LEAD BY EXAMPLE, LEARN FROM EXPERIENCE – DRINKING WATER CASE STUDIES

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ABSTRACT

The *Safe Drinking Water Act 2003* (the Act) requires all water agencies (water storage managers and water suppliers) to develop, implement and review risk management plans in relation to safe drinking water. Specifically, under the Safe Drinking Water Regulations 2015, water suppliers must assess the risk that hazards pose to drinking water and determine if the current treatment processes can adequately remove those hazards. Every raw water source has unique characteristics which affects treatment plant operations. Likewise, each treatment plant has its own operating conditions and limits.

Case study examples and lessons learnt from other water agencies are valuable resources and education tools for the water industry to prevent similar occurrences elsewhere. Through the discussion of three real cases, issues are highlighted with regard to computerised plant control, reliance on automated alarms, and detailed system interactions.

1.0 INTRODUCTION

Water treatment plants are designed to remove hazards from water to produce safe, aesthetically pleasing drinking water. Of the many hazards in source waters, microbial are the greatest risk to drinking water safety. The *Safe Drinking Water Act 2003* (the Act) requires all water agencies (water storage managers and water suppliers) to develop, implement and review risk management plans in relation to the supply of safe drinking water. The *Safe Drinking Water Regulations 2015*, which came into operation on 18 July 2015, are made under the Act to provide more detail as to what is required to be included within risk management plans. So what does this mean for a water treatment operator practically or is it just more regulatory jargon?

As part of the risk management plan process, water suppliers are required to identify potential hazards in their raw water sources. The main microbial hazards of concern to the provision of safe drinking water are viruses, bacteria and protozoan. The Regulations require water agencies that provide primary treatment to document the methodology used to quantify microbial hazards in their drinking water supplies by 1 January 2016.

Water agencies must assess the risk that hazards pose to drinking water and determine if the current treatment processes can adequately address those hazards. The treatment processes which are critical to the effective management of these hazards must be identified as Critical Control Points (CCPs). Every raw water source has unique characteristics which affects treatment plant operations. Water treatment plants may be able to effectively address microbiological hazards under specific operating conditions but if those conditions change, the potential for the drinking water to remain safe may be questionable. The Regulations require that the effective operating limits are documented and therefore understood by those operating the treatment plants. It is also equally important that operators understand that if the treatment plant is operating outside these limits, the plant may be producing unsafe water. These limits or conditions are referred to as a Critical Limits. Water agencies should set triggers or alarms well within the critical limits to ensure the critical limit is never reached.

These alarms should trigger a response from operators to take action and investigate why the plant is not operating within normal specifications and to take corrective actions or escalate to management where required. Where a critical limit of a CCP is breached, the water may no longer be considered safe and immediate notification to the Department of Health & Human Services is required under Section 22 of the Act.

When things are going well, it can be assumed that there are no potential issues on the horizon. Experience is gained by learning from past events, involvement in responding to those events and reflecting on the potential for such events to occur again in the future.

Through discussion of three real cases, issues have been highlighted with regard to computerised plant control, reliance on automated alarms, and detailed system interactions. Programmable Logic Controllers (PLCs) and Supervisory Control and Data Acquisition (SCADA) systems are critical elements of any treatment plant operation and are required to be handled with diligence. Case study examples and lessons from other water agencies are valuable resources and education tools for the water industry to prevent similar occurrences elsewhere.

2.0 CASE STUDIES

2.1 Case Study 1 - Learning From Experience

Case study 1 relates to a city with an approximate population of 31,000. The raw water source is from surface water from an unprotected catchment. The source water is extracted and stored in an off-stream raw water storage basin. The water treatment includes flocculation, dissolved air flotation and filtration, and disinfection is chlorination. The treated water is then pumped to the clear water storage located on site.

The water treatment plant is a relatively large plant, with seven individual filters. The plant does not have a filter-to-waste mode for normal operation and requires the treatment plant to be operating to backwash the filters.

In 2012 the raw water storage had been taken off-line for annual maintenance and cleaning. The raw water was being extracted directly from the run of river raw water source, by-passing the raw water storage basin and being fed directly to the water treatment plant. To minimise the risk to the treated water supply whilst the storage basin was off-line, the raw water turbidity alarm in SCADA had been reduced and backwashing of the filters had been reduced to 8 hours from the normal 24 hours. While procedures were updated for the period of the storage basin maintenance they had not addressed risk management considerations with respect to drinking water quality.

There had been a significant rainfall and as a result the turbidity of the raw water source had increased to 50 Nephelometric Turbidity Units (NTU). The water treatment plant was working well, producing safe drinking water at this turbidity. This was an unusually high turbidity for the raw water supply.

A large forecasted storm event occurred with the local area receiving 36.5mm of rain. This storm event was underestimated by operations staff and resulted in another significant increase in the turbidity of the raw water overnight, from 18 NTU to 100 NTU. A raw water turbidity of 100 NTU for this system was unprecedented.

The treatment plant experienced issues with filter loading and plant shutting down due to changes in raw water turbidity. Operators tried to restart the plant a number of times but due to the filters blocking, the treatment plant continued shutting down. During this period the clear water storage capacity was decreasing. All of the filters became blocked and the combined filtered water turbidity from all of the filters was 33 NTU. There was only a critical limit alarm set point of >0.5NTU for 30 minutes for the filtration CCP. This duration contributed to elevated turbidity into the clear water storage. The clear water storage had decreased to 47 % capacity. It was necessary to start producing water to prevent air getting into the distribution system. All filters required backwashing.

During the backwashing process some high turbidity filtrate entered the clear water storage contaminating the already treated drinking water. While trying to get the treatment plant operating within normal specifications the turbidity in the clear water storage increased to 13-20 NTU. Disinfection residuals were being maintained. It took a further 12 hours for the plant to return to normal operation. The turbidity within the reticulation was measured at 1 NTU and flushing was undertaken. There were no reported cases of illness associated with this incident.

In 2015 a rain event resulted in an increased turbidity in the raw water storage of the same water treatment plant. The plant auto crashed (shutdown) during the night on an operational High-High alarm for the filtration CCP. As a result of the auto crash, poor quality water did not continue being produced. The plant remained off until the following morning. The operator attended the site the next day and as a result of jar testing set a new alum dose at the plant. The streaming current detector (SCD) was reset and aligned to the new alum dose. The operator checked the plant and, as it was running well, left the site. A programming glitch caused the SCD to reinstate the previous alum dose settings, resulting in an under-dose of alum. The filtered water turbidity rapidly increased above the High-High alarm level and the plant auto crashed again.

The operator returned to site and implemented a new procedure; configuring a manual filter to waste. This process required manual operation of valves to redirect water back into the raw water reservoir rather than the clear water storage.

To enable the filter to waste process, CCP and SCD alarms must be temporarily changed. Any CCP changes require staff to follow change management procedures which includes prior approval from the water quality team manager.

The water was recycled to the raw water basin for approximately an hour until the filtered water was below 0.1 NTU and the SCD was operating well. When the plant was running normally the CCP alarms were reset to normal operational targets and the configuration to the clear water storage was re-established. No compromised water went to the clear water storage or customers as a result of the controls initiated and actions taken by staff.

2.2 Case Study 2 – Leading By Example

During a routine day at the treatment plant, the lead operator received a routine call from an instrument technician who had identified an issue with SCADA. The pH meter had just been calibrated and challenged with standard buffer solutions, with the local instrument display reading correctly. However, the SCADA pH reading didn't match the instrument reading.

At this plant the pH meter reading was used to calculate the critical contact time (CT) required for disinfection. This differs from the standard approach to allow for a greater CT if the pH increases. Source water pH is observed in this plant to change over time, so it was important to optimise chlorine dosing and chemical usage. The actual CT is also calculated using the flow-rate and free chlorine residual, along with the baffling factor of the contact tank. Only where the actual CT does not meet the critical CT are alarms raised.

On this day the pH value in the PLC was reading lower than the instrument therefore the system thought the water was at a lower pH than it actually was, and calculated the critical CT lower than it should have been. There was a risk that the water was not being disinfected adequately. The operator escalated the issue to the plant engineer, DHHS was notified of a possible issue, and an investigation commenced.

The first step was to establish how long the issue had been there. Initially staff were unsure but knew that there was some PLC code work completed 6 months ago, which was investigated further. Secondly the PLC code was looked at in detail, to understand where the problem was coming from. This investigation found a factor relating the instrument output to the PLC reading was incorrect, meaning the scale between the instrument and the PLC was different. This was rectified. The investigation also revealed that other instruments had similar issues with scaling. These issues were not "critical" and were related to things like levels for pump wells, and other operational monitoring. Functional testing and checking of the PLC code reviewed relevant systems and these were found to be operating correctly after the identified issues were resolved.

After resolving the PLC code issues the quality of water produced over the last 6 months was reviewed to determine if customers were at risk from inadequately disinfected water. The calculated critical CT was incorrect (low); however the weekly water sample results for this period of time were free of microbial indicators. It was not clear as to what had happened for the remainder of the time.

Evaluation of six months of source water pathogen and indicator data demonstrated that the source water was of a better quality than predicted in the treatment plant design calculations. Final water quality testing results did not detect any microbial indicators or pathogens. To understand the operation of the overall system, a comprehensive test of all critical systems, dose rates, flow rates, pumps, instruments, local alarms, SCADA values and remote alarms was undertaken. Onsite challenge testing of SCADA values from instruments through to alarms was also completed to check system responses were adequate.

Although this incident was at a recycled water treatment plant, the lessons learned from this case study are directly applicable to both drinking water treatment plants and recycled water plants.

2.3 Case Study 3 – Learn From This Experience

This case study relates to a town with a population of 8,000. The raw water source for the town is surface water from an unprotected catchment. The source water is extracted and stored in an off-stream raw water storage basin. The water treatment for the supply includes coagulation, flocculation, dissolved air flotation and filtration, and disinfection is chlorination. The treated water is then pumped to the clear water storage located on site. A treatment plant upgrade has recently been completed.

Wednesday: At 11:15am both alum dosing pumps faulted and the treatment plant shut down. The duty operator attended site and repaired the fault and requested the customer service centre (CSC) to monitor the situation.

Thursday: 7:50am the operator attended site and undertook routine maintenance of the alum dosing pumps that had failed the previous day. At the time the operator was on site the plant was operating and the filters producing water at 0.04 NTU. At 10:30am the plant was still operating and the filters producing water at 0.3 NTU (CCP alert limit), no alarms activated. By 10:40am the filters were producing water at 0.5 NTU (CCP critical limit), no alarms activated. At 10:55am the filters were producing water at 0.9 NTU (has now breached the CCP), no alarms activated. At 11:10am the filters were producing water at 2 NTU and still no alarms activated. The operator on site believed the plant was running normally and left site. At 12:20pm the filters were producing water at > 5 NTU (turbidity meter only measures to 5 NTU), no alarms had activated.

At 12:50 pm the plant automatically shut down due to the high level in clear water storage.

At 4:30pm work was being carried out on SCADA and the operator could not remotely check the operation of the plant at the end of the day.

At 5:05 pm the CSC notified the duty operator that the alum pump faulted and shut the plant down. The duty officer phoned the operator who had been working at the plant during the day. The operator advised of the planned cleaning of the alum dosing pipework the following day. The duty operator was unable to remotely access SCADA therefore could not access information about the plant so attended site. The duty operator found a problem with the alum pump and repaired it on site, checked the time the plant had been shut down, changed the duty pumps to look for faults and then reset all of the alarms.

At 6:20 pm the plant restarted and the filters were producing water > 5 NTU, no alarms were activated. The plant continued operating until it shut down at 11:15pm.

Friday: At 6:30am the plant started up and the filters were producing water at > 5 NTU, no alarms activated. An operator arrived on site at 7:40am and noticed the plant running but the alum pumps not dosing and the filtered water at > 5 NTU. The operator reinstated the alum dosing and commenced backwashing and escalated the incident.

Corrective actions taken in response to this incident included issuing a boil water alert for the town, dumping water in the clear water storage (6 ML and 4 ML sent to waste), widespread water sampling, flushing the reticulation with good quality water. It is estimated that 14 hours of potentially unsafe water was produced, pumped into the clear water storage and supplied to customers.

Two weeks after this incident another almost identical incident occurred at another treatment plant run by the same water agency. This water treatment plant supplies a population of 1500. This treatment plant has a similar raw water source and treatment processes as the previously discussed incident and the clear water storage is also located onsite. The operator carried out the routine alum drop-down test and but did not turn the isolation valve back on.

This resulted in no alum being dosed to the plant. The filters were producing water above the filter CCP overnight and the alarms did not activate. Four hours of potentially unsafe water was produced and potentially supplied to customers. When the operator became aware of the situation, as with the previously discussed incident, it was immediately escalated and corrective actions were implemented. Corrective actions in response to this incident included issuing a boil water alert, dumping water in clear water storage, widespread water sampling and flushing the reticulation with good quality water.

3.0 DISCUSSION

In ***Case Study 1*** having no filter-to-waste mode was a known risk, but how big of a risk to drinking water safety only became evident after the 2012 incident. The water agency conducted a debrief after the 2012 incident. Corrective actions were identified and implemented. Two of these corrective actions were:

1. Establishing a "High-High" set-point prior to the critical limit for the filtration CCP. If the filtered water reaches the "High-High" value the plant will auto crash (shutdown).
2. Modifications at the plant using existing infrastructure to allow water to be redirected/recycled to the raw water basin by manual operation of valves.
   When the water agency realised how great a risk not having filter-to-waste mode at their plants is to their business, all of their plants were reviewed and the risks reassessed. All similarly configured plants, where it is physically possible, have had filter to waste modes implemented.

If the water agency had not effectively reflected on this incident, learned from their experience and made changes to their plant and processes, a similar event would likely have occurred in 2015, putting their customers again at risk.

The event in ***Case Study 2*** shows how a seemingly minor change in PLC coding could have resulted in inadequate disinfection and put public health at risk. Understanding the impact that relatively minor changes and errors in the PLC and SCADA system can have is valuable to justify a greater risk focus on change management and verification testing of these systems.

All water industry facilities will be familiar with "permit to work" and other safe work systems focused on prevention of injury, but commonly the risks to the product (i.e. treated water) are overlooked. Key questions to ask when reflecting on this event are:

1. How did these problems go undetected for this amount of time?
2. Were system tests completed after the last PLC programming, and have the records been kept?
3. Are there adequate controls around the programming of PLCs and access to PLC systems to prevent this in the future?
4. Does there need to be a schedule of checking instrument readings with SCADA and PLC readings?
5. What would have happened if the pH reading was out by more, or multiple errors added together created a greater problem than just any one problem on its own?
6. Are the correct values being used in calculations?
7. What is the source water quality compared to the pathogen treatment capability design of the plant? Can periodic testing or challenging of critical alarms and instruments be completed?
8. Is there a change management process for appropriate risk assessment prior to

work and good record keeping of the work completed? Can the plant be recovered if it all goes wrong? Is the PLC or SCADA code backed up and stored?

Consideration of these types of questions is essential for the reliability of operations, planned changes and emergency situations. PLCs and SCADA systems are just computers and required reliable quality inputs to produce reliable quality outputs. .

There are many lessons to take away from ***Case Study 3***. In determining the root cause of both incidents, it was identified that the main failure was in relation to ineffective change management. After the upgrade to the plant, the alarms had been reset but had not been tested to ensure that they were active. The regional SCADA showed that the alarms were activated, however, after the incident SCADA on site identified that the alarms were not actually active. In the second incident it was identified that the alert and critical limits for the filtration CCPs had been entered incorrectly. This plant had also recently completed upgrade works. The alert and alarm limits had not been adequately checked to ensure that the correct values had been entered into SCADA for the correct treatment process. There was no auto crash (shutdown) enabled for either of these plants. For the first plant discussed, auto crash and activated alarms would have avoided the incident. For the second plant discussed, auto crash may not have been successful in stopping potentially unsafe water being delivered to customers as incorrect critical limits for CCPs had been entered.

Boil water alerts were issued in response to both of these incidents. There is significant cost to a business where a boil water alert is issued. With the greatest cost being damage to the agencies reputation and the loss of public confidence in the safety of drinking water.

4.0 CONCLUSION

These three case studies were chosen to demonstrate how important it is for operators to know the risks to their plants, to thoroughly understand their treatment systems and plant capabilities. This knowledge and experience is directly linked to the production of safe water and the *Safe Drinking Water Act*. Not every risk will be obvious, and sometimes events occur that bring these risks to light. It is what is done with this information that is important. It is crucial that lessons are learnt from incidents and events and that change is implemented as a result of the experience to reduce the likelihood of it occurring again.

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