BEYOND ALUM: ALTERNATIVE COAGULANTS FOR FULL-SCALE WTP PERFORMANCE IMPROVEMENT

Paper Presented by:

Con Pelekani

Author:

Michael Corena, *Operations Treatment Engineer,*
Con Pelekani, *Manager Water Treatment Performance & Optimisation,*

SA Water Corporation

79th Annual WIOA Victorian Water Industry Operations Conference and Exhibition
Bendigo Exhibition Centre
31 August to 1 September, 2016

BEYOND ALUM: ALTERNATIVE COAGULANTS FOR FULL-SCALE WTP PERFORMANCE IMPROVEMENT

Michael Corena, *Operations Treatment Engineer,* SA Water Corporation
Con Pelekani, *Manager Water Treatment Performance & Optimisation,* SA Water Corporation

ABSTRACT

The Mount Pleasant Water Treatment Plant (MPWTP) in the Adelaide Hills has experienced sub-optimal performance since it was commissioned in 2000. The conventional train has not been able to achieve its design capacity of 15 L/s, with a sustainable limit of 10 L/s. Higher flows result in excessive floc carryover into the granular media filters, with consequent rapid head loss and low filter productivity. In March 2015, the UF membrane treatment train began to show evidence of irreversible fouling, with decreased permeability in filtration and backwash modes. It was proposed that the combination of in-line alum dosing onto the UF membranes and sludge thickener supernatant recycle were the main contributing practices. Module autopsy confirmed presence of aluminosilicates. Extensive chemical cleaning was unsuccessful in restoring performance, confirmed by laboratory cleaning studies. Strategic investigation was initiated to develop management plan for new membrane procurement to prevent reoccurrence. The significant operational issues with both Streams catalysed a process design and operations review, including alternative coagulants. Two aluminium chlorohydrate (ACH) products and a polyaluminium chloride (PACl) were selected. Testing was undertaken with and without MIEX® pre-treatment. UF performance stabilised once ACH/PACl dosing commenced. Optimisation of conventional train performance was more challenging with respect to achieving improved floc formation, clarification and filtration. This paper will describe the operational challenges and successes associated with a *'beyond alum'* approach to water treatment.

1.0 INTRODUCTION

MPWTP has two process streams, each with a rated capacity of 1.25 ML/d (maximum instantaneous flow of 15 L/s). Raw water is sourced from the River Murray via the Mannum-Adelaide pipeline (MAPL). Both streams have MIEX® pre-treatment. Stream 1 employs conventional treatment (coagulation, two-stage flocculation, high rate tube settler clarification and dual media filtration). Stream 2 employs submerged UF with in-line coagulation. Since commissioning, alum has been used as the primary coagulant. Based on long-term operational experience Stream 1 has not been able to operate sustainably at flows greater than 10 L/s. Excessive floc carryover (clarified water turbidity >15 NTU) results in high rate of filter head loss development. For these reasons Stream 1 is normally operated at a baseline flow of 3.5 L/s, with Stream 2 responsible for the bulk of water production. The inability of Stream 1 to achieve design flow resulted in derating of the plant capacity to 2 ML/d. As part of the development of the future process strategy for MPWTP, restoration of plant capacity to 2.5 ML/d is necessary.

In a regulated business environment, it is prudent to identify cost-effective strategies to recover performance and optimise the life of existing assets. Challenging the status quo with respect to alum as the primary coagulant was recommended in the future process strategy. The '*Beyond Alum*' initiative was based on the hypothesis that the use of pre-polymerised coagulants, such as ACH, provide faster kinetics that may counter some of the suspected hydraulic/design issues associated with Stream 1. In addition, the formed floc may be less susceptible to shear and result in improved clarification and filtration performance. In March 2015, Stream 2 UF performance deteriorated significantly, with rapid increase in backwash pressure and decrease in membrane permeability.

Extensive chemical cleaning was unable to restore performance. The observed irreversible fouling was attributed to in-line alum dosing (insufficient reaction time prior to UF membrane contact) and recycling of sludge thickener supernatant (may contain unreacted polymer residuals). The typical UF membrane life for this drinking water application was considered to be on the order of 5 years. However, the membranes were substantially fouled after 2½ years, with flow limited to 10 L/s. The premature fouling of the membranes and high replacement cost necessitated a process review and implementation of alternative operating strategy to prevent reoccurrence. Polymer dosing to the sludge thickener ceased in May 2015, just prior to extensive CIP activities. Alum dosing to the UF system ceased in August 2015.

Separate to MPWTP, SA Water operates ten (10) submerged UF WTPs on River Murray water, albeit different membranes and process configuration. These plants have operated in a stable manner since 2008 and have been subjected to wide variations in source water quality (drought, flood, black water). To date these membranes have not been replaced. One of the key differences between the operation of the UF system at MPWTP and the other ten WTPs is the use of alum vs ACH coagulant. In-line alum coagulation at MPWTP is a legacy practice associated with improving capture of diatom spicules in feedwater that were found to deleteriously impact UF membrane integrity. However, since transition to more robust Memcor S10N membranes the requirement for this practice may not be required on a routine basis. In-line coagulation may reduce colloidal fouling, but lack of dosing control, dose optimisation and contact time can result in irreversible fouling (Wray *et al*, 2016). Garcia *et al*. (2015) reviewed 90 sets of UF membrane autopsy results from a wide range of operations worldwide. Coagulant dosing practices were found to be the primary contributor to irreversible fouling in 17% of cases. The trial of an alternative coagulant in Stream 1 provided an opportunity to undertake a wholesale plant change to assess whether the use of pre-polymerised coagulant could stabilise and/or improve performance of the existing fouled membranes. An effective management strategy for the membrane system was critical prior to installation of new membranes.

Initial jar testing of an ACH coagulant (PAC23, IXOM) was completed in late 2014. MIEX treated water was tested under standard conditions (1 minute rapid mix, 14 minutes flocculation and 15 minutes settling) and sub-optimal conditions (50% reduction in contact times – to mimic possible short-circuiting in the full-scale plant). PAC23 yielded marginally slower floc growth and settling than alum under standard conditions, whilst for sub-optimal contact conditions PAC23 yielded superior floc formation.

2.0 DISCUSSION

2.1 Coagulant Selection Process

Jar testing of polymerised aluminium coagulants was completed in consultation with our Water Treatment Research group. Three coagulants were selected for full-scale trial. Key assessment criteria included floc formation and settleability. DOC removal performance was not as critical due to the availability of MIEX® pre-treatment. Coagulants screened for full-scale testing included:

- Alum, PAC23, PAC10LB and LiquiPAC (IXOM)
- AlChlor Gold and AlChlor Gold CR (Hardman Chemicals)
- MegaPAC23 and MegaPAC Blend (Omega Chemicals)

Qualitative observations were as important as quantitative data (settled water turbidity).

At optimal dose rates all coagulants displayed similar performance. However, observations of floc formation, final floc size and settleability allowed improved discrimination of performance. Photometric Dispersion Analysis was used to support visual floc characterisation observations. Jar test observations coupled with settled water turbidity data were used for coagulant selection. Key findings included:

- Alum showed good floc formation, size and settling but high variance in size.
- Low initial floc aggregation, floc size and variance for the IXOM products demonstrated why they are a good choice for membrane pre-treatment applications, but not necessarily suited for conventional treatment if hydraulic short-circuiting may be significant.
- Hardman AlChlor Gold showed equivalent floc growth and size characteristics to alum and performed best of all ACH products.
- Omega MegaPAC Blend produced the best floc growth, size and settling characteristics for ACH type coagulants, but contains a proprietary flocculant aid that may compromise membrane warranty for direct, in-line dosing application.
- IXOM LiquiPAC displayed very fast flocculation kinetics, with most floc growth within the first 2 min. Large, settleable floc resulted in very low settled water turbidity. DOC removal performance was inferior to alum and ACH.
- High basicity of ACH type coagulants resulted in significant decrease in caustic pH correction dosing requirements.

Coagulants selected for full-scale testing were PAC23, AlChlor Gold and LiquiPAC.

2.2 Coagulant Dosing and Operational Challenges

For the purposes of the trial, chemical dosing pumps were fed directly from 1,000L IBCs. MPWTP has three coagulant dosing pumps, sized for use with alum. These were initially used for dosing of ACH type coagulants. Coagulant aid dosing pumps were also available, although the polyDADMAC system had not been used for years. Incompatibility of neat alum and ACH necessitated extensive line flushing, with pH monitoring to confirm effective transition.

Poor coagulant performance in Stream 1 at trial commencement in September 2015 was attributed to dosing instability. ACH type coagulants are much more concentrated than alum: 8%w/w versus 23-25%w/w Al_2O_3 for alum and ACH, respectively. Low flow operation resulted in erratic coagulant dosing. Combined with an input error for the concentration of the ACH stock solution (g/L as product versus g/L as Al_2O_3), the trial was suspended. To improve dosing accuracy the smaller coagulant aid dosing system was used. However, this system employs carry water which could not be turned off due to the size of the dosing lines and set-up of existing control system. Excessive dilution of pre-polymerised coagulants with works water can result in pre-flocculation in dosing lines, which is exacerbated if dosing lines are dirty. At minimum plant flow the dilution factor was as high as 2000:1, which can contribute to accelerated hydrolysis and fouling of dosing lines. Feedback from plant operations staff included: blockages in the static mixers (downstream of carry water addition) requiring regular cleaning. Operations staff were able to manage dosing line blockage issues, however, a permanent installation will require removal of the carry water system.

2.3 Conventional Treatment Performance

Raw water quality was monitored during each testing phase (Table 1). Source water was not challenging, with turbidity well below long-term average of ~80 NTU and DOC ~ 7 mg/L. This is reflective of the low River Murray water flow into South Australia.

Table 1: ***Raw water quality entering the conventional process stream***

Raw Water Quality	PAC23	AlChlor Gold	LiquiPAC
Turbidity (NTU)	26.8	20.1	15.8
DOC (mg/l)	4.0	3.3	3.1
UV254 (1/cm)	0.087	0.079	0.067
pH	7.3	7.3	7.4

Jar tests were regularly undertaken to ensure optimal dose rate for each coagulant were applied with changing raw water quality (Table 2).

Table 2: ***Optimum coagulant dose rates***

Coagulant	Stream 1: Dose with MIEX (mg/l)	Stream 1: Dose without MIEX (mg/l)	Stream 2 No MIEX (mg/l)
Alum	35	N/A	N/A
PAC23	7	N/A	4.5
AlChlor Gold	4	9	4
LiquiPAC	14	18	3

The key objective for Stream 1 was to assess suitability of polymerised coagulants to improve operational performance under design flow conditions (15 L/s). Filtered water turbidity target (<0.15 NTU) was achieved with all 3 coagulants. At design flow, typical values of clarified water turbidity for the three coagulants (Figure 1) were 11 NTU (PAC23), 6 NTU (AlChlor Gold) and 4 NTU (LiquiPAC). Only LiquiPAC was able to achieve values below 5 NTU 100% of the time. This is the recommended maximum turbidity for clarifiers prior to media filtration (Mosse and Murray, 2015). Although clarification performance varied, media filter productivity (as measured by Unit Filter Run Volume - UFRV) were comparable and low: ~ 75 m^3/m^2. A minimum value of 200 m^3/m^2 is considered acceptable for long term process sustainability. The comparable UFRV data suggests different characteristics of floc carryover, with varied penetration through the filters (750mm of 1.1mm ES filter coal over 300mm of 0.5mm ES quartz sand). At time of writing, detailed analysis of head loss profiles was not completed to understand floc interaction with the media. The larger floc formed with LiquiPAC may not penetrate the filter coal as much as the smaller floc associated with AlChlor Gold.

Short-term sustainable operation of Stream 1 at design flow can be achieved with LiquiPAC and AlChlor Gold. Long term operation at design flow is not sustainable due to low filter productivity and high volume of dirty backwash water. For the existing process configuration, upgrades to the tube settler and filters would be required.

2.4 UF Performance Analysis

Since the current membrane set was installed in January 2013, permeability has declined significantly (Figure 2). Following cessation of in-line alum dosing in August 2015 and commencement of alternate coagulant dosing the permeability trend has stabilised. Based on the available data set no significant difference between coagulants can be observed. The faster coagulation kinetics is able to create stable microfloc prior to contacting the UF membranes. Coagulant doses reflect microfloc formation in jar tests (Table 2).

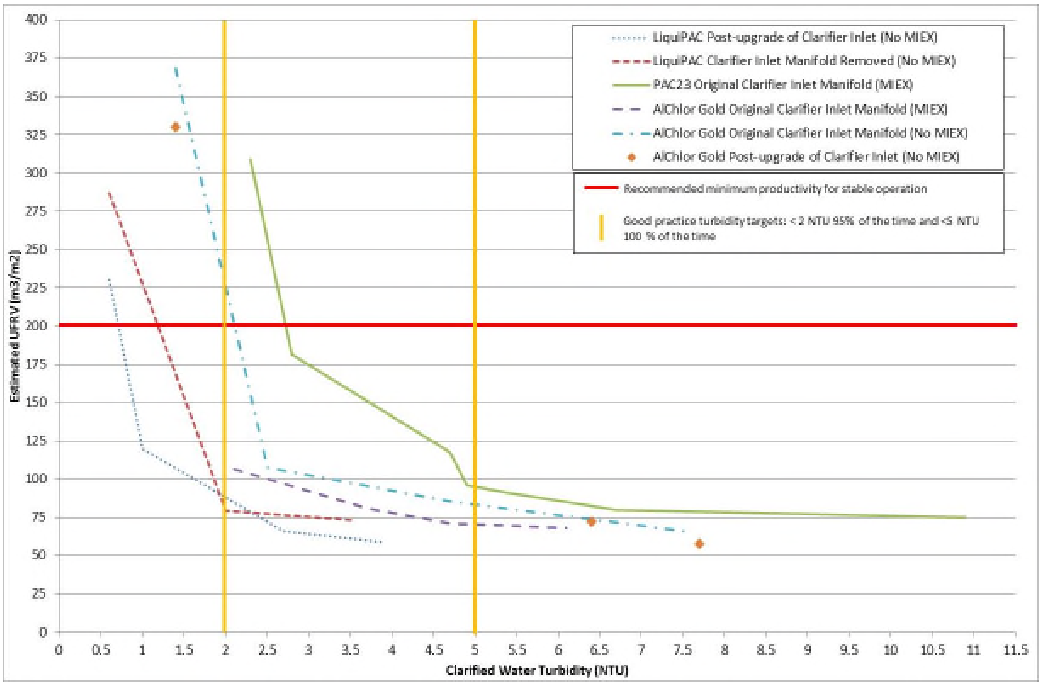

Figure 1: ***Clarified water turbidity vs Unit Filter Run Volume***

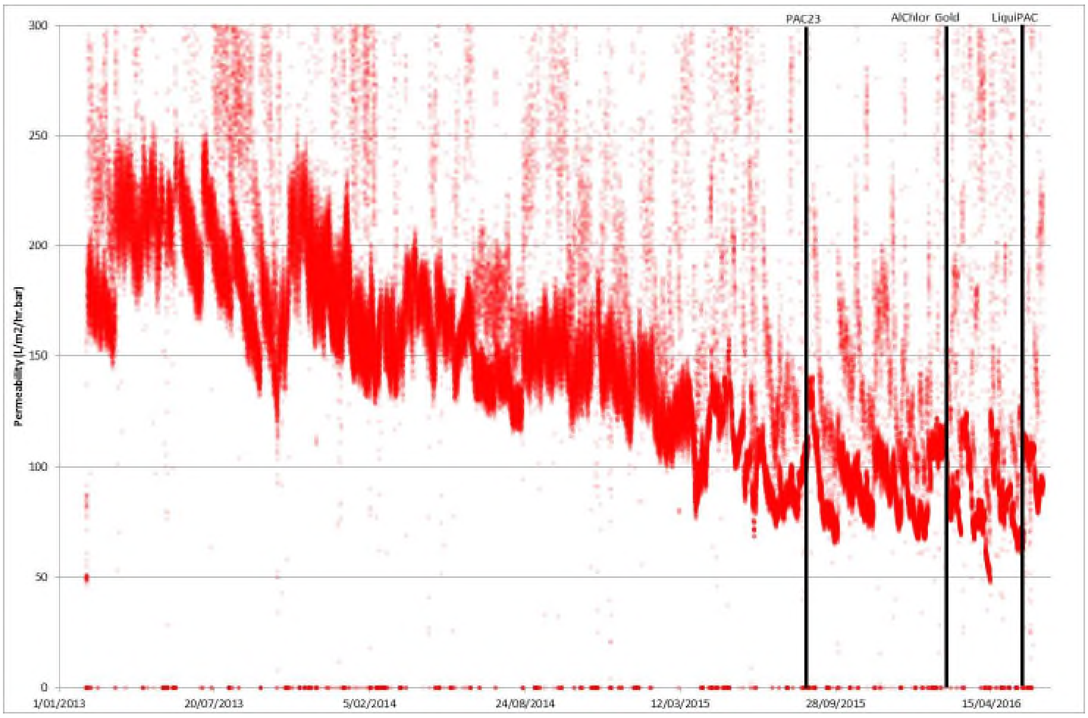

Figure 2: ***UF membrane permeability trend dosing different coagulants***

2.5 Economic Evaluation

Normalised chemical treatment costs ($/ML water treated) were used to compare different coagulant operating regimes. Although the alternative coagulants are more expensive on a unit mass basis the increased cost is offset by decrease in pH correction requirements (Figure 3). Transitioning from alum to polymerised coagulants resulted in comparable costs. The costs associated alum are based on slightly lower quality source water at the commencement of the trial. LiquiPAC, which is 5x more expensive than alum on a unit mass basis yielded the highest chemical treatment cost.

Coagulant selection was not based solely on treatment cost, but achievement of required process improvements for both streams. All 3 coagulants appeared to be compatible with UF membrane operation. Although LiquiPAC was the most expensive option it provides the best treatment conditions for the conventional train to operate reliably at design flow during short-term peak demands. Hence, LiquiPAC may delay need for process upgrades.

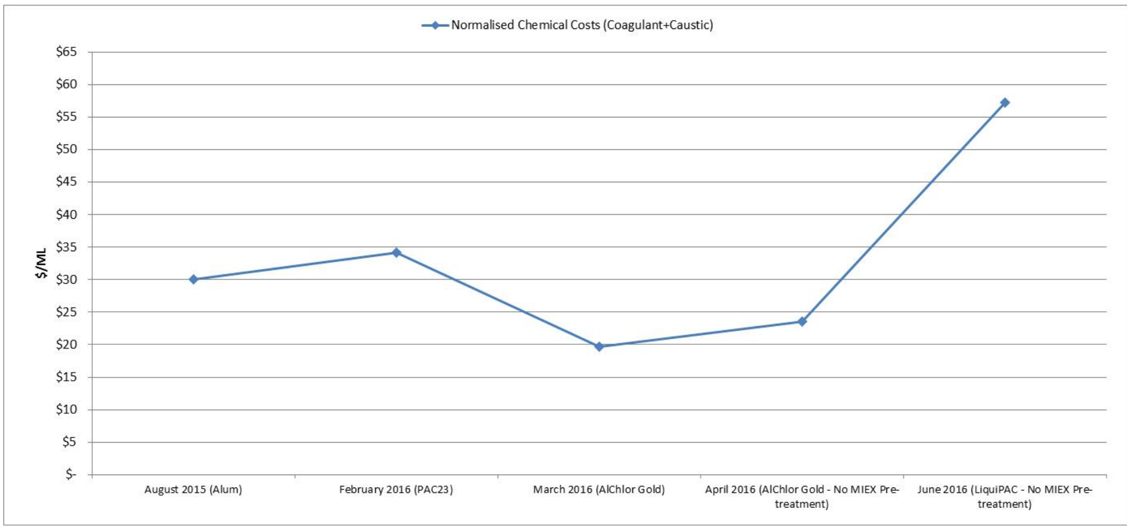

Figure 3: ***Normalised chemical costs during full-scale trial***

3.0 CONCLUSION

Due to low cost of supply and high availability, alum is used at all of SA Water's conventional treatment plants. However, to address performance issues at MPWTP required a significant mindset change across the business. '*Beyond alum*' challenged the status quo and provided an opportunity to review alternative coagulant opportunities to address process issues of operational and strategic asset management importance.

4.0 ACKNOWLEDGEMENTS

Dedicated support of plant operations staff at MPWTP, Gavin Ralston (Treatment & Network Water Quality Manager) and Water Treatment Research Group at SA Water.

5.0 REFERENCES

Garcia N. P., Rodriguez J., del Vigo F. and Chesters S. (2015). *UF Membrane Autopsies: An approach to hollow fibre membrane surface.* Proceedings of International Desalination Association World Congress on Desalination & Water Reuse, San Diego, USA.

Mosse P. and Murray B. (2015). *Good Practice Guide to the Operation of Drinking Water Supply Systems for the Management of Microbial Risk.* Water Research Australia.

Wray H.E., Andrews R. C. and Berube P.R. (2016). Coagulation optimisation for DOC removal: pilot-scale analysis of UF fouling and disinfection by-products formation potential. *Water Science & Technology: Water Supply*: 16(2): 473-480.