SLUDGE SETTLEABILITY CONTROL AT ELANORA WWTP RAS CHLORINATION TRIAL

Paper Presented by:

Martin Hindmarsh

Authors:

Mark Wilson, *Process Engineer,*
Martin Hindmarsh, *Treatment Plant Operator,*

Allconnex Water

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ABSTRACT

Poor sludge settleability, caused by high concentrations of filamentous bacteria in the mixed liquor, was limiting the capacity of the Elanora Wastewater Treatment Plant; with solids carryover causing high effluent turbidity during wet weather flows. A range of solutions were considered in addressing this problem. The option considered most likely to provide a robust improvement in settleability, with acceptable process risk and cost, was RAS chlorination.

RAS chlorination was trialled over a 3 month period on the smaller stage of the plant. An acceptable improvement in settleability was recorded. Detrimental impacts on effluent quality were observed at high doses, providing guidance on the operational limitations of RAS chlorination.

1.0 INTRODUCTION

It was identified in the Elanora Wastewater Treatment Plant (WWTP) Planning Study (MWH, 2007) that the plant capacity is currently limited to 20.7 ML/d by the ability of the clarifiers to settle solids. Elanora currently receives approximately 24.7 ML/d of raw sewage. Solids that are not separated from the mixed liquor by the clarifiers will carry over with the launder into the chlorine contact tanks and effluent lagoon. The potential consequences of solids carryover are:

- Inadequate disinfection due to increased chlorine demand
- Development Approval breaches of faecal coliform and suspended solids requirements
- Reduced recycled water quality

The Hazard Analysis Critical Control Point (HACCP) system includes a critical limit for effluent turbidity. Elanora WWTP regularly exceeds this limit during wet weather events. Turbidity is directly linked to suspended solids, therefore this indicates that biomass is being lost from the system during these events.

The settleability of the sludge, as quantified by the diluted sludge volume index (DSVI), was poor, approximately twice that of other Gold Coast plants. Improving the settleability reduces the tendency for solids carryover and increase the hydraulic capacity of the plant.

Table 1: ***Current and target DSVI***

mL/g	Stage 1	Stage 2
Median current	213	204
Maximum permissible for sustained wet weather	175	131
Maximum permissible at which solids separation will not be capacity limiting	151	107

The Elanora WWTP Planning Study and Short-Term Biosolids Strategy (TYR Group,

2008) have identified target values for the DSVI derived from a dynamic model of the treatment plant (Table 1). The current DSVI is substantially higher than the target values. Elanora WWTP consists of two parallel stages with separate sludges. Stage 1, incorporating bioreactors A and B, treats approx 10 % of the total flow.

1.1 Options

Methods to improve the settleability can be classed as either specific, which address the cause of the problem, or non-specific, which treat the symptoms.

Specific Methods

Samples of Elanora mixed liquor have undergone microscopic analysis in an attempt to diagnose the cause of the poor settleability. The results confirmed that the sludge contained an abundance of filamentous bacteria, renowned for causing settleability problems. The Elanora sludge contained six abundant filamentous species known to gain a competitive advantage over floc-forming bacteria in low dissolved oxygen (DO), low food / microorganism (F/M) and high sulphide conditions, depending upon the particular species. In the case of Elanora, it is safe to rule out other documented causes of poor settleability such as macronutrient deficiency and micronutrient deficiency.

The primary settling tanks remove approximately half the substrate from the raw sewage. Of the remaining substrate, some is inefficiently utilized when clarifier F return activated sludge (RAS) drops into the bioreactor inlet channel, creating higher than desirable DO in the anoxic zone. These factors result in a low F/M ratio. The substrate in the bioreactors can be supplemented by primary sludge, however trends were inconclusive in determining the effect of primary sludge dosing on the DSVI.

Optimal DO conditions for floc-forming bacteria are: very low and consistent DO in the anoxic zone and high and consistent DO in the aerobic zone. Furthermore, it has been documented that ‘activated sludge settling usually is poorer if the initial mixing between RAS and influent wastewater contains DO and/or is aerated rather than being devoid of DO and/or unaerated’ (Chiesa and Irvine, 1985). The high DO in the anoxic zone could be improved by extending the clarifier F RAS pipe to discharge under the surface of the inlet channel and preventing the discharge from the inlet channel from dropping into the anoxic zone of the bioreactor. These modifications should be undertaken for this and other reasons, however it is considered unlikely that these modifications would result in the required settleability improvement.

The rapid cycling of the mixed liquor between high DO and low DO zones of the aerobic zone was proposed in the Elanora Planning Study as the predominant cause of the poor settleability. There is little that can be easily done to address this problem. Installation of variable speed drives on aerators could create more consistent DO conditions, however this would be an expensive undertaking and could not guarantee improved settleability.

Other process variables that could impact on settleability are the RAS return ratio and A-recycle ratio. No distinct relationship could be observed between these variables and the settleability.

Non-specific methods

Ferric chloride dosing is one non-specific method for settleability control currently used

at Elanora. The ferric dosing system was installed for phosphorus removal, however during wet weather events the operators increase the dose of ferric in the hope of improving settleability and retaining solids.
This strategy could theoretically produce some improvement in the settleability, however based on the continued HACCP exceedances it does not improve the settleability adequately. Ferric overdosing has the side effect of accelerating corrosion and increasing conductivity.

Dosing chlorine into the RAS is a non-specific method for improving settleability that has been used in many wastewater treatment. Chlorination has been used successfully to control bulking caused by every type of filamentous organism observed in activated sludge (Jenkins et al, 2004). The concept is to dose the chlorine at a concentration that kills filamentous bacteria but not the useful floc-forming, nitrifying or de-nitrifying bacteria.

1.2 Selected Option

It was concluded that RAS chlorination was the only solution considered likely to robustly achieve the required settleability. The process risk associated with RAS chlorination is that overdosing will cause:

- Inhibition of nitrifying and denitrifying bacteria resulting in elevated effluent ammonia and/or nitrogen.
- Floc disruption resulting in high effluent turbidity.

RAS chlorination would incur the expense of installing dosing pumps and lines, which is not considered to be a prohibitive expense.

2.0 AIM

It was proposed to trial RAS chlorination on stage 1.

The objective of this trial was to demonstrate the use of RAS chlorination to improve the settleability of the Elanora WWTP stage 1 sludge below the target value of 151 mL/g.

Secondary objectives were to identify the optimal chlorine dose and explore the operational limitations of RAS chlorination.

3.0 APPARATUS

10 % sodium hypochlorite solution was stored in 2 No. IBCs (bulky boxes) of 1000 L capacity each with hoses venting to the atmosphere and a pedestal fan to ventilate the room. Dosing apparatus including piping, ball valves, check valves, pressure sustaining valves, injection quills, a calibration cylinder and a Grundfos Alldoss DDI 222 digital dosing pump.

Existing online effluent nutrient and turbidity analysers, grab sample nutrient and turbidity analysis equipment and a microscope were onsite for monitoring purposes.

3.1 Safety

Consideration was given to safety in the design and placement of the apparatus. Sodium hypochlorite solution is classified as a class 8 corrosive substance. The design of this trial complied with the Australian Standard *AS 3780 -- 2008: The Storage and Handling of Corrosive Substances*.

4.0 METHODOLOGY

Prior to startup, the dosing apparatus was operated for over 24 hours dosing water instead of hypo to check for leakage. Daily checks of the dosing apparatus were made to check for leaks.

4.1 Dose Calculation

The hypo solution dose calculation was performed each time either new mixed liquor suspended solids results became available or the dose rate was changed.

The dosage range guidelines documented in Jenkins et al (1993) were considered when setting the dose. The hypo solution flow rate set on the dosing pump was determined using the calculations set out in Jenkins et al (1993).

4.2 Procedures

Daily checks were performed to ensure all equipment was safe and operational. Effluent quality, mixed liquor protozoa / metazoa abundance and settleability were monitored regularly.

5.0 RESULTS

5.1 Safety

No hypo was leaked or spilled throughout the duration of the trial. No health or safety incidents occurred throughout the duration of the trial.

5.2 Settleability

The DSVI for both stages over the duration of the trial is compared in Figure1. RAS chlorination was applied to the sludge from bioreactors A and B (stage 1) only. The DSVI of bioreactors A and B declined substantially following the commencement of RAS chlorination, while over the same time the DSVI of bioreactors C to F remained steady.

The DSVI of bioreactors A and B was maintained at approximately 125 mL/g for a period of approximately two months – well below the target DSVI of 151 mL/g.

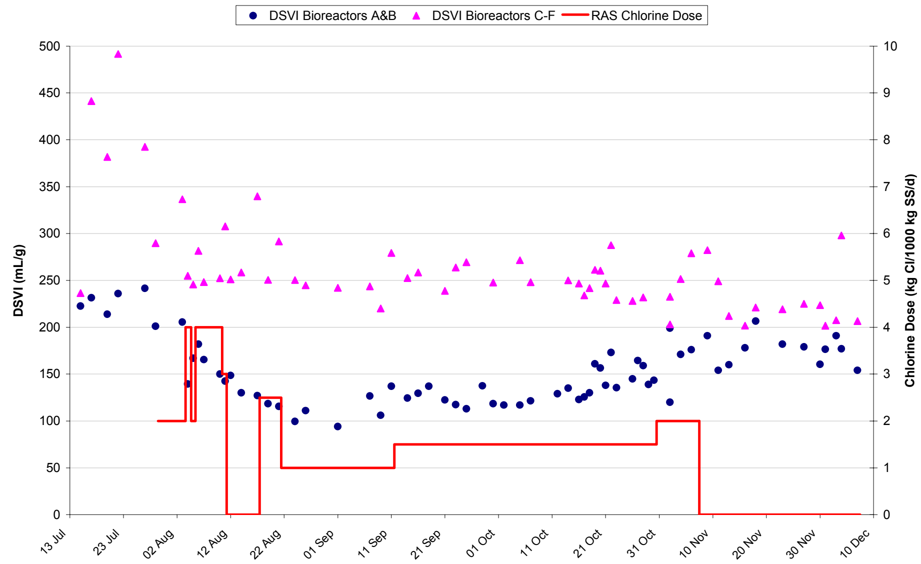

Figure1: ***Settleability comparison of the two stages at Elanora WWTP. RAS chlorination applied to bioreactors A&B only.***

On 19 October 2009 the DSVI of bioreactors A and B increased and became more variable. This coincided with an odour control trial being conducted at Elanora that involved dosing ferric chloride solution at the inlet and turning off the ferric chloride dosing usually applied to the outlet of the bioreactors.

5.3 Microscopic Observation

Conclusions drawn from regular microscopic observation of bioreactors A and C mixed liquor were:

- Bioreactor A filament abundance rating improved from *very common - filaments observed in all flocs, but at medium density (5-20 filaments per floc)* to *some - filaments commonly observed, but not present in all flocs.*
- Bioreactor C filament abundance rating remained constant as *very common - filaments observed in all flocs, but at medium density (5-20 filaments per floc)*.
- The abundance of crawling or free swimming ciliate protozoa decreased in bioreactor A but remained constant in bioreactor C.
- Stalked ciliate protozoa and rotifer metazoa remained prevalant in bioreactor A.

5.4 Effluent quality

During the early stages of the trial (approx 10 August 2009) the stage 1 effluent ammonia plus nitrate (forthwith referred to as inorganic nitrogen) spiked substantially as shown in Figure 1. At the same time effluent turbidity spiked.

Stage 1 inorganic nitrogen and effluent turbidity returned to normal levels following a reduction in the RAS chlorination dose.

There was a subsequent increase in effluent turbidity between 21 and 25 September 2009 that coincided with bioreactor E being taken offline for maintenance.

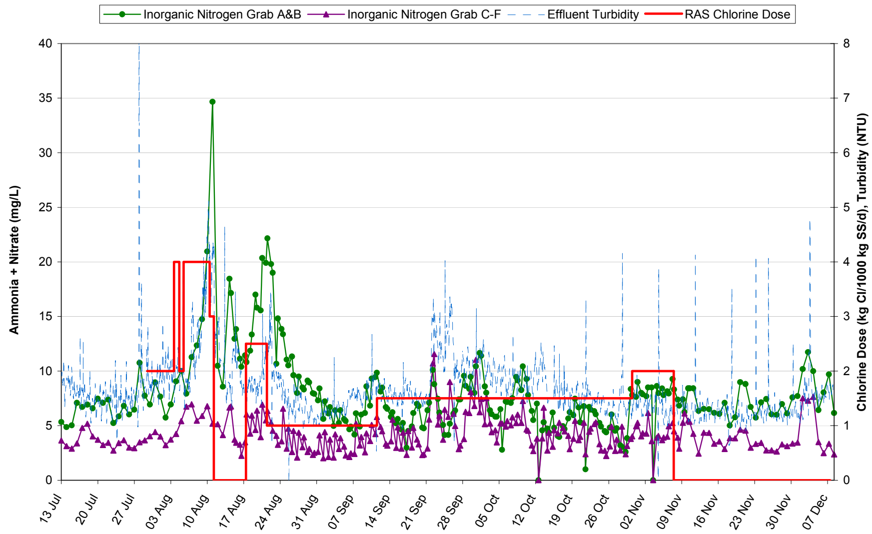

Figure 1: ***The effect of RAS chlorination on effluent quality*.**

6.0 DISCUSSION

6.1 Settleability Performance

RAS chlorination of stage 1 sludge has demonstrated that the DSVI target value can be robustly achieved using this method. Stage 2 sludge is separate from stage 1 sludge and as such may have different microbiological composition, however is it likely to be similar to stage 1 sludge and hence likely to respond similarly to RAS chlorination.
It would be ideal to achieve a stage 2 DSVI of 107 mL/g, which is the DSVI at which the settleability will no longer be capacity limiting. This target for stage 2 is substantially lower and that for stage 1 of 151 mL/g. Based on the results of this trial, achieving the stage 2 target DSVI may be possible, but will not be easily met. The required stage 2 DSVI for the clarifiers to operate effectively during a sustained wet weather event based on current loading is 131 mL/g. This target is likely to be using RAS chlorination.

6.2 Effluent quality

The effluent quality was initially detrimentally impacted by a chlorine overdose, which occurred because the stage 1 sludge was more responsive to RAS chlorination than was expected based on the guideline values. The RAS chlorination dose was reduced and the trial proceeded without further deterioration of the effluent quality due to RAS chlorination. The increase in effluent turbidity between 21 and 25 September 2009 coincided with bioreactor E being taken offline. There were also some increases in stage 2 inorganic nitrogen around this time which would be an expected outcome from taking one quarter of stage 2 treatment capacity offline.

6.3 Microscopic Examinations

Microscopic examination of the mixed liquor confirmed that there was a reduction in filamentous bacteria abundance within the stage 1 sludge. This result confirms that the mechanism of stage 1 settleability improvement was via filament die-off due to RAS chlorination and not any other means, although this was already evident from the DSVI and chlorine dose trends presented in Figure1.

Microscopic examination also revealed a die-off of free swimming and crawling ciliate protozoa within stage 1 sludge, however stalked ciliate protozoa and rotifer metazoa, in particular, remained in abundance. The presence of protozoa / metazoa within the sludge is an indicator of a healthy biomass. Free swimming and crawling ciliates are clearly more susceptible to chlorine than other protozoa / metazoa. Given the continued existence of some species of protozoa / metazoa this finding is not concerning, however it may be useful for future treatment investigations.

6.4 Equipment and costing

The scope of this RAS chlorination trial did not include costing the permanent installation of RAS chlorination equipment. This trial has provided operational experience with the equipment likely to be used for a permanent installation. The Grundfos Alldos DDI 222 digital dosing pump performed suitably. Short injection quills with integrated check valves were used without any negative issues arising.

7.0 REFERENCES

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