A CASE FOR CORROSIVITY MONITORING IN CANBERRA

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ABSTRACT

A recent study was undertaken to assess the corrosivity of Canberra's water supply, which affects the asset life of water pipes and fittings in the distribution system. The aim of the study was to determine appropriate targets for treated water pH and alkalinity, to minimise the potential for corrosion.

The Calcium Carbonate Precipitation Potential (CCPP) for Stromlo WTP treated water leaving the plant was calculated using StaSoft 4.0 software for the available water quality data between 2005 and 2011. The CCPP results revealed occasional cases of highly corrosive (aggressive) water, while most of the samples showed only mildly corrosive or passive conditions.

The CCPP results were then correlated with the parameters of pH and alkalinity to draw conclusions about the specification of targets for Stromlo WTP treated water. The correlation analysis showed a strong relationship between CCPP and pH. On average, the benchmark CCPP of -6 can be achieved at pH 7.6.

The study highlighted the importance for WTP operators to understand the long term implications of corrosivity and the impact of processes they control. Water utilities can easily use simple software to monitor corrosivity so long as the required data is collected.

1.0 INTRODUCTION

Eighty percent of Canberra's water is supplied from the Cotter Catchment. Alkalinity levels of Cotter River water are very low, around 11-14 mg/L. Low alkalinity water is unusual for surface water sources in Australia, and presents a challenge to water treatment in managing the corrosivity to water pipes of the final water.

In the case of cement-lined water pipes, corrosivity refers to the capacity of water to leach calcium from cement mortar linings, thereby increasing water pH and decreasing effectiveness of chlorine disinfection, and reducing the lifetime of pipes and fittings.

For many years, Cotter River raw water was only disinfected, fluoridated and pH corrected at Stromlo WTP before supply to the distribution system. During this period the alkalinity of treated water was typically around 12-16 mg/L. These conditions existed for over 80 years, during which time the water is assumed to have been corrosive in nature.

In 2004, the Stromlo WTP was upgraded to include coagulation and filtration. The existing lime dosing system was also upgraded to improve post-treatment pH correction and provide lime pre-treatment. Lime pre-treatment increases alkalinity and assists in the coagulation and flocculation processes. The post-treatment lime dosing upgrade included provision of a lime saturator to manage turbidity resulting from lime dosing in the filtered water. The post-lime dosing system controls the final pH and increases alkalinity of the treated water.

Limitations in the hydraulic capacity of the lime saturator result in variability in meeting pH and alkalinity targets. High alkalinity increases the buffering capacity of the water; therefore the quantity of “milk of lime” required to achieve pH correction increases with increased alkalinity throughout the process and the required water flow through the lime saturator exceeds the hydraulic capacity of the system.

A further problem results from the large ambient temperature fluctuation in Canberra’s climate, which affects the stability of the lime sludge blanket in the saturator. At times this affects the treated water turbidity.

Given the lime saturator system limitations, compromises must be made to balance the performance for treated water turbidity, alkalinity and pH. The result is that the corrosivity of the treated water is variable.

The most significant water treatment processes for corrosivity and their effect on pH and alkalinity are summarised in Table 1.

Table 1: ***Significant stages of treatment for pH and alkalinity levels. “↑” indicates an increase; “↓” indicates a decrease***

Parameter	Raw water	Pre-Lime	Carbon Dioxide	Coagulation & Flocculation		Post-Lime	Fluoride	Treated water
pH	6.9-7.3	↑	↓	↓	6.1-6.2	↑	↓	7.4
Alkalinity	11-14 mg/L	↑	-	↓		↑	↑	30-40 mg/L

Treated water is delivered to Canberra and Queanbeyan via 3,080 km of water mains and pipes made up of several varieties of pipe material. Material selection was largely dependent on the technology available at the time of construction. A consequence of the various pipe materials throughout the distribution system is that there may be differing corrosion issues within water pipes at various locations around Canberra.

Samples taken from the distribution network indicate that the cement linings in pipes have been effective in preventing internal corrosion. Even some of the oldest cement-lined pipes still have linings intact; however, it is uncertain to what extent the calcium carbonate may have leached out, or whether the lining has thinned over time.

2.0 DISCUSSION

2.1 Water Quality and Corrosion

The corrosivity of water depends on its chemical and physical properties. Water with low pH has potential to cause corrosion. In contrast, high pH reduces the solubility of any calcium carbonate ($CaCO_3$) present, and the tendency to produce scale increases. Adjustment of the pH by water treatment plant processes is therefore important to the management of water corrosivity. Alkalinity is also an important factor affecting corrosion. Higher alkalinities are generally associated with lower iron corrosion rates.

Low alkalinity water tends to be corrosive - leaching calcium carbonate from cement linings, thus leading to significant increases in bulk solution pH, calcium concentration and alkalinity. The alkalinity should also be high enough to maintain a high buffering capacity, ensuring the stability of pH as it moves through the distribution system.

While high pH is advantageous for corrosion control, it has a negative impact on chlorine disinfection due to the relationship between hypochlorous acid and hypochlorite ion. At lower pH hypochlorous acid dominates, while at higher pH the hypochlorite ion dominates. Hypochlorous acid is a much more effective disinfectant.

Stromlo WTP has two disinfection barriers: ultraviolet light treatment followed by chlorination. Chlorine is dosed to a mg/L setpoint which is seasonally adjusted based on temperature, water age (demand) and verification monitoring in the distribution system. ACTEW Water maintains a relatively high free chlorine residual (i.e. 2011/12 mean free chlorine residual was 0.75 mg/L at customer taps) to ensure that disinfection is not compromised.

2.2 Saturation Indices

Saturation indices are used to provide a guide of calcium carbonate ($CaCO_3$) stability in water. The indices quantify the potential of water to be either scale forming or dissolving. The indices were primarily developed in the USA and the UK, where the deliberate precipitation of $CaCO_3$ was a common solution for protecting the large amount of unlined pipes (WSAA, 2008). In Australia there has been wide-spread use of mortar-lined pipes since the late 1920s, reducing the need for deliberate $CaCO_3$ precipitation. The saturation indices are important for cement-lined pipe networks when water quality is at the extremes of the saturation index.

Two commonly used indices are the Langelier Saturation Index (LSI) and Calcium Carbonate Precipitation Potential (CCPP).

LSI estimates the theoretical tendency for a water to dissolve or precipitate $CaCO_3$. While this index is commonly used by water utilities because it is simple to calculate, it only highlights the existence of a driving force and provides a qualitative indication for the occurrence of scale or corrosion.

CCPP is a more reliable index, providing a quantitative measure of $CaCO_3$ that will precipitate or be dissolved in order to reach equilibrium in solution. The most sensitive parameters for CCPP calculation include pH, alkalinity, calcium and temperature. The day-to-day use of CCPP has previously been limited as it is time consuming to calculate. However, the development of computer software has made quick data processing possible.

Table 2: ***Guide for corrosivity state of water for various CCPP values (Gebbie, 2000)***

Corrosivity state of water	CCPP value, mg/L $CaCO_3$
Scaling (protective)	> 0
Passive	0 to -5
Mildly Corrosive	-5 to -10
Corrosive (aggressive)	< -10

Following literature review and benchmarking against several water utilities around

Australia, ACTEW Water revised its target range for CCPP to be "greater than -6".

2.3 Data Analysis

The CCPP for Stromlo WTP treated water leaving the plant was calculated using StaSoft 4.0 software for the available water quality data between 2005 and 2011. The CCPP results revealed occasional cases of highly corrosive (aggressive) water, while most of the samples showed only mildly corrosive or passive conditions.

The CCPP results were then correlated with the parameters of pH and alkalinity to draw conclusions about the specification of targets for Stromlo WTP treated water. The correlation analysis shows a strong relationship between CCPP and pH (Figure 1). On average, the benchmark CCPP of -6 can be achieved at pH 7.6.

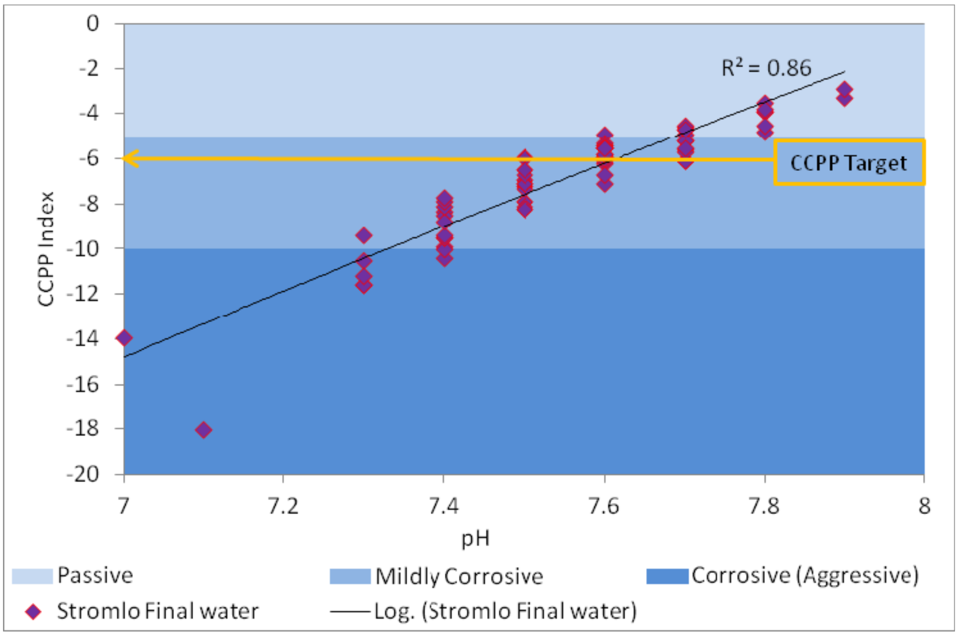

Figure 1: ***Correlation of pH and CCPP for Stromlo treated water (2005 to 2011)***

The correlation between alkalinity and CCPP is shown in Figure 2. The analysis showed that a reasonable CCPP index can be achieved at pH 7.6 for a wide range of alkalinity values. Therefore, the current alkalinity targets for Stromlo WTP treated water of between 30 to 40 mg/L are appropriate for minimising corrosion.

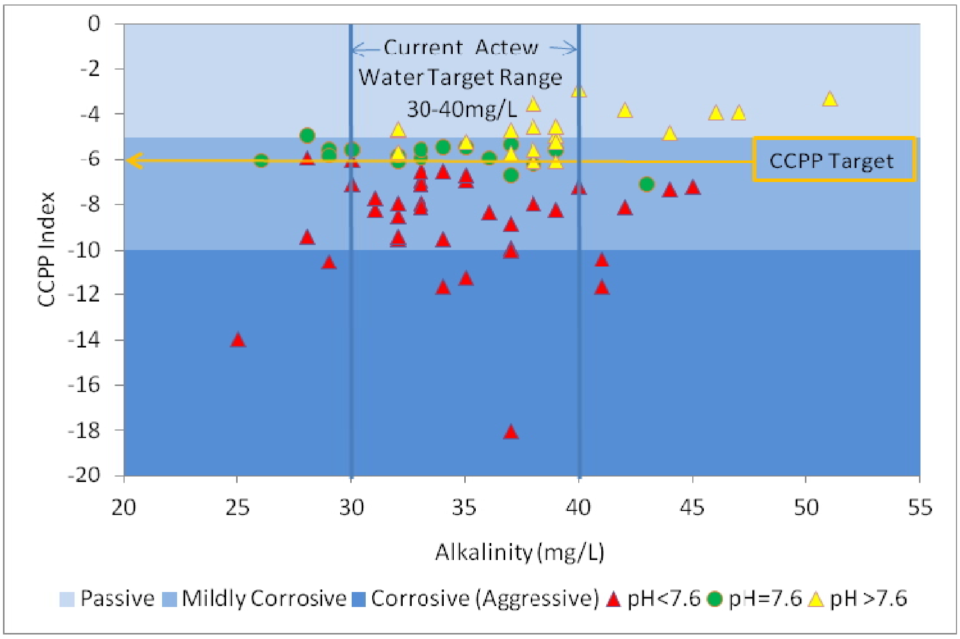

Figure 2: ***Correlation of alkalinity and CCPP for Stromlo treated water (2005 to 2011)***

To investigate the effects of corrosivity within the existing distribution network, analysis was also undertaken comparing water quality data from Stromlo WTP with water from customers' taps for 2005-2011. Topographical maps were used to divide the list of customer taps into groups according to the pipe material present. Statistical data was calculated for pH, alkalinity and calcium.

The pH was found to be higher in the cement-lined pipe areas of the distribution system compared to the treated water from Stromlo WTP (Figure 3). This is due to the leaching of calcium hydroxide from cement linings. The plots for alkalinity and calcium showed similar trends. This information has provided a basis for a further detailed assessment and monitoring of target areas in the distribution system which will inform ongoing management practices.

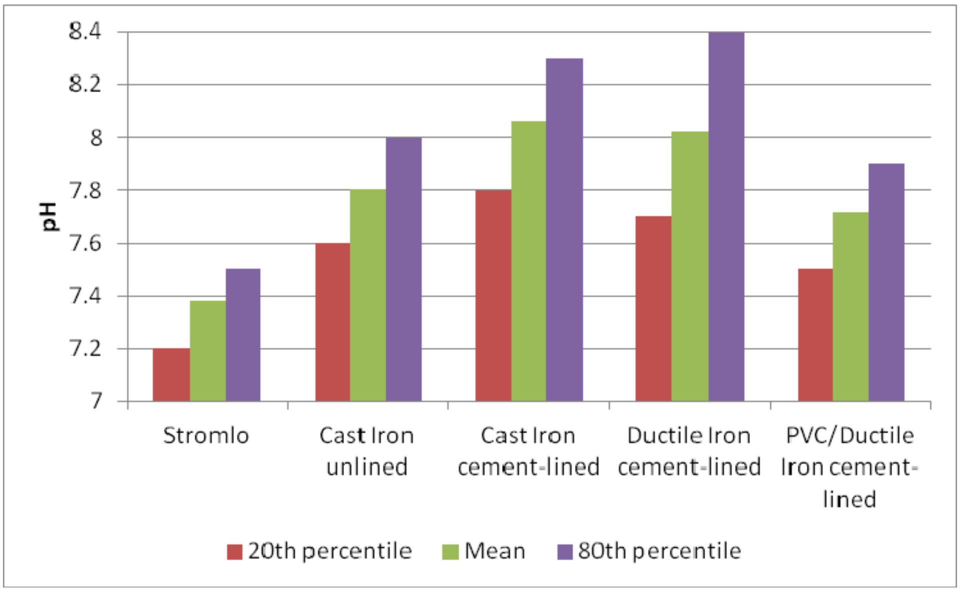

Figure 3: ***Statistics of pH for Stromlo WTP and customer taps (2005-2011)***

3.0 CONCLUSION

The study highlighted that water corrosivity is very sensitive to pH. Although alkalinity also affects corrosivity, it is possible to produce water with reasonable alkalinity but with pH that is too low, resulting in corrosive water (with low CCPP results).

As a result of this study, ACTEW Water raised the final pH set point controlling the post lime dosing system to pH 7.4 (from 7.2), while maintaining the current alkalinity target range of 30 – 40 mg/L. A treated water pH of 7.6 was identified as an appropriate target to achieve the revised CCPP target of -6. ACTEW Water is continuing to investigate the balance of pH, alkalinity and disinfection potential throughout the distribution system to manage corrosivity without compromising chlorine disinfection.

The water quality monitoring program was revised to ensure that all of the required data for CCPP calculation is routinely collected. CCPP results for Stromlo WTP treated water are regularly reviewed to confirm that corrosivity targets are being achieved.

The study highlighted the importance for WTP utilities to understand the long term implications of corrosivity and the impact of processes they control. Water utilities can easily use simple software to monitor corrosivity so long as the required data is collected.

4.0 ACKNOWLEDGEMENTS

Thanks to Tim Crockford for his work as a vacation student engineer who completed the painstaking data analysis including manual calculation of CCPP. Tim completed his honours thesis on this topic and co-authored the article for Waterworks.

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