WATER FLUORIDATION PLANTS IN VICTORIA

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ABSTRACT

In March 2009, the Department of Health published the *Code of practice for fluoridation of drinking water supplies* (the code). The code supports the *Health (fluoridation) Act 1973* by detailing the design and operation requirements for water fluoridation plants. The purpose of the document is to ensure the safe and effective addition of fluoride to drinking water supplies. Importantly, it recognises advances in technology and the risk management framework underpinning the *Safe Drinking Water Act 2003*. The timing of the release of the code coincided with a period of rapid construction of fluoridation plants across the state. This paper outlines experiences which will assist the water sector to continue to effectively deliver fluoridated drinking water.

1.0 INTRODUCTION

The *Australian Drinking Water Guidelines* (ADWG) details the framework to achieve safe drinking water in Australia. With respect to fluoride, the ADWG provides a health related guideline value "which is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption" (ADWG 2011). This provides an authoritative reference base for water fluoridation legislation in each Australian state and territory.

In Victoria a water business adds fluoride to drinking water supplies at the water treatment plant in accordance with the *Health (Fluoridation) Act 1973* and the *Code of practice for fluoridation of drinking water supplies, 2009.* As well, the water business must incorporate each fluoride plant within its water quality risk management plan and comply with the *Safe Drinking Water Act 2003*.

From 2004 to 2010, water businesses across Victoria designed and built 30 plants in 26 towns. The majority of plants constructed were acid plants and retrofitted to existing infrastructure. In Victoria all water businesses have at least one fluoridation plant within their asset bases.

2.0 DISCUSSION

At present, 45 water fluoridation plants are operating across Victoria. Each plant has its own operational conditions and therefore presents its own unique challenges. Using four case studies as examples, this paper identified key issues and challenges and outlines the assessments that followed. From these reviews a number of design and operational actions are provided to improve the Victorian water industry's ability to deliver fluoridated drinking water.

2.1 Case Study 1

At a water treatment plant, a fluoride dosing line was scheduled for flushing in order to replace a leaking injection pit valve.

During this flushing, a leak in the chlorine injection line was detected resulting in the suspension of the scheduled fluoride works. Fluorosilicic acid (FSA) supply was resumed on the flushed dosing line for overnight standby purposes. The next day flushing on this dosing line was repeated. The plant was placed in calibration mode to stop the plant swapping to duty on low fluoride residual. The FSA was shut off and the plant was run manually to introduce water via the calibration tube into the dosing line. This was to ensure no FSA remained in the line but as there was fluoride in the pipe-work supplying the pump a slug of water with fluoride >1.5 mg/L was sent through into the supply system.

Analysis of causes identified a combination of design and operational issues had contributed to the event.

The design issues which contributed to the situation included dead sections of pipe-work and the retrofit design which allowed for dosing direct to supply. To resolve these design inadequacies, the debrief actions identified a number of measures to reduce these risks. These included investigation of back flushing lines into the chemical waste tank and consideration of pipe and valve redesign. The business also recognised that another plant with a similar design should also be incorporated in the follow up process.

Operationally the incident identified the absence of procedures for flushing fluoride lines and processes to deal with interruption of works. Another operational issue was the consequence of switching to calibration mode which disabled the high-high fluoride alarm and shutdown. Consideration of another method to inhibit the low fluoride duty change when performing a flush to ensure high fluoride shutdown is still functional, was also identified.

2.2 Case Study 2

The second case study occurred at a plant which has had historical issues with high treated water fluoride spikes (prior to clear water storage). These typically followed filter backwashes and were due to the associated rapid changes in treated water flow. This frequently triggered the automatic shutdown of the fluoride plant. Unlike many previous occasions, following the shutdown of the fluoride plant, Citect events and alarms were generated indicating the detection of flow from the FSA flow meter and the loss of FSA from the day tank over a 20 hour period whilst the system was offline. In response to this, the isolation valves at the injection point were closed. An investigation into the possible loss of FSA commenced through the reopening of the isolation valve and process testing of various combinations of valve settings and day tank isolations. Testing confirmed the detection of inconsistent small flow through both the FSA flow meter and the draw down tube. The system was restarted briefly to assess the effect of change in pressure had on the system and the observed FSA flow rate. This inadvertently pushed a slug of neat fluoride from the FSA dose lines into the treated water main and clear water storage.

Analysis of this event also identified design and operational issues. This particular plant is a secondary plant for supply, operated intermittently and therefore experiences more shutdown and start up procedures. The constant experience with fluoride spikes during filter backwash meant the operators had developed a degree of fatigue with responding to the nuisance alarms as often no faults were found.

Investigation of the event identified the following:

- Historical high fluoride spikes and subsequent alarm fatigue had masked this different type of failure. Alarms were generated on Citect, but not sent to the auto dialler. On review this was changed to ensure appropriate auto dialler alarms were in place to notify chemical usage during FSA plant offline conditions to allow earlier corrective actions which may have prevented the extent of the incident.
- The load valves had failed much sooner than expected and were the cause of the siphoning of FSA from the day tank into the dosing lines. The hydraulic profile of the plant also contributed to the siphoning situation. Therefore the business has installed an auto isolation valve on the injection point to isolate the dosing system when the plant is shut down. A review of the business' other FSA plants identified another plant with a similar hydraulic profile requiring similar action.
- The rate and degree of asset deterioration in the FSA plants was not initially anticipated to be so severe when the plants were commissioned. The business has now moved to a very conservative maintenance program for the valves and other fittings in the FSA plant.

2.3 Case Study 3

The third case study involves a fluoride plant at a water treatment plant which dosed fluoride at concentrations up to 1.65 mg/L into the clear water storage. The fluoride plant was automatically shut down by the SCADA alarm system.

Whilst it was unclear at the time, there was a gradual increase in the fluoride dose which started a week prior to the incident. The fluoride plant had been experiencing repeated 'no flow fault' with the FSA carry water flow switch. During this time, two operators had been sharing plant duties with each operator responding and resetting the 'no flow fault' on at least four separate occasions. However, neither of the operators communicated this issue with each other nor investigated the reason for the 'no flow fault'.

Subsequently, with each reset of the dilution water pump, there was a build up of FSA in the dose line until the increase in the fluoride concentration was detected by the fluoride analyser on the inlet to the clear water storage which triggered the plant shut down.

An investigation into the cause of the incident provided the following findings:

- The FSA carrier water pump was not interlocked to shut down the fluoride dosing pumps. This allowed for the gradual build up of FSA in the dose line which was a type of failure not commonly observed.
- The alert and critical limit alarms were set on local SCADA and not on regional SCADA. As a result the operators were not receiving any alarms while being offsite prior to the automatic shut down of the fluoride system. Had the operators been alerted, earlier corrective actions may have prevented the extent of the incident.
- Due to the lack of clear standard operating and escalation procedures, the breach of the critical control point was not escalated to the duty operator. Poor operator communications had hindered the realisation that a potentially more serious problem was about to occur.
- If a plant has repeated faults and requires resetting several times over a short period of time, it is often a sign of an underlying fault/issue which requires investigating.

2.4 Case Study 4

The last case study involves a water treatment plant which runs a fluoride system using sodium fluoride (NaF) in prepacked 5kg dissolvable polyvinyl alcohol (PVA) bags. These bags were placed directly into a saturator tank with mixer and heater to assist the dissolving of PVA bags to form a constant 4% saturated NaF solution. This solution is then transferred into a day tank via an inline filter and dosed into the treated water. This system was selected due to the ability to reduce the exposure of the fluoride chemicals to operators.

During operations there were various issues in the control of the NaF system resulting in inaccurate fluoride concentrations. As the control logic was reliant on an accurate concentration of sodium fluoride being dosed the plant could not reliably maintain the optimal level. Inaccurate fluoride concentrations also created a number of operational issues for the operators.

An investigation into the fluoride concentration problems identified both design and operational issues. These include:

- The precipitation and accumulation of flocs/undissolved matter in the saturation tank. Undissolved PVA residues from the bags acted as a flocculant and promoted large flocs and impacted on settling rates.
- Blocking of the inline strainer with undissolved PVA gel required frequent cleaning. To avoid frequent cleaning, a larger strainer was adopted by the business for more carry over of solids. However this has the potential to create a fluoride overdose if it enters the water main.
- Recrystallisation/sedimentation of fluoride in the day tank as the saturated solution is transferred from the heated saturation tank to the unheated day tank. This could contribute to an event if the accumulated solids passed through the dosing pumps. To overcome this, periodic cleaning of the day tank has been adopted by the business with unknown effectiveness. The introduction of a mixer also provides energy in the day tank to enable an increase in the concentration of dissolved sodium fluoride.

This case study also highlights the importance of maintaining optimal levels. For the investment made by a water business it is important that the plant is able to produce water that can provide a dental health benefit. The health-based guideline value for fluoride in the *Australian Drinking Water Guidelines, 2011* is 1.5 mg/L. In conjunction with this value, the *Health (Fluoridation) Act* 1973 states that the annual average for fluoride in drinking water must not exceed a level of 1 mg/L.

The *Health (Fluoridation) Act, 1973* also specifies that:

> A water supply authority may and when required by the Secretary shall add fluoride to any public water supply under its control in the manner determined by the Secretary pursuant to this Act for dental health purposes.

In providing the Secretary's approval, certain requirements are also outlined, including the fluoride concentration range which should not be exceeded. A lower action-process limit of 0.6 mg/L is provided to ensure that the minimum concentration that confers a dental health benefit is achieved. An operating target (of either 0.8 or 0.9 mg/L) is also provided to achieve the optimal level.

A well-operated fluoride plant should achieve: a minimum level greater than or equal to 0.6 mg/L; a maximum level less than or equal to 1.0 mg/L and an average level as close as possible to its operating target.

3.0 CONCLUSION

A greenfield plant, (a project that lacks any constraints imposed by prior work), can design all the measures in accordance with the code however as many of these plants are being built onto existing assets, the design issues are more complex. Designing onto existing structures has at times required alternative controls that can demonstrate an equivalent or greater level of safety. However, if the design is deficient in any measure then assessment of the risks associated with these deficiencies may require other works and additional procedures. These case studies were chosen to demonstrate the impact of design and to highlight the importance of understanding each plant's challenges, equipment, alarms and processes in place. It should be noted that in these case studies, no unsafe levels of fluoride that could cause any illness were delivered into the drinking water supply. This was due to implementation of a range of controls outlined in the code and the quick responses of operators. While these cases also demonstrate debrief processes, it is important to note debriefing is only useful if the actions are implemented.

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