RYLSTONE WTP TRACER TESTING REVELATIONS - HOW EFFECTIVE IS YOUR CHLORINE DISINFECTION BARRIER?

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ABSTRACT

Chlorine disinfection is vitally important as it is typically the final barrier to pathogens and algal toxins at a water treatment plant (WTP). Fluoride tracer testing studies were undertaken at Rylstone WTP as a method to determine the mixing conditions and residence time in the clear water tank (CWT) in order to validate and verify Chlorine Contact Time (C.t) calculations.

The existing fluoride dosing system was used to collect data and enable determination of the baffling factor under various plant conditions. The tracer testing revealed that the baffling factor was much lower than expected and changed "unexpectedly" under CWT levels. The baffling factor was also in fact found to vary and was <u>not</u> a constant. Following the tracer testing study, immediate modifications were made in an attempt to reduce short-circuiting within the CWT with the aim to improve C.t. Additional tracer testing was then undertaken to assess improvements to disinfection following the modifications.

With the recent introduction of Microbial Health Based Targets in the Australian Drinking Water Guidelines (ADWG) and an increasing algae toxin risk profile across many parts of the country, there has never been a more important time to undertake tracer testing to confirm baffling factors and your C.t, because applying a constant baffling factor assumption could overestimate disinfection effectiveness.

1.0 INTRODUCTION

1.1 Background

Chlorine disinfection is a vitally important barrier against both pathogens (virus and bacteria) and algae toxins. Chlorine disinfection exposure and intensity can be assessed via the Chlorine Contact Time (C.t) which is used to describe the effectiveness of the disinfection process. It is defined as the disinfection concentration in the water and the time that the water is exposed to the disinfectant (Lanchbery, 2019) expressed as the C.t value (mg.min/L). The C.t value, or exposure value, for chlorinated systems is simply the product of contact time (t in minutes) and the free chlorine residual concentration (C in mg/L) at the end of the contact time. However the actual contact time needs to account for short circuiting and thus a baffling factor is used. The baffling factor is also known as a short circuiting factor or mixing factor and is defined as the time for 10% (T_{10} in minutes) of the incoming water to pass through the tank to the outlet divided by the total theoretical detention time (tank volume divided by flowrate).

The effectiveness of major disinfectants (including chlorine) against a range of microorganisms at various C.t values can be found in published scientific research and guidelines (including the ADWG). The C.t values achieved by the treatment plant are compared to the treatment levels required due to the risk of pathogens in the catchment and raw water. The ADWG recommend achieving a C.t of 15 mg.min/L for pathogens (bacteria and virus) while if algae toxins are a concern the industry often adopts a higher C.t of at least 30 mg.min/L which NSW Health also recommend for *Naegleria Fowleri.*
C.t as a barrier to pathogens can be correlated to both bacteria or virus removal, typically described as the log reduction value (LRV). With the recent introduction of Microbial

Health Based Targets into the ADWG in 2022, validation is needed to confirm LRV credits claimed for a treatment process. The purpose of validation is to demonstrate that claimed LRV's are achieved under defined operating conditions providing that operational monitoring targets (i.e. critical limits) are achieved (ADWG, 2022). However the actual C.t achieved within a reservoir depends on the amount of mixing, short circuiting and dispersion of the chlorine that is dosed into the water prior to entering the reservoir. This is referred to as the baffling factor and this factor can be determined from experimental data using a step dose tracer testing method.

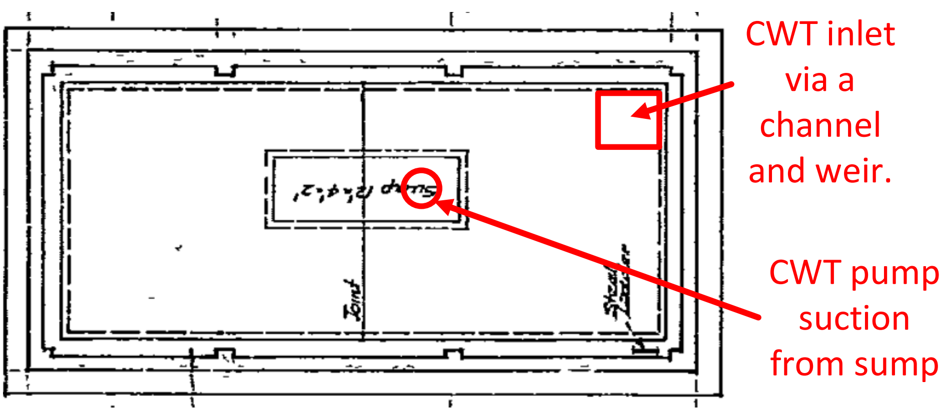
Based on previous tracer testing studies undertaken by the Author in conjunction with various water utilities around Australia, the baffling factor can sometimes vary considerably under different plant operating conditions (WTP flow and CWT level). Hence to validate the C.t, validation of the baffling factor is essential.

1.1 Why did we do this?

Mid-Western Regional Council (MWRC) sought assistance to have a detailed review completed on the effectiveness of the current chlorine disinfection process at the Rylstone WTP as part of a larger review to confirm the ability of the WTP to meet current and future water quality targets. This review subsequently identified concerns about the location of the chlorine dosing point, CWT geometry and position of the CWT pump suction pipework which was suspected to encourage short circuiting (Figure 1).

MWRC's previous calculations had determined the C.t value to be 30 mg.min/L by adopting a baffling factor of 0.3 (as per USEPA baffling factor guidance tables). However during the detailed review the ability of the current CWT to provide a baffling factor of 0.3 was considered questionable. It was suspected that the actual baffling factor could be less than 0.1 and thus provide a C.t value of only 10 mg.min/L, which is less than the target 15 mg.min/L required for effective disinfection.

The objective of this project was to calculate the current C.t attainable in the CWT at Rylstone WTP through accurately determining the baffling factor through onsite tracer testing and determination of the various baffling factors under differing conditions. Following determination of the baffling factors under various tank levels and flow conditions it would then be possible to accurately calculate the C.t values. Either confirming effectiveness of the barrier or identify deficiencies in the disinfection process.



<u>Figure 1:</u> ***Rylstone WTP CWT***

2.0 DISCUSSION

2.1 Methodology and approach

A procedure was developed to assist MWRC in undertaking the tracer testing under specific plant conditions. The procedure consisted of the following:

- Bring the WTP online and ensure fluoride dosing is operational and set to the correct dose rate based on the plant flowrate
- Establish a stable plant flowrate and clear water tank level
- Commence monitoring of the fluoride concentration in the water leaving the CWT at regular intervals to ensure steady state conditions establish (i.e. constant fluoride concentration).
- Once steady state conditions are achieved and allowed to run for some time, stop fluoride dosing (concentration decreasing profile).
- Continue to collect and test CWT outlet samples for fluoride concentration at regular intervals and record this data along with CWT flowrates and level until the fluoride concentration matches the natural background concentrations and is stable.
- Repeat the test in reverse (concentration increasing profile). That is, from a stable low natural background fluoride concentration in water passing through the CWT, restart fluoride dosing and monitor until the concentration reaches a stable dosed level again.

The data was then sent to Beca Hunter H2O for processing and calculation of the baffling factor. This process consisted of:

- Graph the raw data (time and fluoride concentration) for graphical calculation of the T_{10} and resultant baffling factor.
- The concentration data was entered alongside the time data responding to when each measurement occurred.
- The concentration data was then corrected by subtracting the background fluoride concentration. This resulted in another column of data for the 'dimensionless concentration'.
- The dimensionless concentration (C/C_0) was then determined by dividing the concentration, C (mg/L) at each time interval by the dosed concentration, C_0 (mg/L).
- C/C_0 was then plotted against time (t in minutes).
- T_{10} was then directly read from C/C_0 versus time chart. T_{10} corresponds to the point on the curve where C/C_0 is equal to 10%.
- T_{10} can then be used to determine the baffling factor.
- This is performed by calculating the theoretical residence time, t (minutes) of the clear water reservoir at the assumed operating level and trial flowrate, where it is simply equal to the volume of the tank (m^3) divided by the flowrate (m^3/min).
- The baffling factor is then determined by dividing T_{10} by the t.

The following test conditions were adopted to assess the baffling factor under a number of CWT levels that are experienced during plant operations. Flowrates were not examined as the plant operates at a fixed flowrate. It is important to examine the conditions that would provide the worst case C.t as we have to ensure that all water that leaves the WTP site is achieving the target. Hence we examined the minimum CWT level even though it typically is much higher than that.

<u>Table 1:</u> **Rylstone WTP Fluoride Tracer Testing Runs**

Test Run	Plant Flowrate	CWT level
1	Typical plant flow 50 L/s	Minimum 30%
2	Typical plant flow 50 L/s	Typical 70%

Prior to undertaking the fluoride tracer testing the fluoride dosing point had to be relocated from the CWT pump discharge pipework to the CWT inlet which required completion of a Form 1 and approval by DPE and NSW Health. Murry Thompson Water Services (MTWS) provided assistance onsite during the initial testing to help train operations staff in the procedures and provide additional classroom training on "Disinfection & Ct Measurement & Application".

Figure 2: ***Old (left) and New (right) temporary fluoride dosing point***

2.1 Tracer Testing Results

Fluoride tracer tests were performed onsite at Rylstone WTP to determine the actual detention time in the CWT, and thus determine its baffling factor under the conditions listed in Table 1. An example graphical output is shown in Figure 3 while the results of the tracer testing are summarised in Table 2.

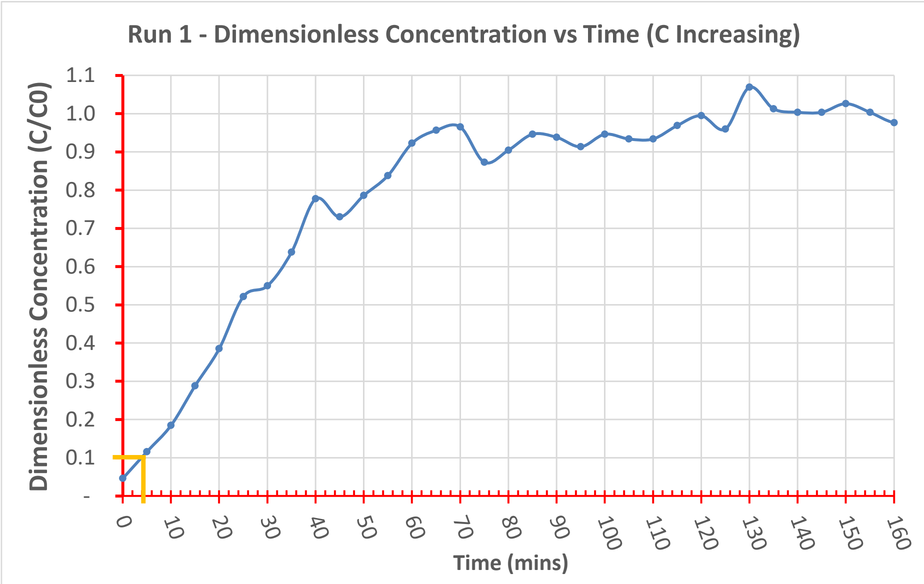


Figure 3: ***Run 1 Tracer Testing Results***

It can be seen from Figure 3 that the T_{10} occurs after 4 minutes.

Table 2: Rylstone WTP Fluoride Tracer Testing Runs

Test Run	Plant Flowrate (L/s)	CWT Level (%)	T_{10} (mins)	Baffling factor	C.t @ 2 mg/L
Before pump mixer was installed					
1	50	30	4	0.16	7.7
2	50	30	2.5	0.1	5.0
3	50	70	2	0.03	3.9
4	50	70	3	0.05	5.9
5	50	60	7	0.14	13.7
After pump mixer was installed					
6	50	70	10	0.17	19.5
7	50	70	5	0.10	9.8

It can be seen from Table 2 that the calculated baffling factors ranged from 0.03 to 0.16 across the various scenarios examined before the pump mixer was installed. This results in calculated C.t values lower than the target of 15 mg.min/L. The really low baffling factor at higher CWT levels triggered a closer inspection and examination of the dose point location and arrangement. It was found the dose point was moved over 10 years ago due to chlorine off gases causing corrosion to the surrounding assets and thus a dedicated dosing lance was used to dose to the bottom of the CWT. However upon review the dosing point with dispersion manifold was located approximately 2 m from the nearest CWT pump suction pipe within a sump in centre of the CWT. Therefore with higher tank levels it was expected that there would be less mixing at the inlet to the CWT (due to less turbulence) and thus more potential for short circuiting (i.e. lower baffling factor).

MWRC immediately acted on this revelation through additional tracer testing to confirm initial results. Interim options were then examined to see what could be implemented quickly to improve the baffling factor and C.t. A pump was therefore used to draw water from the CWT inlet and dose point and pump away from the CWT pump suction point. Further tracer testing was then performed which revealed an increased baffling factor to at least 0.1. Additional testing is planned however to provide further confidence in these results. However, theory dictates that a perfectly mixed reservoir would return a baffling factor of around 0.1. Mixing can therefore be advantageous, as in this case study, increasing the baffling factor from 0.03 to >0.1, or a disadvantage if the baffling factor is already well above 0.1 in a tank as the mixer would reduce this to 0.1. Hence confirmation of the baffling factor and C.t is required prior to considering modifications, because installing a mixer could potentially reduce your overall C.t. A comparison of baffling factors and CWT level was also undertaken (Figure 4).

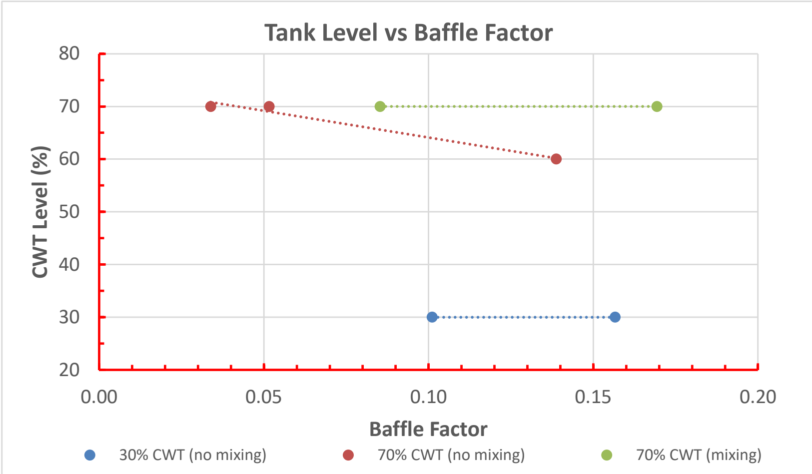


Figure 4: ***Tracer Testing Results – CWT level vs Baffling Factor***

As seen in Figure 4 the baffling factor appeared to vary considerably under the same testing conditions however there appeared to be less variability at lower CWT levels which may have been due to better mixing at the dose point due to more turbulence as the water enters the CWT. Initial results from the tracer testing undertaken after the pump mixer was installed also suggests there is less variability in the baffling factor.

3.0 CONCLUSION

This project has proven the value in undertaking tracer testing to verify the baffling factor used in C.t calculations and highlighting the risk of replying on a static baffling factor based on the USEPA guidance table. With more stringent water quality guidelines now in place following the introduction of Microbial Health Based Targets into the ADWG in 2022, validation of the most critical barrier within the water treatment plant has never been more important to ensure the safe supply of drinking water.

MWRC's previous calculations had determined the C.t value to be 30 mg.min/L by adopting a constant baffling factor of 0.3 in line with the USEPA guidance tables. However the tracer testing has revealed baffling factors as low as 0.03 and up to 0.16, prior to the pump mixer being added, resulting in a C.t range from as low as 3.9 mg.min/L up to 13.7 mg.min/L assuming a free chlorine residual of 2 mg/L at the outlet of the CWT. Less than half what was originally calculated and below the 15 mg.min/L target.

Following the addition of the pump mixer the baffling factor ranged from 0.1 – 0.17 resulting in an increased C.t of 9.8 – 19.5 mg.min/L. Thus drastically improving the C.t, however still below the target of 15 mg.min/L at times. Hence further modifications are being considered such as baffling walls to further improve the C.t as there is little ability to further increase the free chlorine residual higher than 2 mg/L as this may result in customer complaints.

4.0 ACKNOWLEDGEMENTS

To the MWRC operations staff who diligently undertook each tracer test and collected manual samples to enable the data to be analysed and baffling factors calculated.

To MTWS for providing onsite support for the initial tracer studies and delivering additional training on "Disinfection & C.t Measurement & Application" to MRWC's engineering & operational staff members.

To NSW Health for providing funding support to undertake this critical project which has supported the implementation of the Drinking Water Management System for MWRC.

5.0 REFERENCES

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