CHALLENGING THE HISTORIC COAGULATION SYSTEM AT STROMLO WTP

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ABSTRACT

Stromlo Water Treatment Plant is a 250 ML/day DAFF plant which operates with seasonal changes in coagulation chemistry. At water temperatures of less than 12°C the process is aluminium sulphate (Alum), polyaluminium chloride liquid (PACL) and polymer. For warmer water only Alum and polymer are used. Mud balls were discovered in the filters in late 2012. In response, a review of the coagulation at Stromlo WTP is being conducted to consider the chemical dosing history that caused the problem, the ongoing polymer dose location and options for primary coagulants.

Alum and PACL are both primary coagulants and in all other known treatment plants either Alum or PACL are dosed, not both. At Stromlo WTP historically both are dosed, in series based on original jar testing and pilot plant operation when the plant was designed. Polymer is currently dosed to the second floc chamber of individual filters via a passive splitter box. This flow splitting arrangement is believed to be unable to provide even flow splitting, resulting in random overdosing and under dosing of polymer. This paper outlines the investigation into the history of the problem, options for modifying the primary coagulation process and the impact of moving the polymer dosing point to resolve the polymer dosing issues.

1.0 INTRODUCTION

Stromlo Water Treatment Plant is a 250 ML/day direct filtration plant with optional in-filter dissolved air flotation. It was constructed in 2004 following bushfires in the Cotter catchment which impacted the low turbidity and low colour raw water supply. In 2010/11 the media in all filters was replaced during works to epoxy coat the concrete structures. The performance of the filters with new media was excellent with low turbidities and good run times. The replacement filter media was slightly different to the original as it utilised garnet as the support layer instead of pebbles. Therefore the process of confirming what was normal for filter operation trends in the rebuilt filters was starting.

During a filter inspection course in October 2012 mud balls were discovered in the filters. It was unexpected that essentially brand new filters could have been impacted so quickly and an investigation was launched. The initial investigation included head loss trends and the history of the filters prior to the filter media being replaced. Known legacy issues with the design of the treatment plant were put forward as well as current issues with coagulation and filter management.

Filter trends showed curve in the head loss development of some filters which suggests an excess of polymer. Also many filters were backwashing due to high head loss, which again suggests an excess of polymer. The first discovery was that the actual polymer batch concentration did not match our SCADA system dosing calculation. This discrepancy meant the dose rate was almost twice the historical normal dose rate. The polymer system is a packaged stand-alone system with limited feedback to SCADA. Batch concentration is manually set by timers on the powder screw feeder (0.17% w/w) following drop testing and the dose rate is calculated from a manual input of the batch concentration on SCADA which was set at (0.10% w/w).

This discrepancy was rectified immediately however we were unable to trace back to exactly when the discrepancy was created. Processes for confirming the actual batch concentration through moisture analysis of solids percentage were implemented to ensure further discrepancies do not arise.

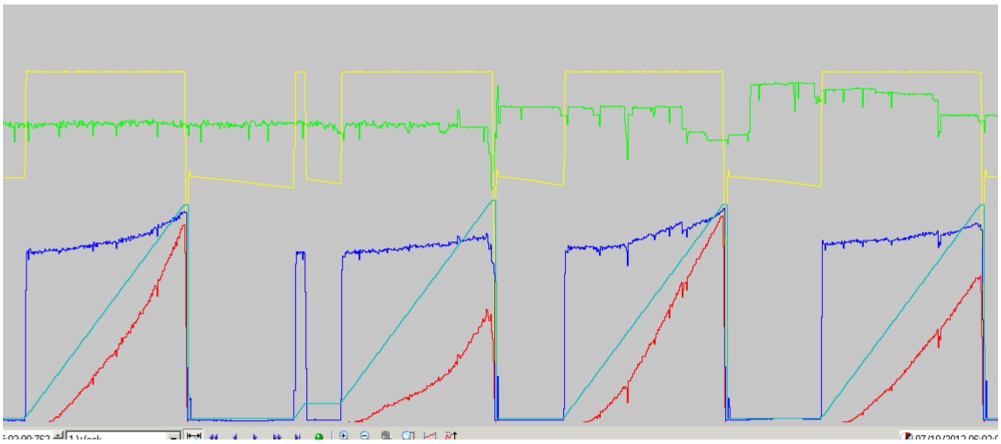

Figure 1: ***Filter 7 trend showing curve in head loss development***

Further analysis of the head loss trends showed that the excess polymer effect on head loss development was not even across all filters. The investigation lead to the distribution of polymer via splitter box, and secondly the distribution of raw water inflow between the filters. It has been observed during the operation of the treatment plant filters that uneven splitting of inflow through the filters does result in higher load on some filters which is compounded by the disproportional polymer flow from the splitter box.

Stromlo WTP inlet flow path consists of three chambers separated by hydraulic baffles followed by a tapered inlet channel that splits flow into the individual filter modules. The flow splitting is achieved by directing inflow from the tapered inlet channel over weir plates directly into the first floc chamber of each filter module. Each filter module consists of a dual stage floc chambers prior to the filter. There are flash mixers located in second and third inlet chambers where coagulants are dosed in series. Polymer is normally dosed into the second floc chamber of the filter module.

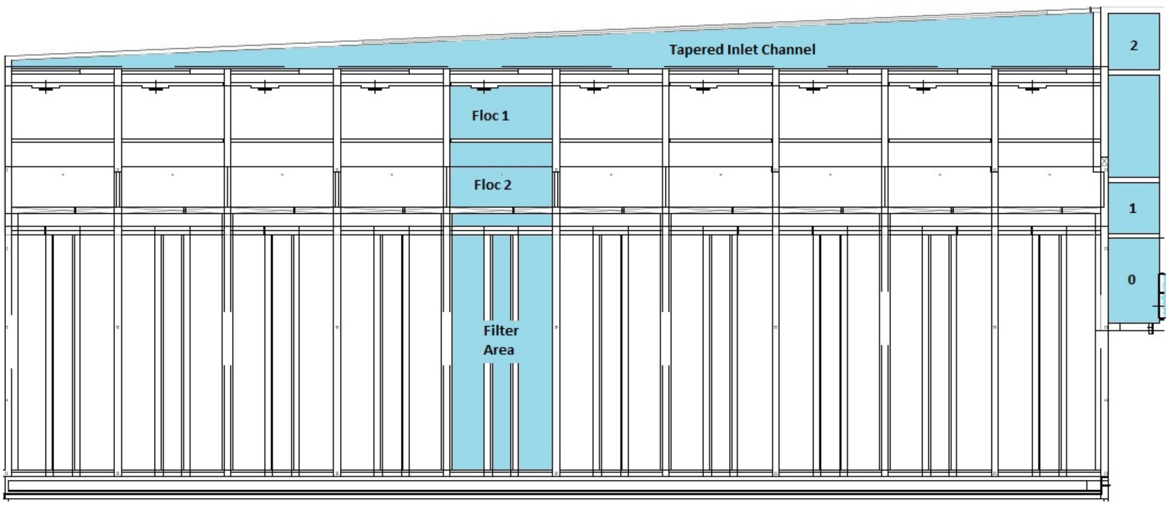

Figure 2: ***Stromlo WTP inlet and filter flow path***

2.0 DISCUSSION

Stromlo WTP operations team discussed many options for improving efficiency of coagulation and polymer dosing to reduce excess mud collecting in the filters and causing formation of mud balls. The performance of filters was not equal. Historically polymer dose was set to optimise the filters that were struggling to make run hours and that were breaking through on turbidity. Filters at the beginning of the inlet channel reached turbidity breakthrough more often. Filters 5 & 6, located in the middle of the inlet channel, were known to be the "more sensitive" and filters 9 & 10 the "least sensitive". This anecdotal knowledge of the treatment plant, along with observation of mud layer and mud ball formation in the filters, confirmed the idea that some filters were experiencing different loading or polymer dose.

Following discussions and brain storming about how to deal with the problem of uneven filter load and polymer distribution, the immediately available option to respond was to change the polymer dosing location to the main inflow prior to any of the flow splitting systems. This would eliminate problems with distribution of polymer and ensure that the chemistry of the water entering each filter was the same. However, moving the polymer dose raised a series of questions about the overall coagulation system of the plant and how the coagulation and flocculation processes would be impacted.

- PACL is dosed in the second flash mixer. PACL is not required in summer, however during winter we will need to modify the normal coagulation setup to allow for dual coagulant dosing.
- Flash mixer mixing energies required for polymer dosing at flash mixer 2 were unknown.
- Location of polymer dosing point needed to be considered in terms of process and practicality of implementation whilst the plant was operating.
- Polymer function changing to flocculation aid instead of filtration aid.
- A much higher dose of polymer would be required at the flash mixer to provide the same effect on the filters turbidity profile; this could have a negative impact on excess in the filter media and mud ball formation.

Therefore changing polymer dosing location would require challenging the historical coagulation system at Stromlo WTP.

2.1 Primary Coagulation

Stromlo WTP operates with two primary coagulants. In summer months the coagulant Aluminium Sulphate (Alum) is effective for coagulation and it is used alone. However in winter, when water temperatures dip below 12°C, the efficiency of Alum for coagulation in our raw water is decreased and PACL is used to improve the coagulation. Since construction of the treatment plant PACL has been referred to as a coagulation aid, however although it was dosed separately, the function of PACL is that of a coagulant. This primary coagulation setup is unusual across the industry and there has been misperception over the function of each chemical in the coagulation process. However experience at Stromlo WTP has proven that it is effective for our raw water.

In response to the mud ball discovery, initially the fastest option for relocating the polymer dosing point was to overflow the polymer dosing splitter box through the existing overflow into the inlet water after flash mixer #1. For this option to be utilised consideration was given to changing the primary coagulation setup.

The flash mixing and inlet channel were designed with the intention for Alum and PACL to be dosed into the separate flash mixers in series. Historically, Alum is dosed into flash mixer #1 and PACL into flash mixer #2. Theoretically, as both Alum and PACL are primary coagulants they should be able to be dosed to the same location. However this had never been attempted at Stromlo WTP.

To confirm the theory for Stromlo WTP on 29th October 2012, a series of jar tests were conducted. The water temperature was 12°C, lime sludge was being wasted and carbon dioxide dosing operating. Comparing coagulation of Alum and PACL blend dosed simultaneously, Alum only and PACL only resulted in negligible difference in indicator true colour. Floc formation was difficult to judge due to the lack of turbidity or colour in the raw water for flocculation. Indicator true colour results were less than 2 Pt Co in comparison to process floc samples of 3 Pt Co.

Table 1: ***Jar testing results with Alum and PACL coagulant options***

Source	**29/10/2012 Inlet Channel**	**29/10/2012 Mixer 0**	**29/10/2012 Mixer 0**	**29/10/2012 Mixer 0**
Coagulant #1	Alum	Alum	Alum	Alum
mg/L as Al2O3	1.12	1.12	1.89	0
Coagulant #2	PACL	PACL	PACL	PACL
mg/L as Al2O3	0.72	0.72	0	1.69
Total Coagulant as mg/L Al2O3	1.84	1.84	1.89	1.69
True Colour Pt Co	4	2	3	2
Floc formation	Pin floc	Pin floc	Pin floc	Pin floc

Supported by jar testing results the coagulant dosing points in the plant were adjusted such that Alum and PACL were being dosed to flash mixer #1 through the same diffuser, without any dose rate change. This coagulation setup was operated from 1 November 2012 until the 13 November 2012 when water temperature increased above the trigger to cease PACL dosing. No significant difference was observed in floc formation, colour removal or filter turbidities.

2.2 Polymer dosing

Experience at Stromlo WTP has proven that polymer is required to maintain filter performance. Filter turbidity breakthrough has been observed within hours of loss of filter polymer dosing. Polymer is normally dosed into the second floc chamber prior to flowing into the filter with the intention of the polymer acting as a filter aid. This location was chosen as it is a low turbulence area after the floc had time to form.

The polymer dose splitter box is a cheap passive method of distributing polymer between the ten filter modules. It is constructed with ten v-notches around a common channel however the turbulence in the common channel makes the v-notches distribution uneven. Blockages and restriction in flow through the polymer dosing lines from the v-notches to the filters are also a frequent issue.

Overflowing the polymer splitter box was a quick and easy way to avoid the problems with flow splitting and move the polymer dosing point to dose the full inflow stream.

Although overflow was not the desired permanent method of polymer dosing, it was possible to implement immediately, where diffusers or additional pipework were difficult to construct with the plant online and chambers full of water. The installation of ten metered dosing pumps was not an option due to cost and given the unknown flow distribution between filters.


<u>Figures 3 & 4:</u> **Polymer Splitter box V notches and turbulence.**

Moving the polymer dosing point to immediately after coagulation affects the function of the polymer. The design intention was for polymer to act as a filter aid. In the new location it would function as a flocculation aid and a higher dose of polymer was expected to be required to obtain the same effect on filter turbidity. In early Dec 2012 the polymer splitter box was overflowed and the polymer dose rate increased to 0.10 mg/L. This relative high dose rate for direct filtration was actively reduced in stages to 0.070 mg/L.

The initial experience from new dosing point was that the filters at the beginning of the filter channel continued to see early breakthrough. The speed of the mixer following polymer dosing has been adjusted and trials were conducted at multiple speeds to improve distribution with limited success. Experience at Googong WTP had highlighted issues with polymer being carried by the fluid dynamics in channels and not being properly mixed or even. A simple diffuser was constructed and installed over the flowing inlet channel at the only available location with the plant online. The diffuser slightly improved distribution however the performance of the filters remains uneven. The next step for optimising polymer dosing is to install multiple diffusers in the channel in the flow prior and in the chamber of flash mixer #2 when the plant is next offline. This will allow trials to obtain the best mixing and most event distribution. Once the mixing and even distribution of polymer are optimised it is expected that the polymer dose rate may decrease, which will further reduce the formation of mud layers and mud balls.

2.3 Floc formation and turbulence

A consideration when moving the polymer dosing point was the turbulence through the process and the impact on floc formation. The original polymer dosing point was chosen as a very low turbulence area where floc would be properly formed. Changing from using polymer as a filter aid to a flocculation aid was expected to impact floc formation. However the additional impact on established floc by turbulence is unknown.
Looking at the flow configuration through the plant, flash mixer #1 is operated at high

speed for rapid reaction of coagulation. Following the polymer dosing as flocculation aid the speed of flash mixer #2 was reduced for gentler mixing. The inlet channel has very smooth flow, in which floc can be seen starting to form. Inlet weir plates result in high velocity between the inlet channel and first floc chamber. The second flocculation chamber is again gentle mixing, followed by insignificant mixing above the filter.

With polymer used as flocculation aid, the concern is that established floc may be subject to high velocity gradients during across the flow splitting inlet weir and become damaged (floc shearing), reducing the size of the floc and impacting filter performance. The impact may be worse in filters at the end of the inlet channel where higher flocculation times result in full floc formation prior to shearing across the inlet weir. Furthermore the flow through the inlet channel appears to carry heavier particles and polymer toward the later filters, increasing load. This is evidenced by the thicker slime forming on the walls of the inlet channel toward the end and on the walls of the floc tanks and filters.

Figure 4: ***Inlet channel gradient of slime***

3.0 CONCLUSION

Discovery of mud balls in new filter media has prompted a challenge to the historical coagulation system at Stromlo WTP. Changes to the primary coagulation dosing point, polymer dosing location, diffusers and mixing speeds have been made to optimise the coagulation system and reduce mud ball formation whilst maintaining the good performance of the filters. Work to further optimise coagulation will continue as an ongoing improvement process.

4.0 ACKNOWLEDGEMENTS

Thank you to Peter Mosse for helping challenge historical actions and to all the operators, water operations team and maintenance staff who have been involved in the optimisation of coagulation and management of the mud balls at Stromlo WTP.

5.0 REFERENCES

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