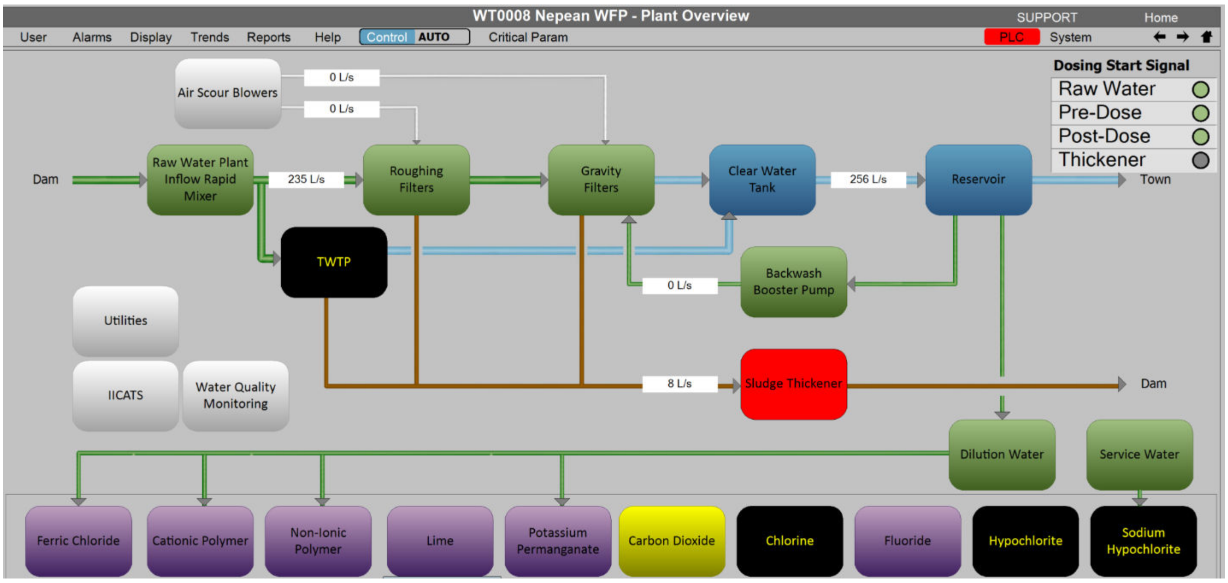

Figure 1-*Nepean WFP Process flow diagram*

During routine operation, the roughing filters exhibited declining hydraulic performance and were unable to consistently provide the throughput required to meet projected summer demand. In the absence of differential pressure monitoring, filter condition was assessed using indirect indicators, including elevated flow splitter levels, restricted hydraulics and airflow resulting in uneven air scour patterns, and increased outlet turbidity. These observations indicated progressive fouling of the polypropylene media by lime scale, ferric solids and residual polymers. The resulting reduction in bed porosity and hydraulic capacity impaired backwash effectiveness and treatment performance. Extended air and water scour cleaning provided only short-term improvements while increasing backwash duration and reducing production capacity. Consequently, chemically enhanced cleaning was investigated to remove accumulated deposits, restore media functionality and recover filter capacity.

2.0 DISCUSSION

Manufacturer guidance indicates that buoyant polypropylene media typically requires routine inspection but not replacement under normal operating conditions (2). However, operational experience has shown that fouling of the media and associated components can progressively restrict hydraulics, reduce treatment performance and, in some cases, necessitate costly refurbishment or replacement (3).

Chemical cleaning was therefore identified as a potential cost-effective alternative to asset renewal and production downtime. However, limited information is available regarding suitable cleaning agents, cleaning frequencies and cleaning methodologies for buoyant media adsorption clarifiers. To address this knowledge gap, the Nepean WFP team undertook laboratory-scale and full-scale investigations to evaluate chemically enhanced cleaning options and identify an effective method for removing accumulated fouling and restoring filter performance. This paper presents the methodology, results and operational outcomes of implementing citric acid cleaning on polypropylene media roughing filters.

2.1 Cleaning agent investigation

A laboratory investigation was undertaken to identify a cleaning agent capable of removing accumulated fouling while maintaining polypropylene media integrity. Based on the likely foulants identified within the roughing filters, several potential cleaning agents were considered **(Table 2).** Literature review identified food-grade citric acid as an effective agent for removing calcium, magnesium, and iron-based deposits through dissolution and metal chelation mechanisms. Citric acid was selected due to its compatibility with polypropylene media and lower material compatibility risks than stronger mineral acids.

Table 2: Literature-based assessment of cleaning agents for roughing filter fouling

Contaminant	Cleaning agent	Concentration
Ferric chloride	Citric acid or dilute HCl	5–10 %
Lime ($Ca(OH)_2$)	Dilute acetic acid or citric acid	5–10 %
CO_2 (carbonates)	Citric acid	5 %
Non-ionic polymer	Alkaline detergent (e.g., Alconox)	0.5–2 %
Cationic polymer	Alkaline detergent + mild acid rinse	0.5–2 % detergent + 5 % acid

DuPont Water Solutions. (2026). *DuPont™ IntegraTec™ module MEV solution: Process and design manual* (Form No. 45-D04596-en, Rev. 2). DuPont de Nemours, Inc.
Gul, A., Hruza, J., & Yalcinkaya, F. (2021). *Fouling and chemical cleaning of microfiltration membranes: A mini review. Polymers, 13*(6), 846. https://doi.org/10.3390/polym13060846

2.2 Laboratory trial methodology

Following selection of citric acid as the preferred cleaning agent, laboratory-scale trials were undertaken to determine an effective concentration and contact time for removing accumulated fouling from the polypropylene media. Representative media samples were collected from the roughing filters and visually assessed to confirm the presence of ferric deposits, lime scale and residual polymer fouling. Samples were then exposed to citric acid solutions at concentrations of 0.5 %, 1.0 %, 2.5 %, 5.0 % and 50 % **(Figure 2).**
To simulate agitation during full-scale implementation, samples were placed on a magnetic stirrer throughout the soaking period. Performance was evaluated after 30 minutes, 1 hour, 2 hours and 3 hours based on observed deposit removal, changes in solution colour and media condition **(Figure 3).**

Following treatment, the media were rinsed and subjected to a crush test to assess potential degradation from acid exposure. Citric acid effectively removed visible ferric and mineral deposits, with no evidence of media degradation observed following cleaning.

A citric acid concentration of 2.5 % with a contact time of approximately two hours provided effective removal of accumulated deposits while minimising chemical usage. Based on these results, a full-scale cleaning trial was undertaken.

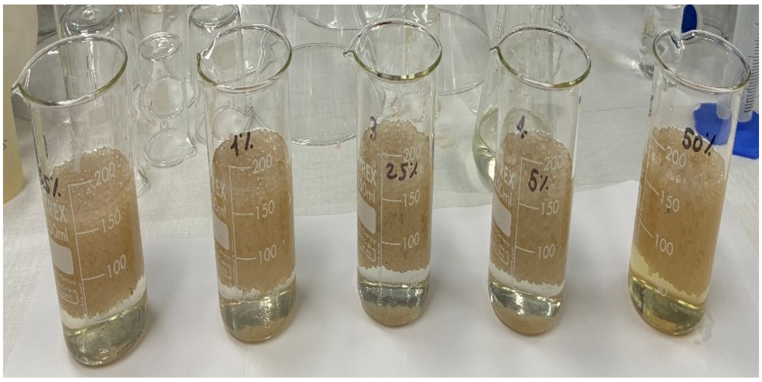

Figure 2- ***Beads with different concentrations of citric acid.***

Prior to full-scale implementation, the volume of an individual roughing filter was estimated from site drawings to determine chemical requirements. The filter dimensions (7.2 m × 2.4 m × 3.0 m) provided a total volume of 51.8 m³. Assuming a media packing efficiency of 64%, the polypropylene media occupied approximately 33.2 m³, leaving 18.6 m³ available for cleaning solution. This assessment was used to determine the volume of citric acid required to achieve the target cleaning concentration during full-scale implementation.

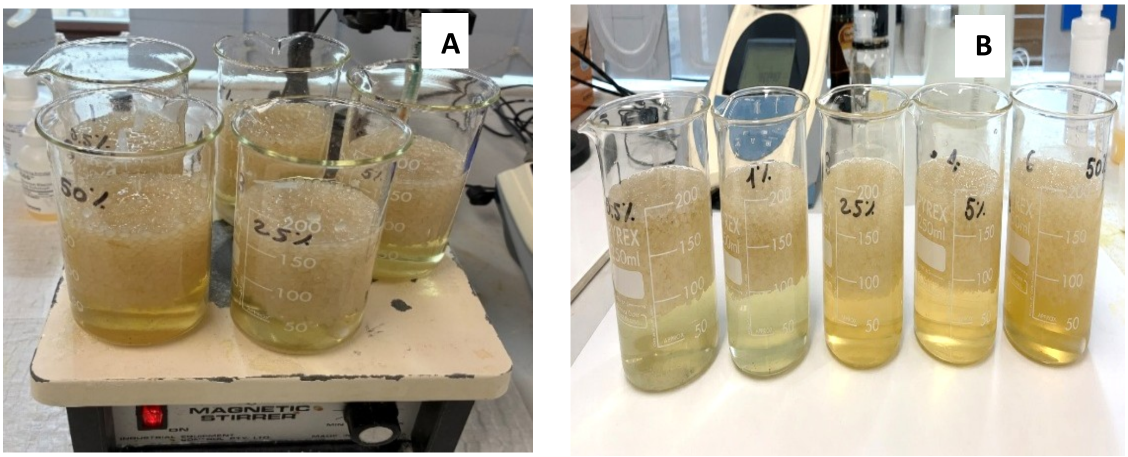

Figure 3A- ***Beads with citric acid soak on magnetic stirrer for varying time periods.***
Figure 3B- ***Soaking and rinse after two hours***

2.3 Full-scale citric acid cleaning trial

A full-scale cleaning trial was conducted on Roughing Filter 4 (RF4) using a 2.5 % citric acid solution. The cleaning solution was introduced into the filter and allowed to soak for approximately two hours before an air scour and backwash sequence was performed to

facilitate the removal of dissolved and dislodged deposits.
Water quality samples were collected during both conventional and citric acid backwashing at different times throughout the trial including the splitter overflow, air scour discharge, end-of-wash discharge and filtered water. The resulting data were used to evaluate the effectiveness of citric acid cleaning in removing accumulated fouling from the polypropylene media.

Comparison of the analytical results demonstrated substantially greater mobilisation of scale-forming and mineral-associated contaminants during citric acid cleaning than during conventional backwashing, indicating enhanced removal of accumulated deposits from the media bed.

2.4 Chemical analysis

Since the submission of the original abstract, further processing and analysis of the full-scale analysis has been completed, and the results presented below **(Figure 4)** therefore supersede the preliminary values reported in the abstract. At the end of air wash (5min), citric acid cleaning increased the release of:

- Calcium by 499 %
- Magnesium by 250 %
- Barium by 240 %
- Strontium by 193 %
- Manganese by 146 %

These results indicate that citric acid effectively dissolved and removed accumulated inorganic deposits, particularly calcium-based scale. The concentration of metals in the filtered water following cleaning returned to, or below, pre-cleaning levels**.** This demonstrated effective removal of fouling deposits without adverse impacts on treated water quality.

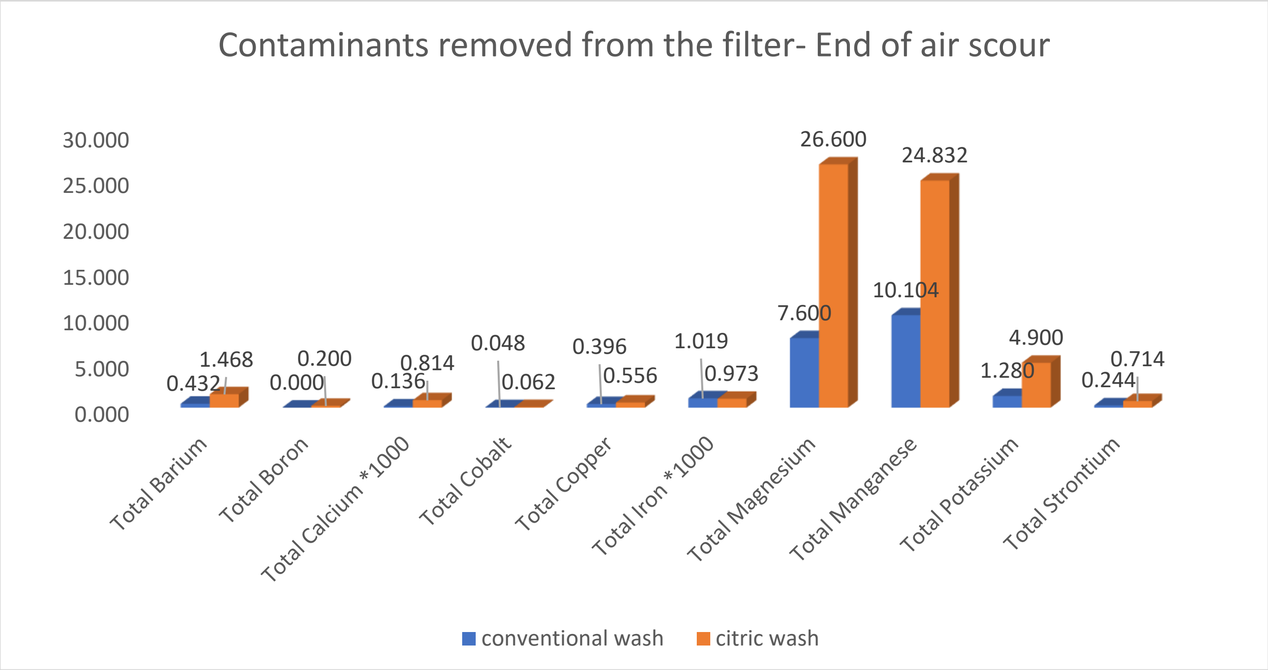

Figure 4- C*ontaminants removed from the filter(clarifier) in grams*

3.0 CONCLUSION

In addition to improving water treatment performance, the cleaning process resulted in a substantial increase in airflow through the roughing filter. Measured airflow increased from 59 L/s prior to cleaning to 197 L/s following cleaning, representing a 234 % increase in airflow capacity.

The increased airflow produced a more uniform scour pattern across the media bed and significantly improved backwash effectiveness. Restoration of air distribution and media fluidisation is expected to enhance solids capture, extend filter run times and reduce fouling accumulation.

The successful trial demonstrated that chemically enhanced cleaning can restore roughing filter performance without media replacement, providing a practical and cost-effective maintenance strategy to improve pretreatment reliability and sustain treatment capacity during periods of elevated customer demand.
The successful outcome demonstrated that chemically enhanced cleaning can restore adsorption clarifier performance without media replacement, providing a practical and cost-effective maintenance strategy for improving pretreatment reliability and supporting improved longer term capacity performance especially during higher customer demand periods.

4.0 ACKNOWLEDGEMENTS

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