ENABLING REGIONAL WATER SUPPLY WITH CERAMIC MEMBRANES – A CASE STUDY

Doug Moorby, *Utilities Manager,* Narromine Shire Council; **Jon Wright,** *Engineering & Product Development Manager,* Infinite Water;

ABSTRACT

Narromine Shire Council in regional NSW installed an innovative water treatment solution which is the first of its kind in Australia featuring next generation submerged flat-sheet ceramic membrane filtration technology. The council needed a system to treat water from an unsecure source high in metals, and susceptible to spikes in turbidity and seasonal algal blooms. Infinite Water supplied Narromine Shire Council with a skid-mounted treatment plant for easy integration with existing infrastructure.

Infinite Water selected Cerafiltec's ceramic flat-sheet membranes due to their:

- High flux rate
- High solids loading capacity
- Superior mechanical robustness
- High chemical tolerance
- Wide temperature range

Other benefits for improved water security and remote locations include:

- Simplified process design
- Compact footprint
- Suitability for intermittent operation & dry storage
- Ease of operation & low maintenance
- Long membrane life (10-year manufacturer's warranty)
- No irreversible fouling and full recovery with in-situ cleaning
- Simple upgrade for existing membrane plants

The Tomingley WTP in Narromine Shire council has received Section 60 approval by the Department of Planning & Environment under NSW's Safe and Secure Water Program.
With its low total cost of ownership, superior treatment capabilities, ceramic membranes are a unique enabler of water security in remote locations.

1.0 INTRODUCTION

Narromine Shire Council is an LGA in the Orana region of NSW, and includes the towns of Narromine, Trangie, and Tomingley. The council serves an estimated population of 7000 residents across an area of 5200km^2. The small town of Tomingley does not have a nearby source of either ground- or surface water and has historically been served by a water allocation from a nearby pipeline owned and operated by a mining company in the area. This groundwater is spasmodically delivered and stored in a surface lagoon prior to treatment and storage in two aboveground storage tanks. The allocation of 11 megalitres (ML) per year has been sufficient in terms of volume, but the treatment process was outdated and not capable of delivering potable water. Water held in the open lagoon not only suffers with high levels of metals such as iron and manganese found in the bore, but also high organic levels and being prone to microbiological contamination and subjected to ingress of fauna and flora including potential for algal blooms.

The decision to replace the plant was based on the severely compromised state of the previous plant which had until early 2013 been a full potable water treatment plant and was downrated to non-potable status. In early 2014 a plan was made to replace the old plant with a new Non-Drinking Water Filtered system only, however the grant received required the plant to obtain full Drinking Water Status. The sum of money initially allocated via the Grant and Councils contribution made this look a very remote possibility.

The requirements for a new treatment process are summarised as follows:

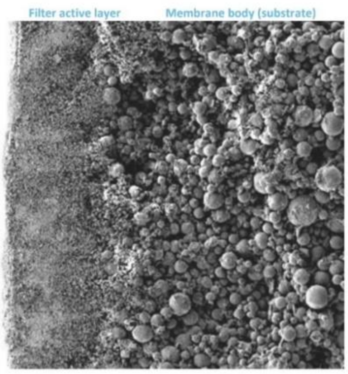
- The remote location required a robust treatment plant solution that could operate without staffing and minimal operator intervention.
- The council needed a system to treat water from an insecure source high in metals, and susceptible to spikes in turbidity and seasonal algal blooms.
- The plant needs to be able to produce 30 kilolitres per day (kL/d) of potable water meeting ADWG guidelines, with a high recovery rate.

2.0 DISCUSSION

2.1 Ceramic Membrane Technology

Submerged ceramic membrane technology has developed many applications in Europe and Middle East over recent years, however was yet to break into the Australian market. At the ultrafiltration scale, they have a number of advantages over their polymeric counterparts:

- Insensitive to pressure, temperature, chemicals;
- Stable, amorphous pore morphology without any size enlarging, dimensionally stable over complete lifetime (no ageing effects);
- Close to zero irreversible fouling;
- Can be exposed to air without detriment
- No polymer dosing required; pin-flocs formed immediately after coagulant dosing are sufficient without the requirement for long mixing or flocculation times;
- Highly hydrophilic and oleophobic; able to remove algae with easy cleaning;
- Uses cake layer filtration (CLF), where pin-flocs of suspended solids and precipitates from coagulation, aids filtration and further protects the membrane surface from fouling
- Ability to easily target PFAS and other micropollutants through addition of powder activation carbon (PAC) through operation with active cake layer filtration (ACLF)



Operational capabilities	
Solids loading tolerance (TSS)	1 ppm – 50.000 ppm
Temperature	2-60°C
Abrasive media in feed water	No limitations
Chemical tolerance	pH 2-12
Fat, Oil & Grease tolerance	Up to 400 ppm
Intermittent operation & dry storage	Allowed
Operational flux rate	1-1000 LMH

Fig 2.1 – Ceramic membrane pore morphology (left); Membrane operational capabilities (right)

Cerafiltec membranes are supplied in standard modules containing 34 ceramic flat sheets with <0.1 micron pore size, which can be arranged in towers up to 16 units tall in height, which in turn can be arranged into banks or trains that can be manifolded together to achieve the required filtration capacity. Ceramic membrane technology can provide an extremely compact, robust and easy to operate solution for drinking water treatment.

Cerafiltec alumina-based membranes are provided with NSF 419 certification providing validation for log 4 removal of cryptosporidium. Ultrafiltration membranes with <0.1um pore sizes are able to consistently treat water to a turbidity < 0.2 NTU and SDI < 3.0, making it ideal also for reverse osmosis pre-treatment as well as wastewater recycling and in MBR applications.

2.2 Process selection

A public RFQ was prepared and distributed for proposals to deliver the new treatment plant. Responses were received and evaluated against the typical factors of cost, robustness, operability and fitness-for-purpose. The water quality used for the design basis is shown below in Table 1:

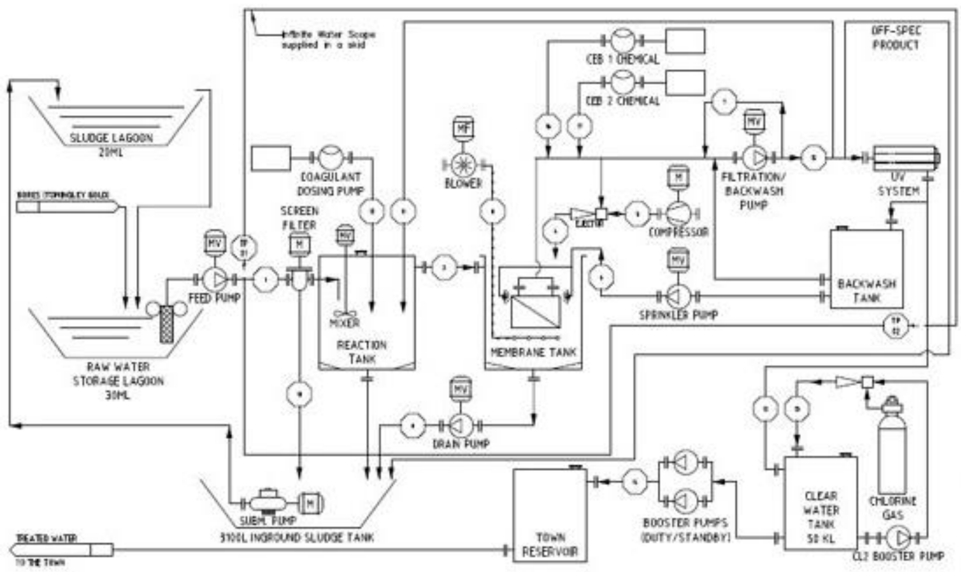
Table 1: Water quality design basis

Parameter (unit)	**Influent water quality**	**Discharge Criteria**
Temperature (ºC)	5-30	-
Turbidity (NTU)	2.5 - 30	≤ 0.1 NTU for 95% of month, not > 0.15 NTU for ≥ 15 consecutive minutes
True colour (HU)	<1 to 25	<10
pH	6.5 to 8.5	7.0 to 8.2
Total aluminium (mg/L)	0.11 to 1.5	<0.2
Total manganese (mg/L)	0.041 to 0.2	<0.05
Total iron (mg/L)	0.09 to 10	<0.1
E. coli (CFU/100mL)	<300	Not detected
Total dissolved solids (mg/L)	781	Not required
Hardness (mg/L)	326	Not required
Chloride (mg/L)	334	Not required

The council decided to pursue an opportunity to deliver a first-in-Australia solution using ceramic membrane technology as the main process element. While this was a novel option for the local market, the Cerafiltec ceramic membrane technology has been deployed internationally in a variety of installations and processes, due to their advantages over more traditional competing products including high flux rate, high solids loading capacity, superior mechanical robustness, high chemical tolerance and wide temperature range.

As Cerafiltec's delivery partner in Australia, Infinite Water was selected to deliver the main process unit for Tomingley. Initial process design was presented to DPE for Section 60 approval, which was subsequently granted and construction was cleared to proceed.

2.3 Process Description



<u>Figure 1:</u> ***Process flow diagram for Tomingley WTP***

The process designed for the Tomingley WTP is summarised below, and shown in Figure 1:

- Coarse screen filtering, to remove large debris prior to entering treatment system
- Coagulation with aluminium chlorohydrate (ACH)
- ORP correction with potassium permanganate
- Membrane filtration with Cerafiltec ceramic membranes (1 module, 6m2 filtration area)

- Ultraviolet (UV) treatment for disinfection
- Gas chlorination for further disinfection and residual as required by ADWG

One of the major benefits of using the ceramic membranes is the removal of a requirement for a separate settling process prior to the filtration process. The membranes can operate at a high flux even with a significant solid loading, allowing for a simultaneous coagulation and filtration step in the membrane tank.

2.4 Construction and delivery

To achieve the goal of a full Drinking Water certified system the decision was made to carry out as much of the design and construction in house by Narromine Shire Council, with the assistance of Infinite Water this was achieved.

Fig 2.2 View of IW Ceramic Membrane Skid after installation (left); View inside ceramic membrane tank during operation on river water (right)

The process train, apart from the chlorination system, was delivered as a skid-mounted solution fabricated in Infinite Water's workshop in Sydney. Delivering a pre-built system has the advantages of reducing commissioning time and rework on site, as well as the ability to carry out pre-commissioning work in a controlled environment – fixes and modifications can be applied quickly and reliably which is not always the case when constructing on a remote site.

Rather than use a container as the plant housing, the decision to utilise the transportable Tilt Panel Concrete building was based on Councils previous experience in using this method as an alternative on their other systems in Trangie and Narromine. The buildings are known to be incredibly strong and robust and are able to be adapted with more design flexibility as other types being easier to heat and cool in the extremes of climate to which this area is subjected. The control interface for the site uses ClearSCADA, allowing for integration into the existing council remote monitoring network and included video technology for process monitoring.

2.5 Commissioning and Optimisation

The process train, apart from the chlorination system, was delivered as a skid-mounted solution from the IW workshop in Sydney. Delivering a pre-built system has the advantages of reducing commissioning time and rework on site, as well as the ability to carry out pre-commissioning work in a controlled environment – fixes and modifications can be applied quickly and reliably.

However, as with any new technology there were a number challenges that arose once wet testing began in earnest once hot commissioning began on raw water:

- The coagulant dose as designed and jar-tested in the laboratory was found to be insufficient at full scale. Forward filtration times were found to be too short before the trans membrane pressure (TMP) increased to the backwash trigger level (around 500 mbar). Subsequent testing settled on a higher dose rate of 25mg/L of ACH. Since the raw water contaminant levels, such as dissolved organics, can vary considerably over time, it was important to develop a flexible approach to manage membrane performance.

- The raw water chemistry, particularly the oxidation-reduction potential (ORP), was found not to be optimal for the surface charge on the ceramic membranes. This both inhibited the maximum achievable flux and increased the rate of surface fouling during initial runs. A small oxidant dose of 0.5mg/L potassium permanganate was implemented during the commissioning process to ensure the ORP was increased sufficiently for optimal membrane performance, which increased from negative ORP in the raw water to above 300mV. This was likely not observed during initial laboratory jar testing initially, since the ORP of raw water samples slowly increases over time and was not representative.
- A chemically-enhanced backwash (CEB) is performed every 24 hours of runtime; first using a strong oxidant (sodium hypochlorite) for organics removal, and followed by an acid wash for removing scale. Chemical soak time is typically 15 minutes. Citric acid is used as it is less dangerous than strong inorganic acids (e.g., hydrochloric, sulphuric) from an operability and storage perspective. However, the citric acid that was available was not capable of reducing the pH of the CEB solution to the desired pH 2 – 2.5 range alone without significant dosing. This was ameliorated by adding 1L of hydrochloric acid to each 20L drum of citric acid. This stronger solution resulted in optimised cleaning performance, with membranes returning to their base clean state after each CEB.

Figure 2.3 shows a typical operating cycle, where backwash drains are conducted every 45 minutes, to align with increase in TMP due to fouling before it reaches its setpoint of 35kPa.

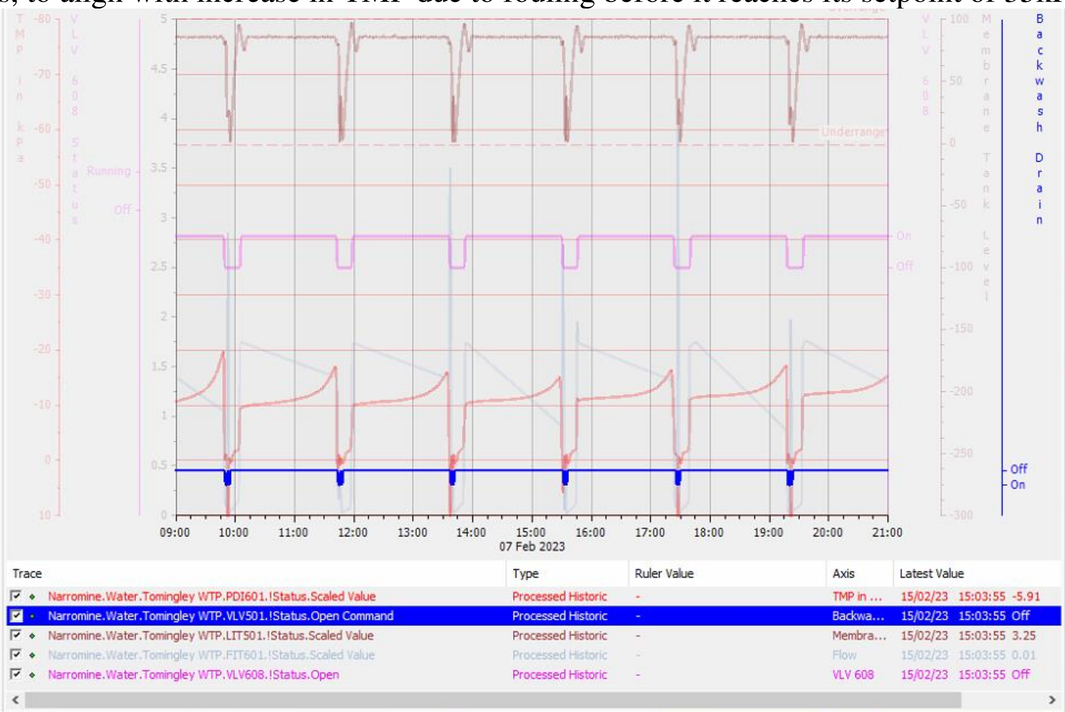


Fig 2.3 – SCADA screenshot displaying membrane plant operating parameters

2.6 Proof of Performance

A performance trial was completed in October 2022, achieving the key parameters required:

- A net total of 30kL was produced over a 24-hour period.
- The water quality was within ADWG specifications.
- The recovery rate of greater than 90% was achieved.

The commissioned plant operates at a peak flowrate of up to 1.8m3/h, with one ceramic membrane module installed with 6.0 m2 filtration area this equates to a gross flux rate of 300 L/m2/h (LMH). Further validation testing will be conducted in the near future to confirm pathogen levels prior to

bringing the system online to supply the community.
Since that time the plant has operated continuously using remote supervision and thrice-weekly operator visits for sampling and chemical deliveries. Over a particularly high-demand period during the December Christmas period, the plant achieved over 34 kL/d of production throughout a fortnight period.

3.0 CONCLUSION

The Tomingley water treatment plant for Narromine Shire Council has been successfully installed and represents the first full scale ceramic membrane filtration technology providing drinking water in Australia. This has provided a benchmark for further use of the technology and a valid and economical solution, capable of addressing difficult water sources that were once inaccessible or considered too expensive or complex to treat. Community benefits from the project include:

- Reliable water supply meeting ADWG and superior;
- Capable of withstanding raw water variations;
- Eliminates fouling from algae;
- Simple single step treatment process, requiring minimal operator intervention;
- Ongoing technical and servicing support for plant operators provided by Infinite Water

4.0 ACKNOWLEDGEMENTS

Narromine Shire Council would like to thank Dr Michael Storey of Isle Utilities and Mr Bruce Murray of City Water Technologies for their assistance in sourcing this solution and their sound advice. Special thanks also to the DPE- Water Western Regional Team and Mrs Cindy Houston of the DPE Water Regulatory Assessment Team for their support and encouragement for what was a radically different solution utilising a totally new technology.
A special mention from Council to our Valuable Partners on this project:

1. Infinite Water (Water Treatment Skid)
2. 360 Engineering (Electrical Control and Telemetry)
3. Portacrete (Pre-Fab Concrete Building)
4. Polymaster (Clear Water Tank and Raw Water Pump Station)
5. Trility Water (Gas Chlorinator)
6. Narromine Shire Council Water and Sewer Team

A very special mention must go to Mr Luke Justus from Infinite Water, whose total commitment and diligence throughout this project has contributed to its ultimate success.

5.0 REFERENCES

Video of Tomingley ceramic membrane plant:https://www.youtube.com/watch?v=pa_M6L87I0U
https://www.amtaorg.com/wp-content/uploads/21_Ceramic_Membranes.pdf
https://info.nsf.org/Certified/PwsComponents/Listings.asp?Company=C0584424&Standard=061
https://www.cerafiltec.com/how-it-works/
https://www.cerafiltec.com/recent-projects/