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TREATING CLARIFIER AND BACKWASH WASTEWATER WITH ULTRAFILTRATION MEMBRANES

PILOT TRIAL RESULTS OF A GROUNDWATER CLEAN-UP PROJECT AT THE BOTANY GROUNDWATER TREATMENT PLANT IN SYDNEY

P El Jbeily, F Barendregt, K Clark, F Akkawi

ABSTRACT

The Botany Groundwater Treatment Plant (GTP), located in Sydney, NSW, forms a major component of the Groundwater Cleanup Project being undertaken by Orica and Chemicals Division (now Ixom Operations)[1] to clean up contaminated groundwater arising from former chemical industry operations at Botany Bay. The GTP generates wastewater from clarifier and backwash processes at 32 kL/h, all of which was formerly discharged to the sewer.

In order to reduce trade waste costs, Orica and the Chemicals Division investigated the use of membranes to recover some of the waste discharged to the sewer and trialled DOW outside-in polyvinylidene fluoride (PVDF) ultrafiltration (UF) membranes in 2013. The trial assessed the suitability of the DOW membrane format and configuration, and enabled optimisation of system design parameters. The feedwater quality to the UF system was particularly challenging as the water was highly biologically active, with the total iron being as high as 10 mg/L and suspended solids up to 45 mg/L.

The objective of the trial was to recover water of sufficient quality to allow it to be returned to groundwater treatment process. From the trial results, reprocessing the wastewater with UF was expected to provide savings of more than $600k annually in reduced trade waste costs to GTP.

The plant has been in operation since October 2014, with the UF system producing filtrate with total iron less than 0.5 mg/L and turbidity less than 1 NTU.

This paper discusses the concept technology selection process, the pilot trial methodology and results, the project delivery, the current plant performance, operational challenges and financial benefits.

INTRODUCTION

Orica is undertaking the Groundwater Cleanup Project to decontaminate groundwater at Botany Bay. One of the essential processes in the Project is the Groundwater Treatment Plant (GTP), which treats groundwater extracted from 113 wells along the three containment lines that intercept the flowing groundwater before it reaches Botany Bay. The GTP process involves removing chlorinated hydrocarbons from groundwater using an air-stripping process. The stripped water is then treated using conventional water treatment technologies such as Actiflo®, media filters, biological filters and reverse osmosis.

Backwash waste from the media, and biological filters and iron flocs from the Actiflo® process, are directed to the wastewater buffer tank. The wastewater in the tank is then pumped to the sludge thickener after the addition of polymer, and the thickener underflow pumped to sewer. The original plant design included recovery of the thickener overflow, but did not cater for the biological activity from the levels of dissolved organic carbon in the groundwater. This requires more frequent backwashing of filters and consequential overloading of the thickener, so the thickener overflow was diverted to the sewer.

GTP investigated whether it was possible to treat the thickener overflow to a standard that will allow the treated water to be returned to the groundwater treatment process, so as to reduce the volume of waste discharged to the sewer and, hence, reduce operational costs.

[1] In 2015, Orica's chemical division separated from Orica as a stand-alone company and is now known as Ixom.

The recovered water would increase the volume of treated water used on the site, further reducing mains water consumption. The quality of the thickener overflow feedwater, shown in Table 1, was particularly challenging as it was high in total suspended solids (TSS) and total iron, with a significant proportion of volatile suspended solids (VSS) from the biological filter backwash. The main criteria to be achieved are shown in Table 1.

GTP opted for the following approach to find the optimum solution:

- Select membrane technology;
- Set up and run a pilot plant to establish optimum operating parameters;
- Implement solution.

MEMBRANE SELECTION

DOW IntegraPac™ IP-51 ultrafiltration modules (Figure 1) were selected to handle the challenging feedwater at the GTP. Selection of these modules was based on several criteria, including the membrane material properties and selectivity, as well as the flow configuration and module format.

Figure 1. DOW UF module.

Each module has an active membrane area of 51m^2 and contains hydrophilic PVDF hollow-fibre membranes with a nominal pore size of 0.03 µm and an absolute pore size of 0.06 µm (Table 2). The tight pore size distribution enables highly effective separation of all kinds of suspended solids, while the hydrophilic surface property enhances membrane permeability and resistance to organic fouling.

Table 1. Thickener overflow water quality during the trial.

Water Quality Parameter	Design Envelope Feed Water	Target Filtrate Requirement
pH	7.0–8.0	N/A
TSS (mg/L)	40–100	N/A
Turbidity (NTU)	20–35	<5
Total Iron (mg/L)	3–8	<0.5
Total VSS (mg/L)	15–30	N/A

Table 2. Fibre physical properties.

Configuration (Fluid Flow)	Hollow Fibre (Outside-In)
Base polymer	H-PVDF
Nominal pore diameter	0.03 µm
Hollow fibre ID	0.70mm
Hollow fibre OD	1.3mm

The PVDF polymer exhibits high-tensile strength and elongation, which result in superior material toughness, enabling resistance to fracturing. The polymer also exhibits a high degree of chemical and thermal stability, allowing operating and cleaning temperatures of up to 40°C and lifetime exposure of sodium hypochlorite up to 1,500,000 ppm. hours. The latter property enables the continuous dosing of NaOCl in the feedwater to prevent biological fouling of the upstream self-cleaning strainer, while ensuring that membrane integrity will not be compromised by oxidant exposure.

The outside-in flow configuration of the IP-51 modules ensures that filtered particles are retained on the outside of the membrane, where air scour can assist backwashing in removing fouling from the membrane surface.

PILOT TRIAL METHODOLOGY AND RESULTS

Pilot Plant Process Description

Prior to the design, fabrication and supply of the full-scale system now onsite, an Ultrafiltration (UF) pilot skid was installed at the GTP. The pilot skid was owned by Chemicals Division and was modified to meet GTP process and site requirements (Figure 2).

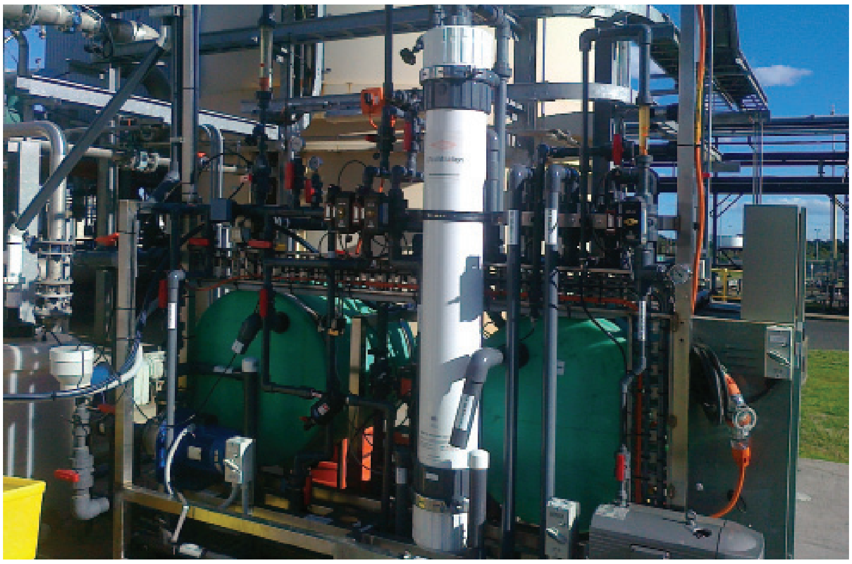

Figure 2. UF pilot skid.

The purpose of the trial was to validate the suitability of the DOW™ UF membrane to treat wastewater from the existing clarifier and filter backwash processes to meet GTP-treated water quality criteria. The pilot trial was also designed to optimise process setpoints and achieve the highest possible recovery.

The pilot skid was fully automated with the ability to dial in remotely and consisted of the following main equipment:

- Feed pump
- Backwash pump
- Pre-filter
- Clean-in-place (CIP) pump and heater
- Pressurised outside-in format DOW SFP-2860 module with PVDF hollow-fibre membranes
- Filtrate tank; CIP Tank
- Blower
- Chemicals stored in 50L drums.

Once installed and commissioned, the pilot skid was remotely monitored and operated by Chemicals Division process engineers. Actions taken included responding to alarms in coordination with GTP operators, reviewing performance data and modifying setpoints as required.

Key feedwater quality parameters were measured and recorded by operators twice a day over the trial period. The feedwater quality during the trial, shown in Table 3, was high in total suspended solids (TSS) and total iron and presented challenging operating conditions.

The pilot plant was designed so it was able to run with filtration cycle durations ranging from 20–40 minutes, depending on the raw water quality.

The backwash mode is initiated automatically and includes the following steps:

- Air scour
- Gravity draining
- Backwash through the top outlet
- Backwash through the bottom drain
- Forward flush.

Table 3. Water quality during the trial.

Feed Water Parameter	Water Quality Over the Trial Period
pH	6.9–8.3
TSS (mg/L)	32–45
Turbidity (NTU)	16–40
Total Iron (mg/L)	2–10
Total VSS (mg/L)	13–37

UF Chemical-Enhanced Backwash

To assist the hydraulic cleaning and prolong the operating interval between offline CIP cycles, automated Chemical-Enhanced Backwash (CEB) was included in the system design. The CEB follows the normal process, similar to a backwash, but includes additional steps for the dosing of chemical inline into the backwash water, soaking and rinsing.

To clean contaminants from the membrane surface, the CEB is performed using sodium hydroxide combined with sodium hypochlorite to remove organic and biological foulants, or using citric acid to remove iron fouling.

Pilot Operating Parameters

During the pilot plant run, the operating parameters were changed as required in order to find the optimum operating conditions for the different parameters:

- Operation flux
- Run time
- Choice of cleaning chemical
- Chemical cleaning frequency.

The various operating conditions tested as part of the optimisation phase of the trial are detailed in Table 4, along with the estimated net daily savings for a similarly operated full-scale plant.

During initial commissioning, the combination of biological flocs in the biological filter backwash with soluble organic carbon in the Actiflo® underflow led to significant biological activity through the pilot plant. The organic carbon is predominantly short-chain fatty acids such as acetic acid, which is readily assimilated by any biomass present. Hypochlorite dosing was introduced to every backwash at low concentration (15 mg/L) to retard the activity on the membranes.

Following commissioning, pilot plant data capture and analysis began in mid-August 2013. On August 12, the plant was restarted after a CIP. The pilot system was initially operated under Operating Condition A (Table 4). Under these operating protocols, the UF normalised permeability, displaying an increasing trend and system recovery was less than 80% (Figure 3). In an effort to improve process recovery, CEB1 interval was reduced to twice per day as shown under Operating Condition B. With reduced CEB1 frequency, the normalised permeability dropped considerably, by more than 70% over the course of one week. CEB1 interval was reduced to every 10 hours under Operating Condition C, but this cleaning frequency was not able to reverse the membrane fouling.

From early to mid-September, the UF pilot plant was shut down for CIP and maintenance work. On start-up post-CIP, the plant was running under condition D where CEB1 and CEB2 interval were reduced to every eight hours and 12 hours respectively. Under these operating protocols, the normalised permeability dropped by more than 60% over five days. Under Operating Conditions B, C and D, it was evident that the CEB regime was not effective enough in reversing membrane fouling to enable an acceptable CIP interval when operated at constant flux.

Operating Condition	Filtration Time	CEB1[2] Soak Time	CEB2[3] Soak Time	CEB1 Interval	CEB2 Interval	CEB1 Chemical	Plant Average Recovery	Estimated Net Benefit from Full-Scale plant[4]
	min	min	min	h	h		%	$/day
A	20	5	5	2	24	Caustic/ hypo	78	1,877
B	20	5	5	12	24	Caustic/ hypo	83	1,997
C	20	5	5	10	24	Caustic/ hypo	83	1,997
D	20	5	5	8	12	Caustic/ hypo	82	1,973
E	20	15	15	8	12	Caustic/ hypo	81	1,949
F	20	15	15	8	12	Citric	81	1,949
G	25	15	15	8	12	Citric	84	2,021

Table 4. Estimate of net benefit under different operational conditions.

[2] CEB1: A chemical-enhanced backwash with either sodium hydroxide with sodium hypochlorite, or citric acid, followed by a rinse.
[3] CEB2: A chemical-enhanced backwash with sodium hydroxide with sodium hypochlorite, followed by a rinse, then a citric acid clean, followed by a rinse.
[4] Based on net throughput of 770 m^3/day

Therefore, for Operating Condition E, the CEB soak time was increased from five minutes to 15 minutes, while maintaining the other parameters constant for comparison. As can be seen from Figure 3, the operating protocols, the membrane performance began to recover and the normalised permeability increased by about 50% over five days.

In order to check which chemical was more effective in cleaning the UF membranes, CEB1 chemical was changed to citric acid from sodium hydroxide for Operating Condition F. With more frequent citric acid cleans, the normalised permeability increased by about 80% over three days.

To increase the recovery further, the filtration time was extended to 25 minutes, as shown for Operating Condition G. Increasing the run time between backwashes resulted in greater fouling on the membranes to the extent that the backwash was no longer effective. Under these operating protocols, the normalised permeability dropped by more than 75% over 10 days.

The design flux for the pilot plant was 40 lmh[5] and the skid was operated under variable flow rate, depending on the transmembrane pressure[6] (TMP). As shown in Figure 3, the operating flux dropped below design under Operating Conditions B, C and D.

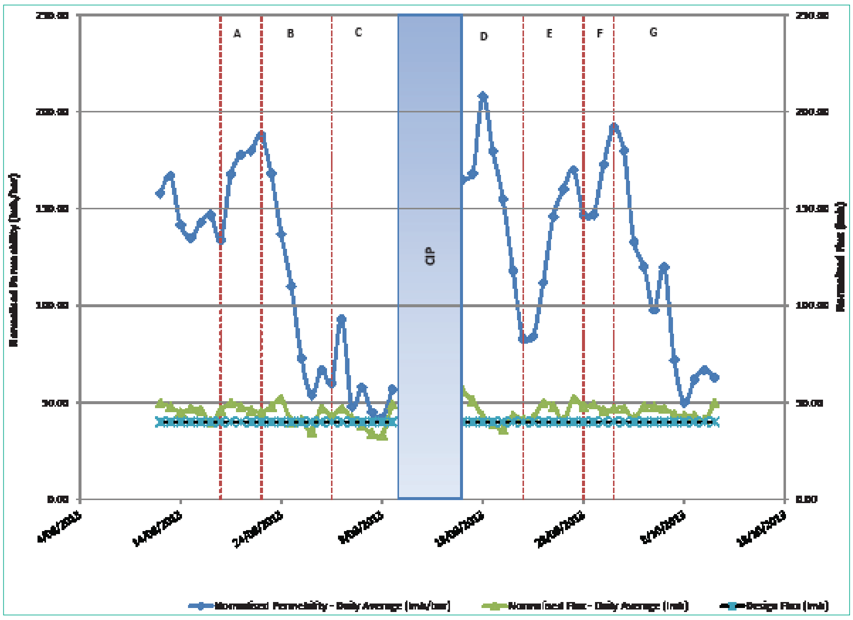

Figure 3. Normalised permeability during the trial.

Over the course of the trial, feed turbidity ranged from 13 to 27 NTU and, as seen in Figure 4, filtrate turbidity ranged between 0.2 and 1 NTU and was not greatly affected by the different operating parameters.

Under Operating Conditions A, B and C the backwash TMP was rising (Figure 5). However, after the CIP conducted in mid-September, the average backwash TMP was relatively stable.

[5] Membrane flux unit: Litre/m^2/hour [not a preferred unit, but used in the membrane industry].
[6] Transmembrane pressure is the feed pressure minus the permeate pressure.

The membranes recovered well after each CIP, with no requirement to use any special chemicals. The general observations were that the CIP was effective at both alkaline and acid pH, which indicates that the fouling on the membranes was due to both organic material and iron oxides.

UF Pre-Filter

The pilot plant was initially fitted with an automatic self-cleaning screen filter with hydraulic control. However, the feed pump had insufficient pressure to effectively clean the filter, so the filter was replaced with an inline 300µm screen filter. A 1.2mm strainer was fitted on the feed break tank.

As can be seen from Figure 6, there was significant fouling of the strainer and screen filter with biofilm forming on the outside and inside of the screens. Initial cleaning with a water hose and metal spatula was effective at removing the biofilm, but a high-pressure spray was required to remove the particles captured in the screen. The initial cleans were successful at returning the screen filter to near its original clean operating conditions (Figure 7). To keep the pilot plant in continuous operation, the screens were removed for off-line cleaning every two to three days.

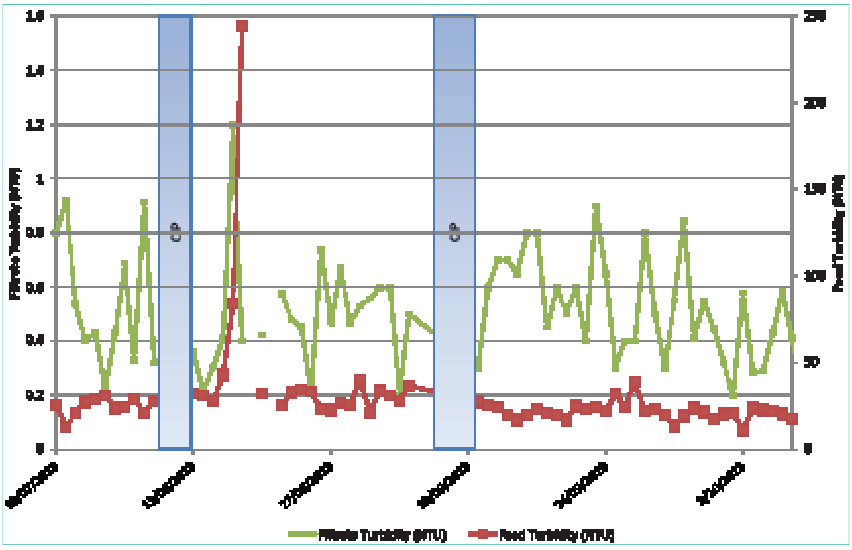

Figure 4. Feed and filtrate turbidity during the trial.

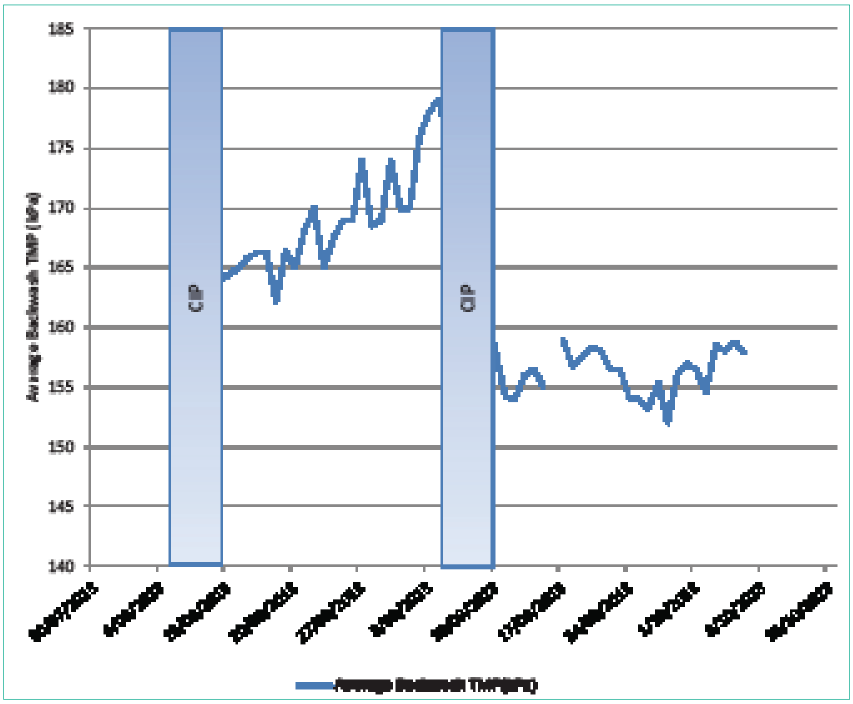

Figure 5. Average backwash TMP during the trial.

Pilot Plant Conclusion

From the pilot plant results and the observed effectiveness of the CIP at recovering the UF membrane performance, it was concluded that a UF process with DOW Ultrafiltration membranes was a viable option to treat the thickener overflow and recover water adequate to return to the process.

Under plant conditions E and F, the plant ran at a high recovery, with the membrane's permeability recovering at the selected backwash frequency and chemical cleaning conditions. The full-scale plant was designed to operate under plant conditions E and F, with the flexibility to modify operating parameters as required.

PROJECT DELIVERY

The project execution strategy was developed with the objective of bringing the UF plant into operation as quickly as possible to enable the financial savings to be realised. This objective was achieved by adopting the following principles:


Figure 6. Screen filter before cleaning.


Figure 7. Screen filter after cleaning.

Table 5. Feedwater quality to UF.			
Parameter	Unit	Design Basis	Maximum Allowable
Turbidity	NTU	15–40	300
TOC	mg/L	7–20	40
Particle Size	µm	130	300
COD	mg/L	<20	60
Oil/Grease	mg/L	0	<2
ORP	mV	10–350	Not Available
Total Iron	mg/L	2–10	Not Available
pH	-	6.9–8.5	2–11
Temperature	°C	15–25	40
Free Chlorine	mg/L	0.5	200
TSS	mg/L	30–45	100
VSS	mg/L	10–37	Not Available

Table 6. Operating parameters.			
Parameter	Unit	Design Case	Operating Range
Operating Flux	lmh	48	40–60
Backwash Frequency	min	21	20–30
Each Backwash Duration	s	30	20–40
Air Scouring Frequency	min	21	20–30
Air Scouring Duration	s	40	20–60
Forward Flush Duration	s	40	20–60
Forward Flush Flow Rate	m^3/h	2.2	2–5
Acid CEB Frequency	h	6	4–38
Caustic/Hypo Followed by Acid CEB Frequency	h	12	4–38
CEB Soak Time	min	15	5–30

- Maximise offsite mechanical and electrical works, including testing and commissioning;
- Early engagement of stakeholders to expedite site integration and commissioning;
- Provide dedicated ongoing technical support in the start-up and operation phases.

Maximising offsite works

The UF skid was designed and manufactured by Chemicals Division, complete with skid-mounted electrical panels for low voltage and extra-low voltage electrical hardware. This allowed motors, instruments and other electrical devices on the skid to be terminated in the factory, thus avoiding the need for on-site work, which is often more expensive and more time consuming.

Another advantage was the ability to factory-test the PLC (Programmable Logic Controller) code. As site electrical standards required all PLC and Human-Machine Interface (HMI) coding to be done on the site's existing PLC/Supervisory Control and Data Acquisition (SCADA) system, a stand-alone PLC/HMI was not an option. Due to this limitation, a spare PLC was programmed offline and then connected to the UF skid in the factory. This allowed the skid to be powered up and 90% of the automation testing was completed in the factory. This proved to be successful and minimised on-site sequence commissioning time, which was reduced to interface commissioning rather than UF-specific process sequence commissioning/troubleshooting.

Chemicals Division engaged with key stakeholders during the project inception to ensure the system could be installed and operated without delay. The output of these consultations identified some gaps that needed to be managed. Chemicals Division and the project owner developed the necessary reports and management plans as required by the stakeholders, and mitigated any potential delays.

Ongoing technical support in start-up and operations phase

Due to the complexity of the existing operations at the GTP site it was imperative for Chemicals Division's process engineers to be made available after handover to ensure any unforeseen integration challenges were promptly addressed. This was achieved through adopting a Plan > Operate > Measure process loop:

- **Plan:** Chemicals Division and GTP operations staff agreed on the operating setpoints and philosophy, including backwash, chemically enhanced backwash and CIP frequencies;
- **Operate:** GTP staff operated the plant in accordance with the Plan;
- **Measure:** GTP staff reported back on the plant performance to Chemicals Division and the operating philosophy was amended accordingly.

FULL-SCALE PLANT PROCESS DESCRIPTION

Design Basis

The plant design was completed on the following basis:

- UF plant to treat 770 m^3/day (32 m^3/h) with 25% expansion capability;
- Feedwater quality for the design basis as seen during the trial period (Table 5);
- Optimal operating parameters as observed from the pilot results (Table 6).

Table 7. UF module design parameters.	
Parameter	Value
Feed Net Daily Flow	770 m^3/day
Filtrate Net Daily Flow	624 m^3/day
Waste Total Daily Flow	146 m^3/day
Overall Recovery	81%
Estimated Daily Net Benefit	$1,950

Figure 8. Botany UF skid installed at GTP site.

Equipment Description

Based on GTP design requirements, Chemicals Division designed the UF plant with one train of DOW Integrapac skid IP-51. The skid included 16 UF modules with the provision for two additional UF modules. This will allow the plant to operate at a flux of 48 lmh (compared to the average operating flux during the trial of 49 lmh. The expected performance outcomes at the design parameters are shown in Table 7.

As shown in the process flow diagram (Figure 9), the UF skid (Figure 8) comprises the following equipment:

- One feed pump (used as CIP pump during CIP);
- One backwash pump;
- One set of 100 micron automatic disc filters;
- One DOW IntegraPac UF IP-18 skid;
- Filtrate tank (used as the CIP tank during the CIP);
- One 45 kW heater for CIP;
- One 50 micron filter for CIP;
- Required valves and instrumentation;
- Electrical panel for motor drive circuitry and other low-voltage equipment;
- Extra-low voltage (ELV) panel for PLC, HMI and other ELV electrical equipment.

Operation

The UF backwash and CEB operation follow the same process as described in the UF pilot plant section. Given the feedwater quality was expected to

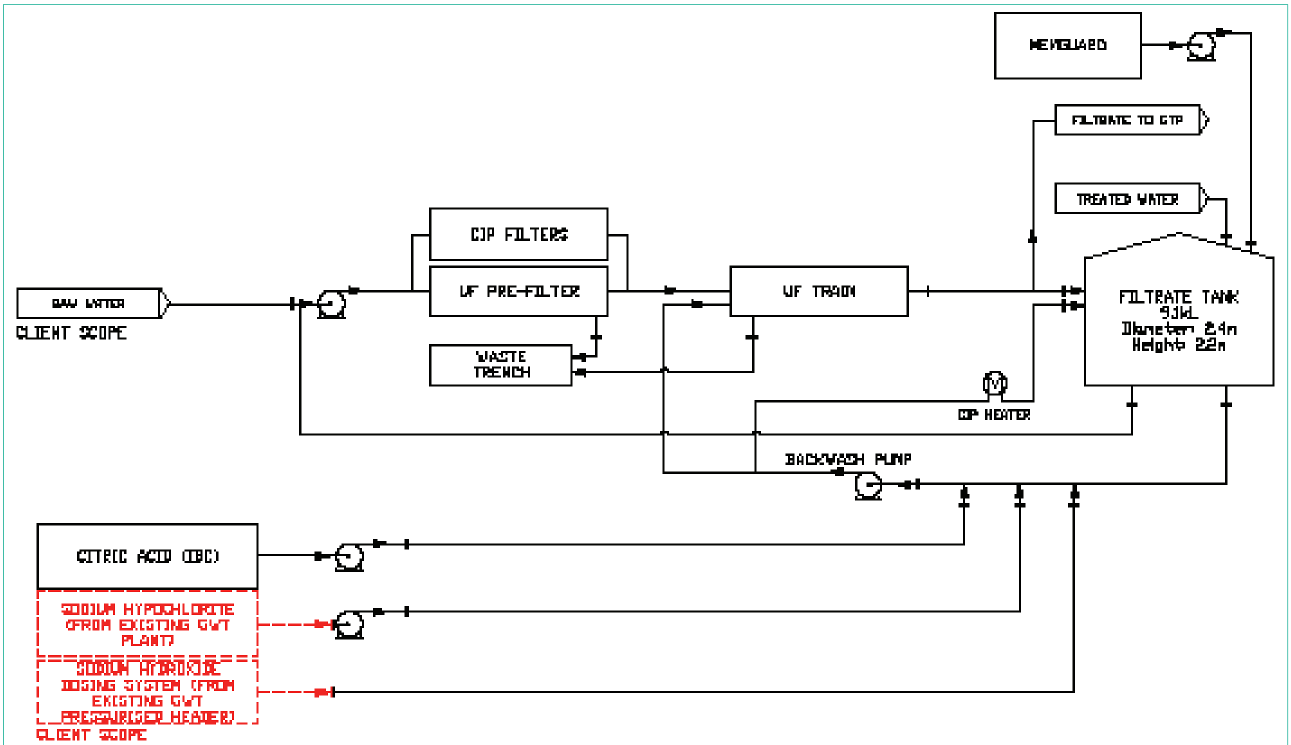

Figure 9. UF plant process flow diagram.

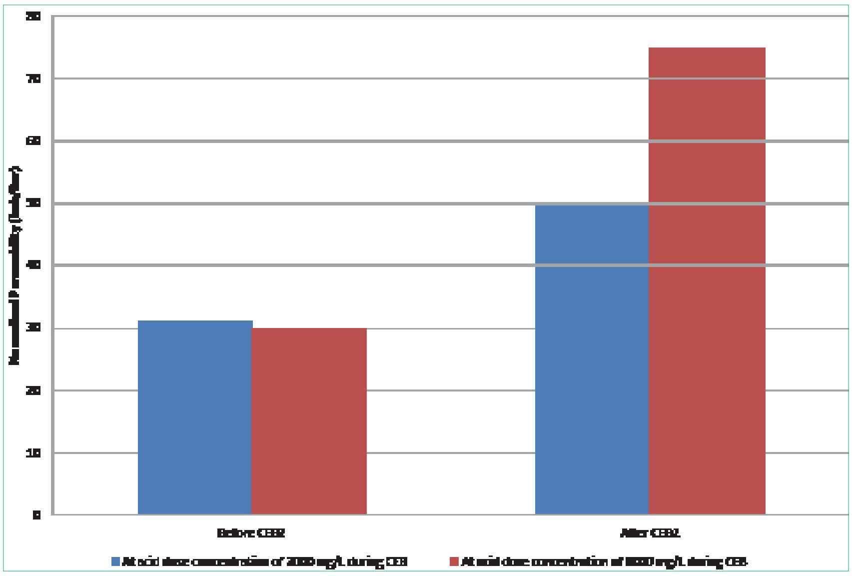

Figure 10. UF normalised permeability at different citric acid dose rates.

vary over time, the plant was designed with the ability for the operator to choose operating setpoints such as the frequency of the different chemical cleans and soak duration.

Plant Performance

The UF system commissioning was completed in October 2014. Up until May 2015, the plant performance was substantially lower than design, with the recovery being as low as 40% and the net benefit averaging about $1,000/day.

In May 2015, Ixom was invited to assist GTP staff in optimising the plant performance to meet design criteria. After reviewing the plant data, the following major changes were completed:

Citric acid CEB The citric acid CEB was found to be ineffective compared to the results obtained during the trial. After reviewing the citric acid dose, it was identified that the dose concentration was ~2,000 mg/L, which was significantly lower than design. To rectify this, the citric acid dosing pump flow was increased to achieve a minimum solution concentration of 8,000 mg/L.

As shown in Figure 10, the increase in concentration of the CEB citric acid solution to 8,000 mg/L improved the membrane's permeability by 250%. This is in comparison to the previous solution concentration of 2,000 mg/L, which increased the permeability by just 61%.

Operation setpoints As can be seen from Figures 11 and 12, the plant was operating at a backwash frequency of 15 minutes with frequent CEBs. The CIP was conducted every two to three weeks. Consequently, the annual economic benefits from the UF plant were about half what had been projected for this project.

In May 2015, the chemical used for CEB1 was changed from caustic to citric acid as per the trial recommendations. It was noted that the CEB using citric acid was more effective than that using caustic in restoring membrane permeability (Figure 13). Nevertheless, the most successful CEB in restoring membrane permeability is CEB2, which first cleans the membranes with caustic, followed by citric. As a result, the use of CEB1 was discontinued.

In June 2015, the GTP plant was shut down for maintenance and the UF plant was not running. During that time, two additional UF membranes were installed on the UF skid to increase the system capacity.

A CIP was completed at the start of July and the plant restarted operating at a backwash frequency

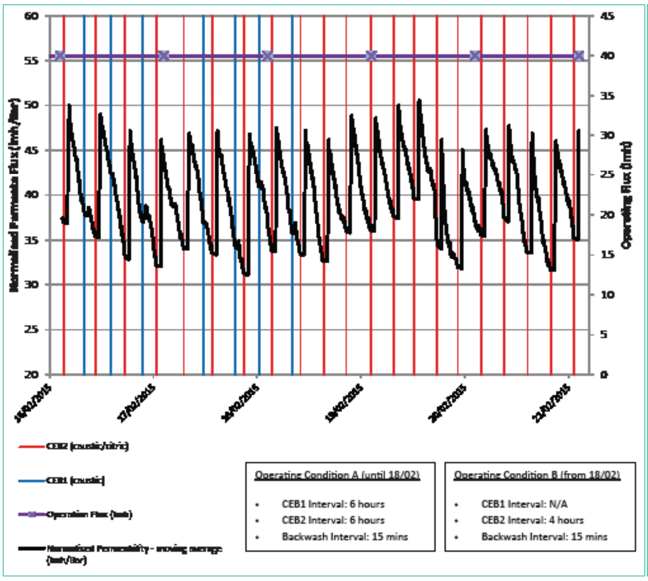

Figure 11. UF performance during February 2015.

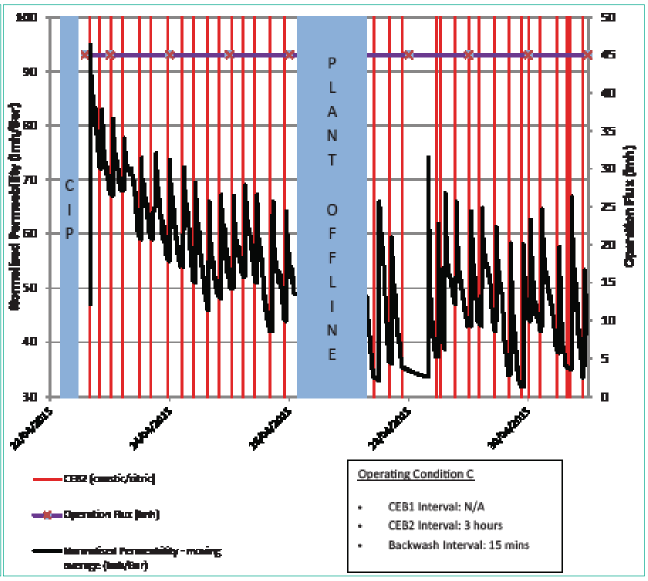

Figure 12. UF performance during April 2015.

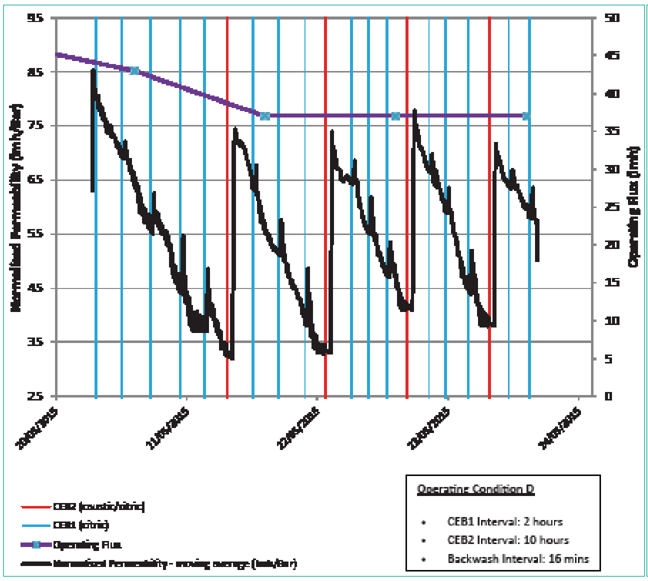

Figure 13. UF performance during May 2015.

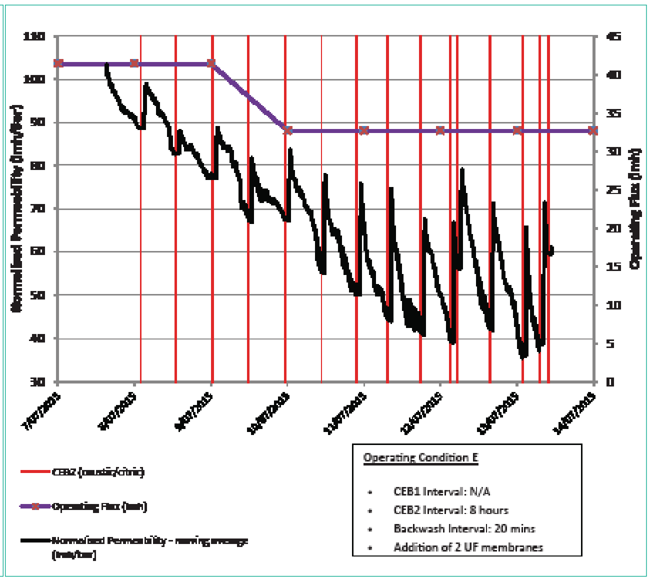

Figure 14. UF performance during July 2015.

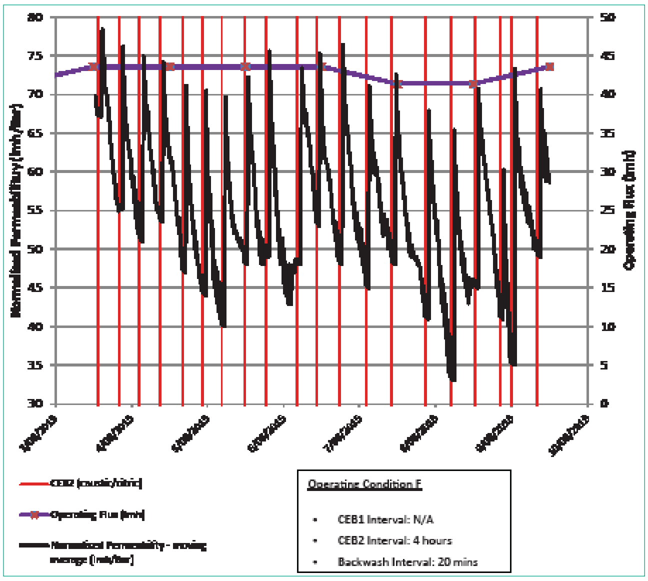

Figure 15. UF performance during August 2015.

of 20 minutes and CEB2 interval of eight hours. As can be seen in Figure 14, the membrane permeability declined by 30% over five days at an average operating flux of 37 lmh; two consecutive CEB2s were conducted to improve the permeability. As a result, the CEB2 interval was reduced from eight hours to four hours. As can be seen from Figure 15, the permeability decline over five days is now around 12% at an average operating flux of 43 lmh.

Overall, the GTP staff needed to reduce the operating flux from time to time, because of high feed pressure alarms.

Currently the plant is operating under Condition F, with the CIP frequency being one month. Under this condition, the daily net benefit is around $1,500. See Table 8 for a comparison in the economic benefit under the different operating conditions discussed.

The reduced capability has been attributed to variable feedwater quality, although this has been difficult to quantify. The original feed turbidity instrument was located on the skid, but this required a long sample line from the feed flow, which is stagnant during backwashes (up to one hour for CEB2). This allowed biological build-up on the inside of the sample line, which resulted in variable measurements when compared to grab samples from the feed flow and thickener overflow launder. A periodic purging regime was established, but the effects were short-lived, with deviations up to 100% evident after the next CEB where the feed system was stagnant.

The turbidity instrument was relocated close to the thickener with shorter and smaller sampling lines, but the deviations remained. The GTP is planning to install a new probe directly in the thickener overflow launder to overcome this problem, and use the data to establish a sustainable operating envelope for the UF process.

Despite the problems in measuring feed turbidity on-line, grab samples have shown the turbidity can rise above 50 NTU, compared to the design envelope of 20–35 NTU established during the trial. The new turbidity measurement will also allow troubleshooting of the upstream processes to reduce the incidence of high feed turbidity.

Table 8. Plant performance under different operating conditions.

Plant Operating Condition	Plant Average Recovery %	Estimated Net Daily Benefit $
A	68	1,280
B	61.5	1,000
C	60.5	950
D	62	950
E	74	1,530
F	72	1,520

Figure 16. UF pre-filters.

Backwash Mode The backwash was found to be inadequate and after further investigation it was established that the design backwash flux could not be reached. The backwash pump was inspected for mechanical faults and repaired.

After the backwash pump repairs, the backwash design flux was achieved, but no significant improvement to the membranes' permeability after a backwash was noted.

Further review of the backwash effectiveness is required.

Operational Challenges

Another operational challenge that GTP staff faced was blockages of the pre-filters by biological "smear", i.e. by non-particulate fouling (Figure 16). This was similar to the experience with the static filters used in the pilot trials. This phenomenon was addressed in the full-scale design by specifying automatic cleaning filters.

The pre-filter cleaning frequency was increased to occur on every membrane backwash cycle. Extended and multiple cleans were also trialled, but these initiatives were not able to keep the filters clean, and manual cleaning was required every two to four days. A fourth pre-filter module was added, and coarser (200mm) discs were trialled, but these changes only extended the cleaning interval to seven to 10 days.

The fouling was addressed by modifying the sodium hypochlorite dosing system to slug dose the feedwater. The slug dosing occurs over a 60-second cycle to achieve an average 2 mg/L of total chlorine in the feedwater to the pre-filters.

This has suppressed the biological activity sufficiently to eliminate manual cleaning of the pre-filters. The residual chlorine in the feedwater has also allowed the sodium hypochlorite dosing to every membrane backwash to be stopped, which has reduced the overall usage of sodium hypochlorite by 75%.

CONCLUSION

The pilot trial conducted prior to the construction and supply of the full-scale plant was able to validate the suitability of the DOW UF membrane and module format for the required application. The trial demonstrated that the membranes were able to treat and recover this industrial wastewater characterised by high suspended solids, turbidity and iron, to meet GTP treated water quality criteria. The pilot trial has also enabled process engineers to optimise process setpoints to maximise water recovery and cleaning effectiveness.

Selection of a membrane material with good tolerance to oxidant exposure has allowed slug dosing of chlorine to resolve the biofouling of the pre-filters.

The project objective of bringing the UF plant into operation as quickly as possible to realise savings was made possible through Chemicals' execution methodology and the selection of a standardised DOW IntegraPac UF module skid. Maximising offsite works, early engagement of stakeholders to expedite site works, and ongoing technical support through the start-up and operations phases were crucial to meeting this objective.

The successful operation of the Orica Botany GTP project demonstrates that ultrafiltration can be coupled with existing conventional processes to reduce waste volumes and trade waste costs.

While further work is required to achieve the full benefit of the UF system, the plant is estimated to be delivering a net saving of $1,500 per day under current operating protocols.

THE AUTHORS

Pamela El Jbeily (email: Pamela.el.jbeily@ixom.com) is a Senior Process Engineer with Ixom Watercare. She has worked extensively with advanced water treatment technologies including ultrafiltration/microfiltration, reverse osmosis and ion exchange. Pamela has led the process design team at Ixom Watercare since 2010.

Fred Barendregt (email: fred.barendregt@kbr.com) is a Principal Process Engineer with KBR. He was seconded to Orica in 2005 to lead the commissioning of the Botany Groundwater Treatment Plant, and continues to lead process development and improvement activities at the plant.

Kevin Clarke (email: kclarke@dow.com) is the regional technical manager for the filtration business at Dow Water & Process Solutions (DW&PS). He earned concurrent degrees in Mechanical Engineering and Computer Science from the University of Western Ontario in Canada, before beginning his water treatment career with Zenon Environmental Ltd, where he worked for six years before joining DW&PS.

Fadi Akkawi (email: fadi.akkawi@ixom.com) leads Ixom Watercare's project management office. He has delivered numerous water treatment projects in Australia, New Zealand and the United Kingdom. Fadi also takes a leading role in the development of Ixom Watercare's treatment plants, especially for customers with difficult waters and remote sites.