MITIGATION OF WIDESPREAD NITRIFICATION EVENTS IN CHLORAMINATED DRINKING WATER SUPPLIES

Paper Presented by:

Brad Smith

Author:

Brad Smith, *Coordinator Drinking Water Compliance,*

Central Highlands Water

78th Annual WIOA Victorian Water Industry Operations Conference and Exhibition
Bendigo Exhibition Centre
1 to 3 September, 2015

MITIGATION OF WIDESPREAD NITRIFICATION EVENTS IN CHLORAMINATED DRINKING WATER SUPPLIES

Brad Smith, *Coordinator Drinking Water Compliance*, Central Highlands Water

ABSTRACT

Nitrification causes a range of water quality issues in drinking water systems that utilise chloramine disinfection. A number of management processes can be implemented to prevent nitrification issues on a localised scale, however if these have not been effective there is the potential for the issue to spread throughout a supply system causing a widespread event. This paper outlines such an event in the Ballarat supply system and the successful mitigation techniques that were used to correct the problem. The benefits of conducting such a program are outlined together with the strategy that was applied.

1.0 INTRODUCTION

1.1 Nitrification

In drinking water supplies, nitrification is a microbiologically assisted process by which free ammonia is sequentially oxidised to nitrite and nitrate. A range of common but harmless nitrifying bacteria are involved in the process including ammonia-oxidising bacteria (AOB) and nitrite-oxidising bacteria (NOB). Nitrification can be problematic in drinking water systems that use chloramines for primary and/or secondary (residual) disinfection. If nitrification is not controlled, it can reduce and ultimately remove the residual disinfectant protection throughout a distribution system.

1.2 Chloramination

Chloramination is a disinfection process whereby chlorine and ammonia are added to treated water to form chloramines. The aim of a chloramination disinfection process is to maximise monochloramine formation (the desired form of chloramines), whilst minimising the level of dichloramines/trichloramines and free ammonia in the treated water. Controlling the amount of excess free ammonia to a low level is critical in preventing system nitrification, along with the optimisation of factors that promote the maintenance of a stable chloramine residual.

1.3 Reasons to Chloraminate

Operating a chloramination disinfection process presents many operational challenges. Close monitoring and corrective actions are required to prevent developing issues. Chloramination is often chosen as the secondary disinfectant of choice in larger distribution systems, as it offers the following benefits:

- longer persistence in the distribution system
- lower disinfection by-products (eg. THMs)
- can be more effective at controlling biofilms, and
- potentially has less taste and odour impacts on customers.

However there are potential disadvantages to chloramination, including operational complexity, a weaker secondary disinfectant ability and the susceptibility of these systems to nitrification.

1.4 Secondary Disinfection Residuals

The presence of a secondary residual disinfectant in the distribution system is an integral part of the multiple barrier approach adopted in the Australian Drinking Water Guidelines. Maintaining an adequate disinfection level in the distribution system provides some inherent protection to control post-treatment recontamination and prevent bacterial regrowth. Secondary residuals may assist in controlling the risks associated with small-scale intrusion or contamination events, although are unlikely to be able to provide adequate protection against larger contamination events.

1.5 Prevention of Nitrification

There are a number of preventative strategies that can be implemented at a treatment plant and distribution level to minimise the chance of nitrification becoming a problem. Many of these strategies involve being able to monitor, detect and respond to the signs of nitrification in a timely manner, before the issue spreads. If however, these nitrification trends are unable to be controlled on a localised basis and the problem extends throughout a system, the range of management options available reduces.

1.6 Widespread Nitrification Events

In practical terms, for a large scale nitrification event, one of the only viable options to correct the entire network is to change the disinfection system to free chlorine for a period of time (ie. a chlorine 'burn'), although this process has been applied with mixed success across the industry. Once established nitrifying bacteria can be very resilient to higher levels of chloramine, but are readily inactivated by free chlorine. The control strategy applied involves introducing free chlorine to the system so that levels of >0.2 mg/L are obtained at the system extremities for at least 1 day. A carefully planned flushing program (including dead ends) and close field monitoring is often required to achieve this outcome, particularly in larger systems. Completing the entire process as rapidly as possible (ideally during high water demand periods) is one of the key success criteria for a nitrification control program.

2.0 DISCUSSION

2.1 Identification of Nitrification

During 2010-2012 Central Highlands Water (CHW) experienced a series of widespread nitrification events in a number of chloraminated systems, caused by the failure of preventive strategies to control nitrification on a localised scale. A temporary free chlorination program was completed in these supplies which resulted in a significant improvement in residual performance. This paper will focus on the free chlorination program completed in the Ballarat system during February/March 2013.

2.2 Description of the Ballarat Supply System

The Ballarat and district water supply is CHW's largest system with ~110,000 customers. The system is supplied by two water treatment plants (White Swan and Lal Lal) and the distribution network is quite large with ~1,500 km of water mains - see Figure 1. The system has a large number of network storage tanks/basins (25) and detention times can be up to 35 days (~ 65 km travel distance) in the outer regions during the winter months.

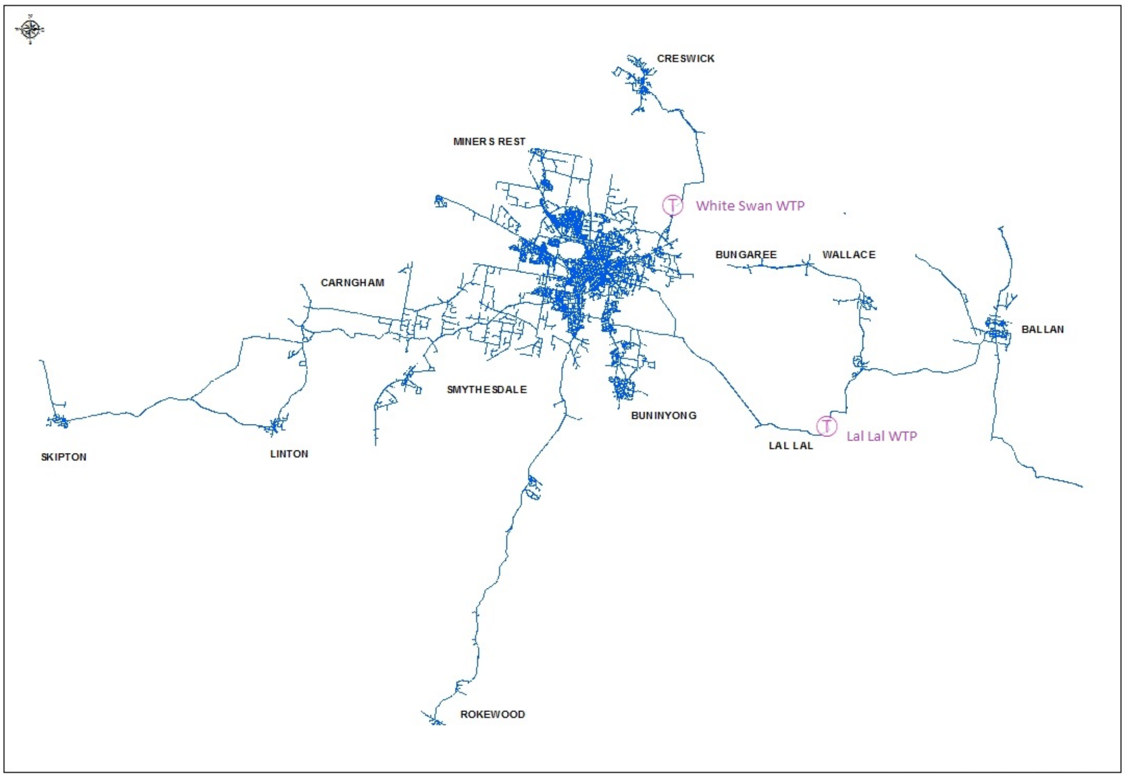

Figure 1: ***The Ballarat and District Water Supply System***

2.3 Residual Performance and Operational Impacts

During 2010-2012 the levels of disinfectant residual varied substantially across the system, with levels decreasing markedly in the outer regions. On occasions, this resulted in elevated coliform and plate count detections in these areas, and required periodic spot dosing of network storages with sodium hypochlorite. In 2006, four network disinfectant boosters were installed and operated with varying levels of success in these high water age areas. The combined effect of these issues meant that a substantial commitment in operational and maintenance costs/resources was required in an attempt to maintain residuals, but this offered a limited sustained benefit.

2.4 Planning for Free Chlorination

Late in 2012, we began planning for this program and it was determined that this would occur during summer 2013, to take advantage of the high demand period. Early consultation occurred with the Department of Health and Human Services as it was anticipated that system THMs might temporarily exceed regulatory standards. Short term increases in THM levels are of less significance than the lack of system residuals. A key element of the planning process identified that an extensive customer communication program was necessary. Customers were informed to expect a change to the taste and odour of their water supply for a defined period due to a disinfection change. We found that this level of proactive customer communication prevented a large influx of customer contacts during the program.

2.5 Implementation of the Free Chlorination program

In early February 2013, water storages at the head of the system were drawn down to a low level and the ammonia systems were deactivated.

In the following weeks a program of systematic flushing and residual monitoring and mapping was conducted across the entire network. It was critical that the initial transition process occurred quickly to minimise the mixing of chloraminated and chlorinated water (the interface) which can lead to taste and odour issues. Once a particular section of the network had achieved a free residual of >0.2 mg/L, it was considered to be free of nitrifiers. Even with the higher flows, this process took up to 2 months to fully complete. In early April 2013, the ammonia systems at the treatment plants were reactivated and the system was converted back to chloramine.

2.6 Results of the Free Chlorination program

Over the period, only two water quality zones out of eighteen exceeded the 0.25 mg/L THM limit as shown in Figure 2. Prior studies have shown that water sourced from the Lal Lal reservoir has a higher THM formation potential than White Swan water. The results in Figure 2 show a temporary increase in THM levels for selected zones that were wholly or partly supplied by Lal Lal water over the free chlorination period. Before the program, THM levels varied in the Enfield and Skipton zones due to the use of booster chlorinators in these areas.

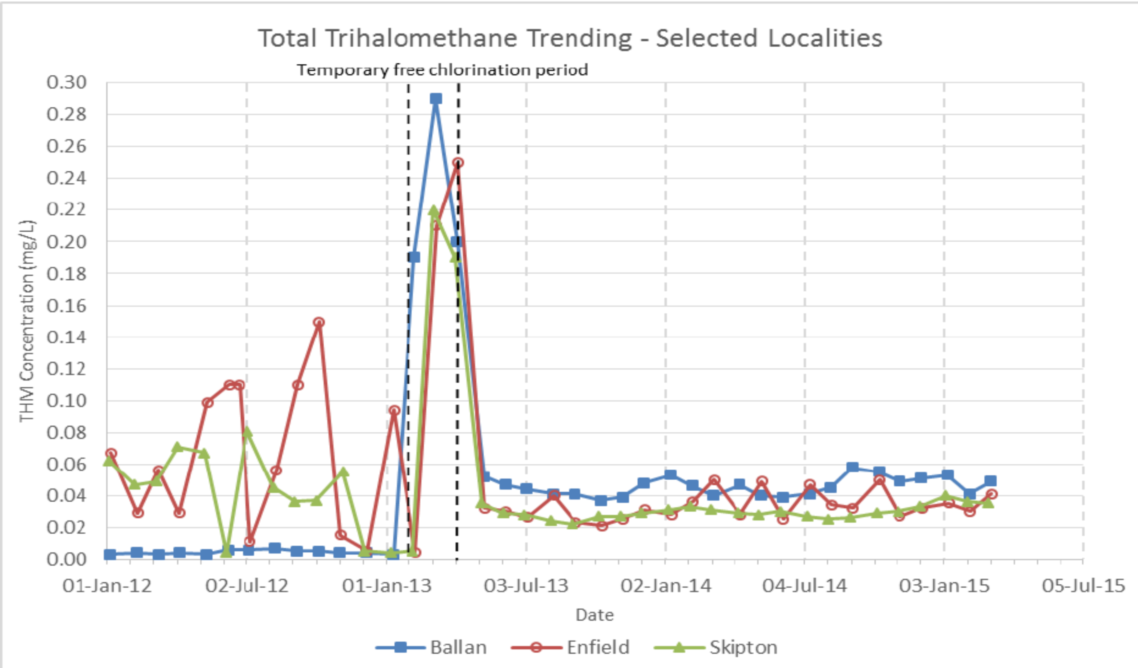

Figure 2: ***THM Trends for Selected Water Quality Zones in the Ballarat System During the Free Chlorination Program***

A significant amount of system flushing was required during the program to draw water with an adequate residual to where it was needed, even under higher demand conditions. This flushing requirement (coupled with the higher THM levels) indicated that it was impractical for the Ballarat system to remain on free chlorine disinfection on a permanent basis. Customer contacts were closely monitored throughout this program and only 62 complaints were received from a customer base of ~110,000. We believed this to be a very good result considering the major change that was completed. Figure 3 shows the residual trends in two key locations within the Ballarat network. The results clearly show the effects of the free chlorination program, with higher and less variable chloramine residuals evident in these zones following the program.

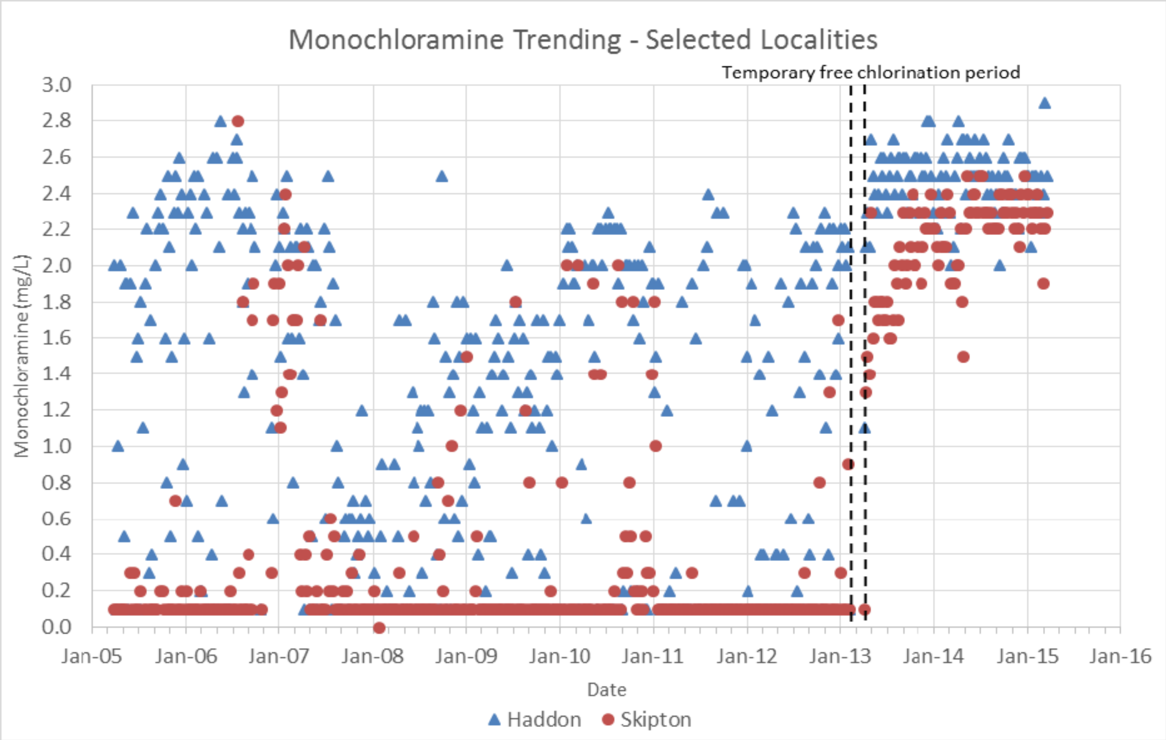

Figure 3: ***Residual Trends at a Selection of Water Quality Zones in the Ballarat System***

Figure 4 shows network coliform detections in the Ballarat system before and after the free chlorination program. There was a substantial decrease in coliform detections after the program, and this is strongly correlated with the increases in disinfectant residual.

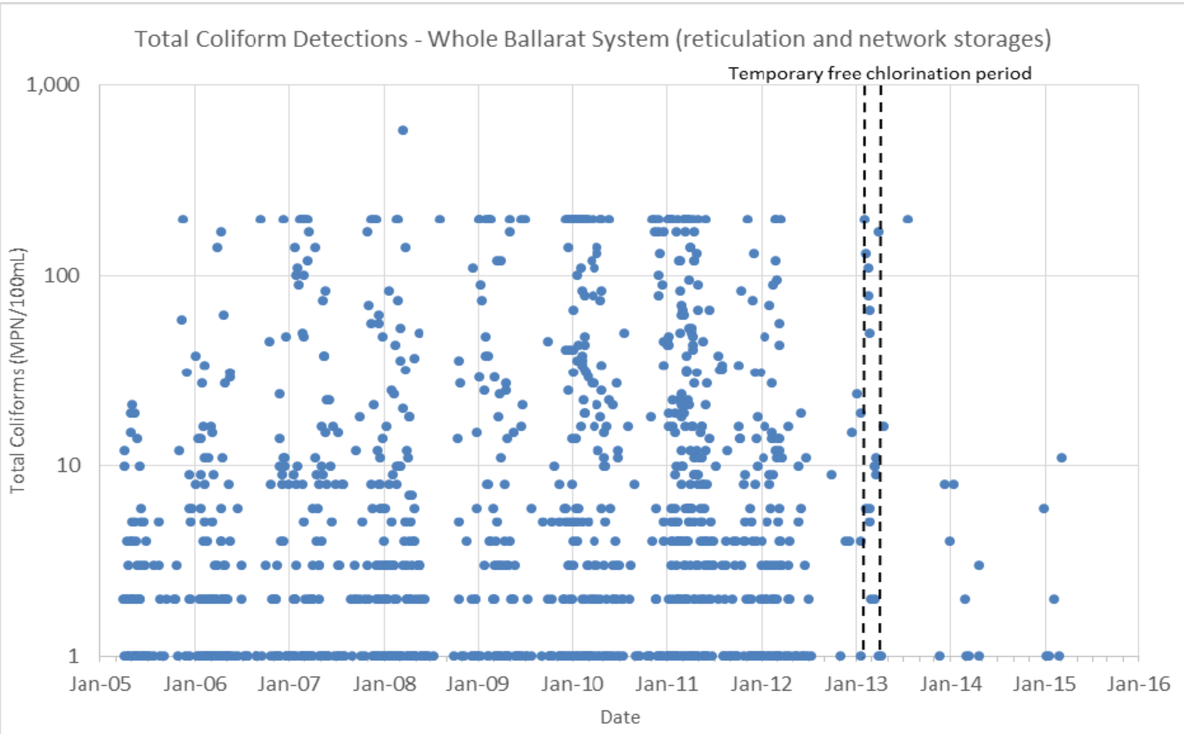

Figure 4: ***Coliform Detections in the Ballarat System***

3.0 CONCLUSION

CHW has demonstrated an immediate and sustained increase in system performance since the nitrification control program was completed in early 2013. All booster disinfection sites have been deactivated and now act as monitoring locations only. There has been almost no need to spot chlorine dose network storages leading to significant savings in operational and resource costs. Whilst we continue to focus on preventative strategies to control nitrification, there is confidence that we can successfully manage a similar system wide temporary free chlorination program as required.

Since the completion of this program, a number of additional initiatives have been implemented to control nitrification and the results have been encouraging. These have included:

- Pre-chlorination during the chloramination process which is known to increase primary disinfection efficacy, but also better satisfy chlorine demand and promote chloramine stability
- Adjustment of the treated water pH to 8.2. Increased pH levels are reported to promote chloramine stability (along with initial chloramine formation).
- Adjustment of the level controllers on a number of network water storages. This allows certain storages to be operated at lower levels as required to minimise water age.
- Installation of a submersible mixer at a key network storage basin to prevent short circuiting
- More timely corrective actions in response to adverse nitrification monitoring trends
- Investigations into an alternate source of backwash water (non-chloraminated) to prevent microbiologically assisted monochloramine decay in water treatment plant media filters

4.0 REFERENCES

American Water Works Association (2013), M56 *Nitrification Prevention and Control in Drinking Water* 2nd ed, AWWA.