# DRINKING WATER QUALITY IMPROVEMENT COLLABORATION - CHLORATE AND THM REDUCTION

*John Granzien* and *Diane Rapson* - Seqwater

**ABSTRACT**

Seqwater is the bulk water supplier to Urban Utilities. Urban Utilities operators reported emerging trends in DBPs (chlorate and THMs) in the Somerset Dam Township. Seqwater operational staff took it upon themselves to get ahead of an increasing problem of high Chlorate levels. Initiating multiple changes to sodium hypochlorite management over a period to obtain the best outcomes. Dosing, container sizing, collection methods and frequency of change outs where all optimised.

Other treatment processes were reviewed with the assistance of the Seqwater Process Engineering Team as part of a holistic assessment have improved Trihalomethane management using enhanced coagulation and pre-filter chlorination. Powdered Activated Carbon has been introduced to assist in THM reduction, with the added benefit of taste and odour management (seasonal requirement). Urban Utilities were frequently flushing mains around the township to decrease the THM levels and this posed a problem for us in keeping the WTP water production flowing due to above expected usage. Similar issues are experienced in the Lowood reticulation network however the problems are solved in the network. Through collaboration and sharing wins and losses across agencies we have reduced risk and improved customer drinking water quality.

## 1.0 INTRODUCTION

As water quality for potable water has really come to the fore across Australia and the World, the anticipation of the consumer has hit new heights. One area gaining attention and potentially more stringent guideline levels within the ADWG are Disinfection By-Products (DBP), specifically chlorates and Trihalomethanes (THM) formed in chlorinated drinking water supplies.

It is proposed that the management of these DBPs without compromising on disinfection effectiveness, is best achieved through a collaborative approach between the bulk water supplier and distributor.

This paper presents the challenges faced in addressing the elevated DBP levels at Somerset Dam WTP and a lesson learned approach for how to better manage DBPs in small regional WTPs.

### 1.1 THM Removal in Chlorinate Drinking Water Supplies

THM DBPs are produced by the interaction of bromide and / or Natural Organic Matter (NOM) with chlorine during chlorination. They represent the four regulated and commonly occurring THM species which are chloroform ($CHCl_3$), bromodichloromethane ($CHBrCl_2$), dibromochloromethane ($CHBr_2Cl$) and bromoform ($CHBr_3$). There is also the added concern of chlorate contamination from the degradation of sodium hypochlorite.

As THMs have potential health hazards, typically through a lifetime exposure, there is a need for them to be maintained as low as reasonably practicable below the health target limits without compromising on disinfection effectiveness. When raw water sources have elevated bromide concentrations and/or NOM, a separate management plan is necessary to operate the plant efficiently in terms of the optimum chemical dose rates, cost, and more importantly, the continuous production of treated water to meet the specified drinking water quality guidelines.

The best means to manage THM levels is to remove higher NOM (as DBP pre cursors) through process optimisation at the WTP prior to chlorination. This removes the organics and potential THM formation, however, the extent of possible NOM removal will depend on the adsorbable and non-adsorbable fractions of NOM in the raw water.

When THM reduction cannot be achieved at the WTP, then consideration for additional mechanical means such as aeration or flushing within the treated water reservoir and network should be considered.

## 1.2 Chlorate Limits

Chlorates are considered an emerging hazard when treating contaminated water. But they are more commonly formed as degradation by-products from the storage of sodium hypochlorite, the rate of which is accelerated due to temperature and age. As sodium hypochlorite decomposes, it decreases the amount of freely available chlorine, resulting in increased chemical dosing to achieve the required disinfection. This increases the concentration of chlorate in the drinking water.

When monitoring chlorate levels in drinking water, there is currently no ADWG limit. Instead, chlorate limits are guided by the World Health Organisation (WHO) and Queensland Health. The WHO has identified a limit of 0.7 mg/L; however, Queensland Health has set a slightly higher interim limit of 0.8 mg/L, adjusting for the larger average body mass in Australia. The later value is used by Seqwater and Urban Utilities as the chlorate drinking water quality health limit.

## 1.3 THM Limits

THMs are the main DBP in chlorine disinfection and are used as the indicator for the presence of chlorine derived DBPs in drinking water. The current ADWG total THM health limit is 250 µg/L, however the growing body of research indicates that this value is high enough to cause health concerns. The Australian water sector recognises that the current guideline limits within the ADWG are likely to be reduced with many service providers working to reduce their THM levels now in preparation for a change. There is also growing pressure on water service providers to manage THM levels year-round, thereby avoiding seasonal exceedances.

Somerset Dam WTP operates under a Drinking Water Quality Management Plan (DWQMP) and Hazard Analysis and Control Point (HACCP) Plan which require Total Trihalomethanes (TTHM) to be maintained below 125µg/L. Additionally, TTHMs within the water grid need to be maintained below Urban Utilities protocol limits of 160µg/L (Trigger level 1), 190µg/L (Trigger Level 2) and 220µg/L (Trigger Level 3) respectively.

## 2.0 DISCUSSION

In 2017, Urban Utilities operators reported emerging trends in elevated THM levels in the Somerset Dam Township year-round. The sample results within the distribution network were much higher than Seqwater's sample results at the WTP bulk water transfer point and in some instances, exceeding Urban Utilities communication protocol Levels 1 and 2 as shown in Figure 2-1.

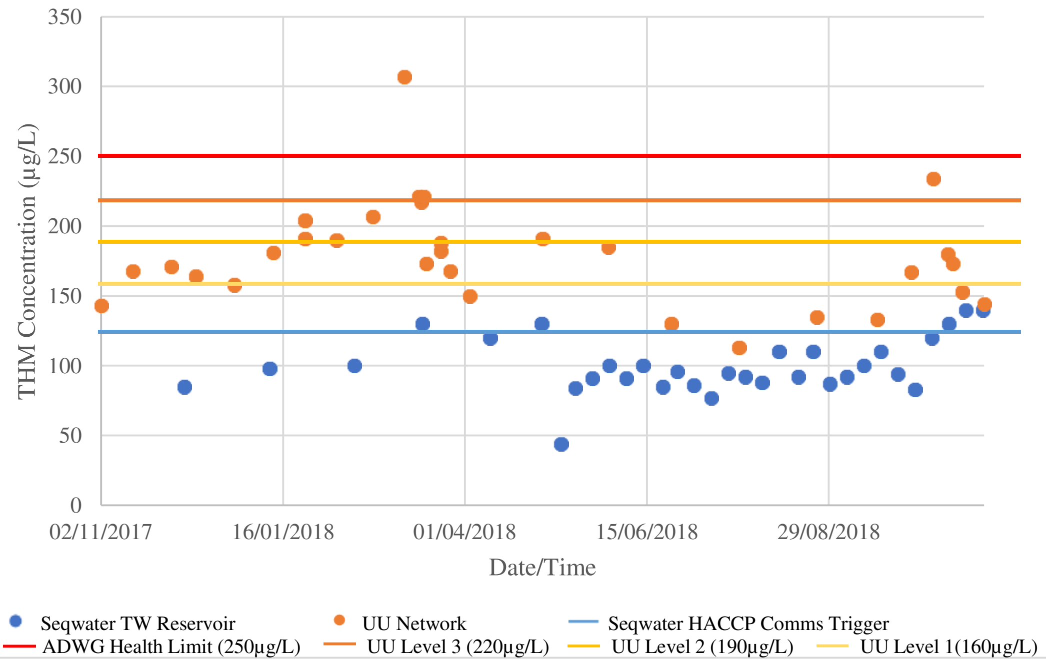



**Figure 1:** ***THM Concentration November 2017 to November 2018***

Seqwater and Urban Utilities also identified ongoing trends of elevated chlorate levels within the network due to degradation of the sodium hypochlorite at the WTP. Both DBP exceedances triggered a review by Seqwater and Urban Utilities.

As the bulk water supplier to Urban Utilities, Seqwater operational staff took the initiative to get ahead of the increasing DBP levels (Chlorate and THM) by trialling and implementing multiple changes to the WTPs sodium hypochlorite management and optimising WTP operation to manage THM levels.

### 2.1 Chlorate Reduction

Chlorates within the Somerset Dam Township were being formed due to the degradation of sodium hypochlorite at the WTP and the associated higher chemical dosing required to meet disinfection requirements. Exceedances in the adopted chlorate limit triggered several operational changes to the sodium hypochlorite storage and chemical management. With the objective of reducing chlorate levels as low as reasonably practicable without compromising on disinfection effectiveness.

Historically, container size and room temperature were both factors in the high chlorate levels. The chemical dosing room and re-chlorination dosing hut were both subjected to high seasonal temperatures as there was no air conditioning or room temperature control. The age of the chemical was also of concern with high chemical age during low demand periods.

As chlorate contamination is accelerated proportionally to the temperature, concentration, and age, operational staff sought to manage the temperature, which is recommended to be kept at < 20°C to slow the process of degradation, and to reduce the chemical age by reducing the total time the chemical is in storage.

To address the chemical age, a review of the overall chemical management process was conducted. At the time of the investigations, chemical was being dosed from 10 L containers. A primary driver for the chemical container size was the unavailability of chemical delivery to the area and the subsequent need for manual handling.

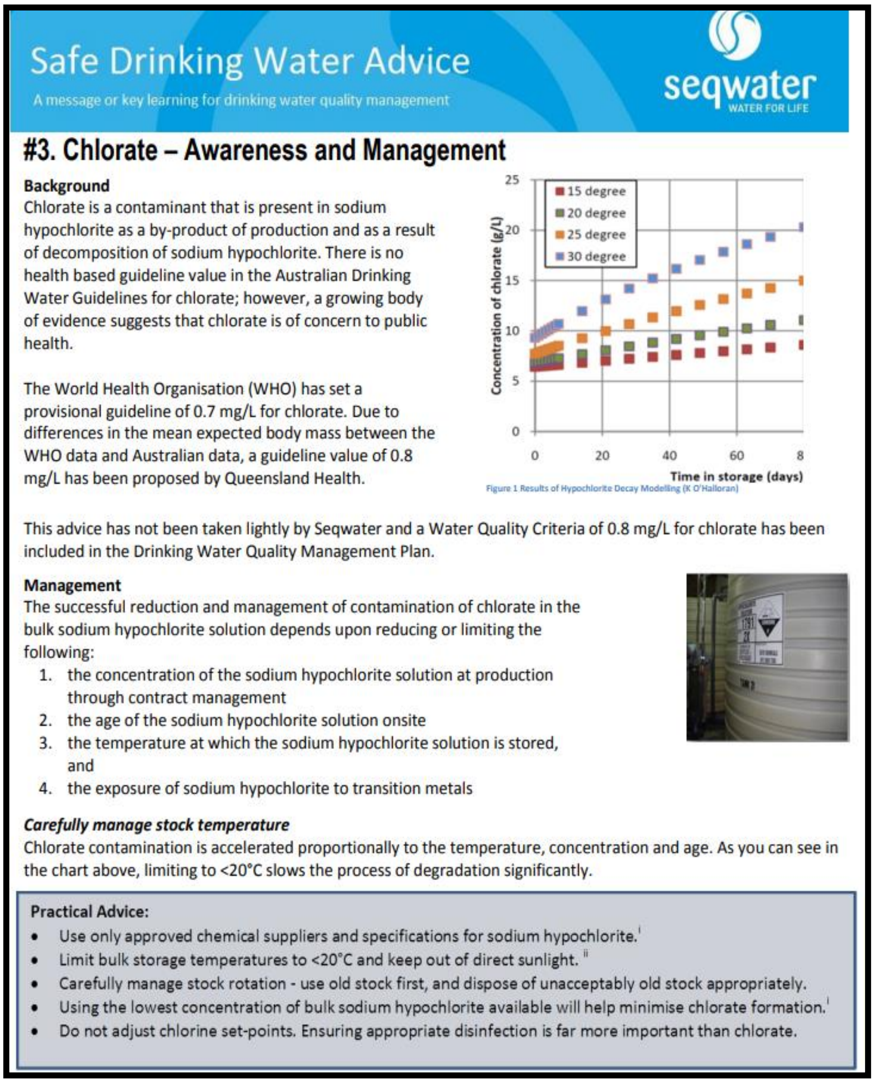
In 2013, the chemical supplier stopped delivering to Somerset Dam WTP as it was no longer viable for them due to the low volumes of chemical required. This led to operational staff taking on the responsibility of decanting sodium hypochlorite into smaller containers from Mt Crosby WTP bulk chemical storage before the containers were stored at Wivenhoe Dam WTP (in an air-conditioned building) and subsequently transferred to Somerset Dam WTP for further storage. This resulted in a high chemical age and storage time. The size of the containers also introduced operational challenges and the risk of the WTP tripping on low chlorine during high demand periods.

To mitigate this, Seqwater's operational procedures were updated to include several contingencies to ensure sufficient chemical dosing and to mitigate chemical age:

- Any containers having a collection date of greater than 2 weeks are disposed of and not used for chemical dosing,
- Weekday site visits are conducted to ensure sufficient chemical is available for dosing and an estimate for how long the sodium hypochlorite container will last based on pump dose rates is completed,
- The WTP is operated to pre-determined setpoints Monday to Thursday, and where practicable, the WTP does not operate over the weekend by having the treated water reservoir full to 94% on Friday afternoon and the treated water reservoir setpoints adjusted for the weekend,
- Exceptions to the above are long weekends where at least one visit may be required for chemical top up (operator judgement required based on demand).

However, the sodium hypochlorite was still exposed to high temperatures due to uncontrolled room temperatures which could result in elevated Chlorate levels over summer. In 2020, Seqwater installed an air conditioning unit in the chemical dosing room for the pre and post filter dosing which allowed for temperature-controlled storage of the sodium hypochlorite. An additional air conditioning unit was set up in the re-chlorination room adjacent to the Clear Water Storage which not only serves the purpose of assisting the sodium hypochlorite's lifespan but also provides an environment for the online analysers to function more effectively. This allows us to re-set up the re-chlorination system if required to maintain effective disinfection.

These changes were done in conjunction with Seqwater's safe drinking water advice shown in Figure 2 that was delivered during the early days of Seqwater's drinking water quality improvement processes. As well as Seqwater's water quality team who continue to monitor and advice of any changes to the overall chlorate level, as shown in Figure 3, to advise of potential issues and the need for chemical changeover.



Safe Drinking Water Advice

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## #3. Chlorate – Awareness and Management

**Background**

Chlorate is a contaminant that is present in sodium hypochlorite as a by-product of production and as a result of decomposition of sodium hypochlorite. There is no health based guideline value in the Australian Drinking Water Guidelines for chlorate; however, a growing body of evidence suggests that chlorate is of concern to public health.

The World Health Organisation (WHO) has set a provisional guideline of 0.7 mg/L for chlorate. Due to differences in the mean expected body mass between the WHO data and Australian data, a guideline value of 0.8 mg/L has been proposed by Queensland Health.



Figure 1 Results of Hypochlorite Decay Modelling (K O'Halloran)

This advice has not been taken lightly by Seqwater and a Water Quality Criteria of 0.8 mg/L for chlorate has been included in the Drinking Water Quality Management Plan.

**Management**

The successful reduction and management of contamination of chlorate in the bulk sodium hypochlorite solution depends upon reducing or limiting the following:

1. the concentration of the sodium hypochlorite solution at production through contract management
2. the age of the sodium hypochlorite solution onsite
3. the temperature at which the sodium hypochlorite solution is stored, and
4. the exposure of sodium hypochlorite to transition metals

***Carefully manage stock temperature***

Chlorate contamination is accelerated proportionally to the temperature, concentration and age. As you can see in the chart above, limiting to <20°C slows the process of degradation significantly.

**Practical Advice:**

- Use only approved chemical suppliers and specifications for sodium hypochlorite.[i]
- Limit bulk storage temperatures to <20°C and keep out of direct sunlight.[ii]
- Carefully manage stock rotation - use old stock first, and dispose of unacceptably old stock appropriately.
- Using the lowest concentration of bulk sodium hypochlorite available will help minimise chlorate formation.[i]
- Do not adjust chlorine set-points. Ensuring appropriate disinfection is far more important than chlorate.

**Figure 2:** ***Seqwater Internal Safe Drinking Water Advice #3 Chlorate – Awareness and Management***

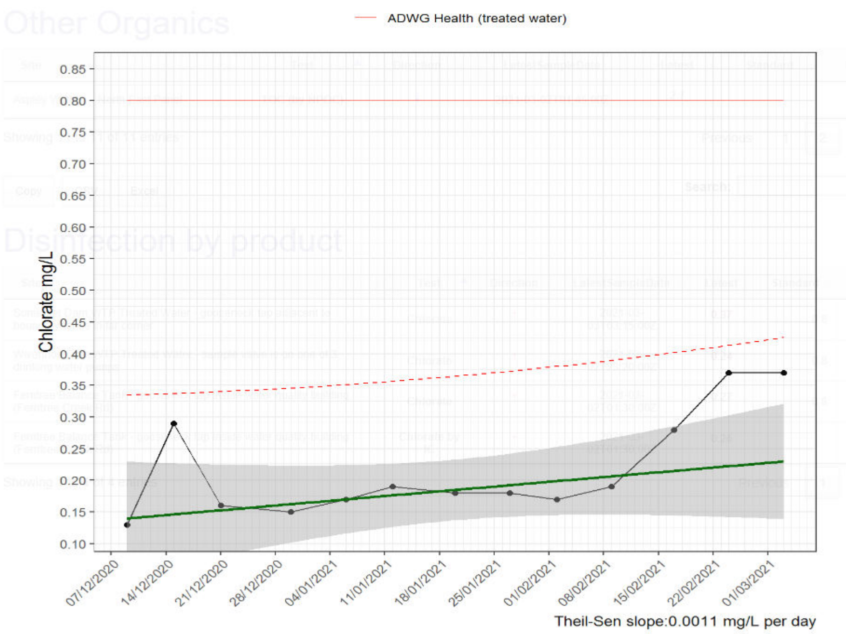



**Figure 3:** **Drinking Water Quality Chlorate Monitoring Trendline**

## 2.2 Trihalomethane Control

In 2017, Seqwater and Urban Utilities identified an urgent need to reduce THM levels and commenced a holistic assessment of the WTP operation and network management. Working closely with operations and water quality advisors, Seqwater's process engineers began investigations into the WTP operation. Three major factors were found to contribute to the increase of THM formation, namely high-water age within the treated water reservoir and network, increased chlorine dose from re-chlorination, and seasonally high temperatures.

No changes in the bromine and organic levels were found in the raw water to give rise to the higher THM formation potential. However, there are known issues in the region with elevated THM levels due to the interaction of NOM and chlorine during chlorination and therefore this could not be discounted as a possible issue in the future.

### High Water Age and Re-Chlorination

Somerset Dam WTP treated water reservoir operates within 60-95% of its maximum capacity and in 2018 had an average residence time in the reservoir of 16 days on weekdays and 4 days on weekends. Plus, additional time within the network itself. In addition, the WTP uses a re-chlorination system in the treated water reservoir to maintain the free chlorine level at 1.8 mg/L. With such a large residence time, especially on weekdays, and additional free chlorine from re-chlorination, this allowed enough time for the reactions to occur to produce high THMs in the reservoir.

### Seasonal Temperatures

Somerset Dam Township is in Southeast Queensland and is subjected to high seasonal temperatures. Given THM formation is accelerated due to high temperatures, it was observed that the majority of exceedances occurred during summer, and this was when the most significant variation in THM concentration was present between Seqwater's treated water reservoir and Urban Utilities sample points.

### Changes in Raw Water Quality (NOM)

At Somerset Dam, raw water quality may vary due to seasonal variations, rainfall, and other extreme events such as fire. When these occur, the WTPs operation needs to be adjusted in terms of coagulant dose rates, coagulation pH and additional monitoring for dissolved organics and THM. Consideration for adjusting chlorine dose rates should also be considered as the WTP operates with pre-filter chlorine dosing and primary disinfection, both using sodium hypochlorite. As the elevated THM levels in 2017 and 2018 were not associated with any notable change in the raw water quality, the THM Formation Potential (THMFP) is believed to be present year-round. And therefore, an ongoing WTP operational plan was required.

## 2.3 Trials and Investigations

Seqwater conducted several trials and investigations to better manage the TTHMs at Somerset Dam WTP. Initial investigations focused on chemical dosing options to manage the TTHMs whilst Urban Utilities conducted flushing within the network to reduce THM levels.

A THMFP analysis was conducted in December 2018 where the sample was maintained at 1.8mg/L free chlorine and TTHM results obtained for 7, 14 and 28 days. A THMFP test was also conducted using a chlorine dose of 10mg/L. The results showed that TTHM levels continued to increase for the duration of the test. With results of 136µg/L, 152µg/L and 172µg/L TTHM for the 7-, 14- and 21-day results respectively. All of these were lower than the THMFP result indicating that additional THM formation could occur. Updated THM formation potential (THMFP) tests were conducted in January 2019 found the 7- and 14-day THMFP to be 185µg/L and 248µg/L respectively. Both of which are above Seqwater's communication trigger levels and Urban Utilities trigger levels.

## High Water Age and Re-Chlorination

Reducing the detention time within the reservoir was assessed, but excluded due to the supply risk, particularly during summer. The re-chlorination dosing, in addition to providing a source of chlorine for THM production, it was a contributor to the high chlorate levels. Through operational trials and additional monitoring in the network, the re-chlorination system in the treated water reservoir was safely stopped in 2018.

Should the need arise, the re-chlorination system adjacent to the Clear Water Storage can be re-started if required as this room now has temperature control to manage the sodium hypochlorite quality.

## WTP Optimisation and Chemical Dosing Changes

During known high TTHM events, the WTP is operated at an increased alum dose rate (enhanced coagulation), however, it was found to have little effect on the TTHM concentrations, with enhanced coagulation alone only providing a 8% reduction in THMFP (Refer Table 1). At the time, the small improvement observed in the jar test environment was considered unlikely to be achievable at the WTP considering other factors such as residence time, chlorine level, and temperature all play an important role in the THM formation.

Therefore, further lab and desktop analysis were conducted to identify other means to improve coagulation and NOM removal. The trials found that lowering the pH to 5.8 to enhance coagulation or adding Powder Activated Carbon (PAC) in addition to increase Alum dose rates were the most effective means of managing the TTHMs at Somerset WTP. However, both would require additional chemical dosing systems on site (Refer Table 2 and Table 3).

**Table 1:** ***2018 THMFP Jar Test Results – Enhanced Coagulation***

| Jar | Chemical Dose | Coagulation pH | Settled water UV254 ($cm^{-1}$) | Settled water DOC (mg/L) | THMFP (µg/L) @21 days |
|---|---|---|---|---|---|
| **1** | Alum Dose (6mg/L) | 6.85 | 0.062 | 4.6 | 229 |
| **2** | Alum Dose (8mg/L) | 6.71 | 0.052 | 3.8 | 209<br>(8% reduction) |

**Table 2:** ***2018 THMFP Analysis on the Effect of Reducing Coagulation pH to 5.8 with an Alum Dose of 6mg/L***

| Jar | Chemical Dose | Coagulation pH | Settled water UV254 (cm-1) | Settled water DOC (mg/L) | THMFP (µg/L) @21 days |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| **1** | Alum Dose (6mg/L) | 6.85 | 0.062 | 4.6 | 229 |
| **2** | Alum Dose (6mg/L) + HCl (10mg/L) | 5.86 | 0.040 | 3.2 | 165 (28% reduction) |

**Table 3:** ***2018 THMFP Analysis on the Effect of PAC Dosing with an Alum Dose of 6mg/L***

| Jar | Chemical Dose | Coagulation pH | Settled water UV254 ($cm^{-1}$) | Settled water DOC (mg/L) | THMFP (µg/L) @21 days |
|---|---|---|---|---|---|
| **1** | Alum Dose (6mg/L) | 6.85 | 0.062 | 4.6 | 229 |
| **2** | Alum Dose (6mg/L) + PAC *PS1300* (25mg/L) | 6.88 | 0.041 | 3.4 | 189 (18% reduction) |

Based on the jar test results and following discussion and agreement with Seqwater's water quality and process engineering teams and Urban Utilities water quality representatives, Seqwater operational staff began trialling enhanced coagulation in the treatment process. This required increased alum dosing to reduce the pH and extra pH correction pre and post filtration to meet the drinking water quality requirements. The target pH range was determined to be:

- 5.8 – 6.4 pH for the coagulation/flocculation step,
- Pre filter soda ash dosing was commenced with a post filter target pH of 6.8 – 7.0,
- Post filter soda ash dosing target was 7.2 pH.

Seqwater also relocated a redundant PAC dosing system from Esk WTP to Somerset Dam WTP to assist with THM reduction and provide seasonal taste and odour management. And operational staff worked with Urban Utilities to cease network flushing.

In 2021, further jar tests were conducted on two PAC products, PS1000 and PS1300F to determine the preferred chemical for NOM and T&O management in conjunction with enhanced coagulation for THMFP reduction. Both showed decent T&O and organics removal with no significant difference between the two for THMFP. Improved performance was found to be based on chemical dose, not product (Refer Table 4).

**Table 4:** ***2021 THMFP Analysis on the Effect of PAC Dosing with Enhanced Coagulation***

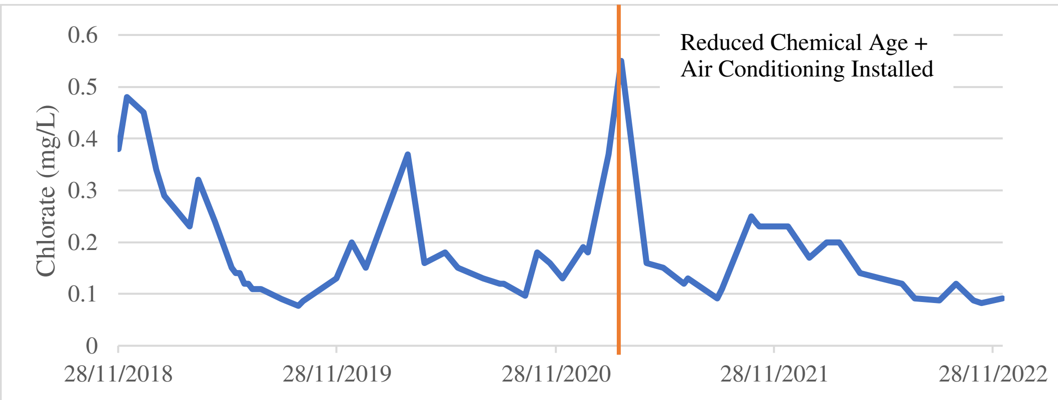
| Jar | Chemical Dose | pH | UV254 ($cm^{-1}$) | DOC Removal (%) | T&O Removal (%) | THMFP (µg/L) @21 days |
|---|---|---|---|---|---|---|
| **1** | Alum Dose (16mg/L) | 6.2 | 0.044 | 44.6 | 15.2 | 191 |
| **2** | Alum Dose (16mg/L) + PAC *PS1000* (10mg/L) | 6.2 | 0.036 | 51.6 | 33.3 | 162 |
| **3** | Alum Dose (16mg/L) + PAC *PS1000* (30mg/L) | 6.2 | 0.029 | 60.7 | 66.7 | 135 |
| **4** | Alum Dose (16mg/L) + PAC *PS1300F* (10mg/L) | 6.2 | 0.038 | 51.8 | 39.4 | 162 |
| **5** | Alum Dose (16mg/L) + PAC *PS1300F* (30mg/L) | 6.2 | 0.029 | 62.5 | 68.7 | 135 |

## 3.0 CONCLUSION

This paper presented the challenges faced in addressing the elevated DBP levels at Somerset Dam WTP and a lesson learned approach for how to better manage DBPs in small regional WTPs. By applying a collaborative approach internally within Seqwater and cross organisationally with Urban Utilities, Seqwater operators were able to manage chlorate and THM DBPs without compromising on disinfection effectiveness.

Through improved chemical management and temperature control, Seqwater were able to consistently reduce the chlorate levels within the network to well below the 0.8 mg/L limit and continues to closely monitor Chlorate levels for any changes.

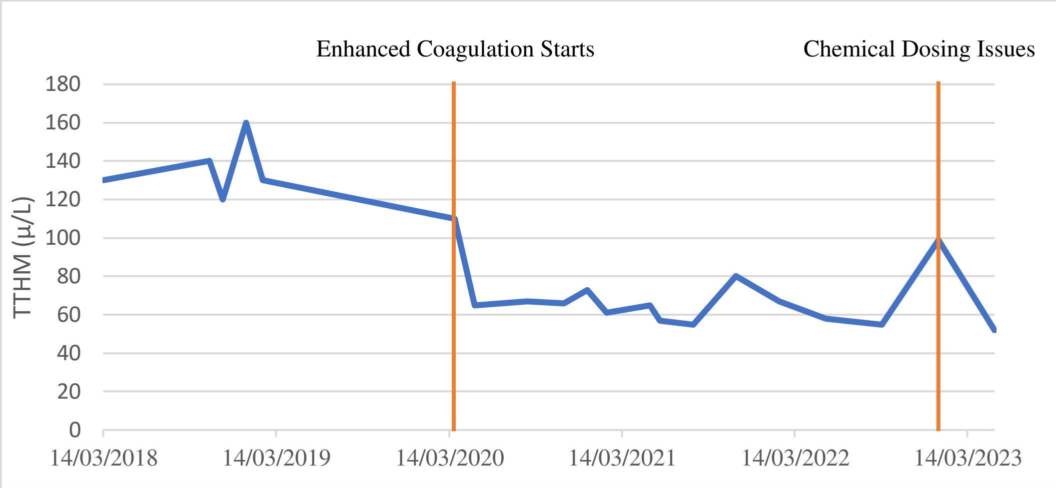
As can be seen in the overall trendline (Figure 4), prior to the introduction of temperature control at the WTP, there were repeated fluctuations in Chlorate levels, particularly over summer. Through temperature control and improved chemical management practices, Seqwater has been able to consistently keep Chlorate levels below 0.3 mg/L without compromising on disinfection.




**<u>Figure 4:</u>** **Chlorate Reduction Trendline November 2018 to December 2022**

The successful reduction in TTHM was achieved through process optimisation, enhanced coagulation, and the addition of PAC dosing. As can be seen in the overall trendline (Figure 5), optimising the chemical dosing systems with enhanced coagulation and pH set points provided a step change in TTHMs at the WTP. The addition of PAC at the WTP assisted in maintaining THM levels at consistently low levels across summer, thus negating the need to Urban Utilities to flush their network to reduce TTHMs.

It can however be seen that when chemical dosing is not optimised and there are issues with enhanced coagulation that THM levels rise rapidly. As such, the collaborative discussions in relation to THM formation and reduction processes are ongoing between Seqwater and Urban Utilities to build better resilience.




**<u>Figure 5:</u>** **THM Reduction Trendline March 2018 to March 2023**

## 4.0 ACKNOWLEDGEMENTS

The authors would like to acknowledge to contribution of Urban Utilities in the successful outcomes at Somerset Dam WTP. Together, Seqwater and Urban Utilities have achieved several successes and are currently collaborating and discussing the way forward to continue to make changes to achieve our goals.