IMPLEMENTATION OF PREDICTIVE ALUM DOSE CONTROL SYSTEMS

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SA Water

77th Annual WIOA Victorian Water Industry Operations Conference and Exhibition
Bendigo Exhibition Centre
2 to 4 September, 2014

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ABSTRACT

Water treatment plant (WTP) operators and managers are continuously seeking ways to improve the efficiency of treatment processes to generate cost savings and achieve desired water quality outcomes. Optimisation of the coagulant dosing step at conventional water treatment plants will potentially achieve both of these objectives. Ensuring that the optimum coagulant dose is consistently applied to variable quality raw water will not only result in water quality improvement, but should also generate chemical cost savings where potential overdosing of coagulant is minimized.

Optimisation of the coagulation process at Adelaide metropolitan WTPs is currently aided through the use of a coagulant dose prediction model. The key advantage of the model is that it uses relatively simple water quality input data (UV absorbance at 254nm, colour and turbidity) to generate dose predictions, and as such is very useable operationally. However, currently the model is used offline for routine (weekly) or ad hoc prediction of coagulant dose in response to water quality changes, and is not being used to full advantage as an on-line feed forward control to optimise the coagulation process.

This project involved developing the existing offline and manual coagulant dose prediction model to an online and automatic predictive alum dose control system (PADCS). This paper describes the key stages of this work, which included the trialling and optimisation of online instruments to reliably measure the model input parameters UV_{254} and colour, assessment of the system by comparison to actual plant doses, and other implementation steps, such as development of a quality control procedure for the new system. Use of the new PADCS online allows operators to observe rapid water quality and coagulant demand changes as they happen, so changes can be made proactively to these events.

1.0 INTRODUCTION

SA Water is subject to increased economic regulation and efficiency targets. The production of safe drinking water cost effectively is challenging given the poor source water quality available to Metropolitan Adelaide water treatment plants (WTPs). Raw water quality is poor and often highly variable making it difficult to treat. It contains elevated DOC concentration in the range 3 to 7 mg/L and if sourced from the River Murray it can contain high turbidity often exceeding 100 NTU. It may contain a large algal population with algal metabolites if sourced from a reservoir. *Cryptosporidium* oocysts are also present in raw water. Treatment includes alum coagulation, flocculation, clarification, granular media filtration and disinfection using chlorine (Edzwald *et al*, 1998; Korich *et al*., 1990).

Ways to reduce operational cost while improving compliance with the Australian Drinking Water Guidelines (ADWG) are highly valued. Optimisation of specific treatment processes may serve to achieve both these objectives.

An example of this is the optimised dosing of coagulant at conventional WTPs in Metropolitan Adelaide to ensure the correct amount of coagulant is consistently dosed to meet water quality demands while not incurring excessive treatment cost. The removal of oocysts using clarification and filtration is extremely important as they are resistant to chlorination at Ct conditions normally found at WTPs.

Coagulation is a critical process limiting step at conventional WTPs as this process precedes clarification, filtration and disinfection. Coagulation plays a pivotal role in the performance of downstream treatment processes and finished water quality (Letterman et al., 1999). A key requirement for successful coagulation is the application of the optimum coagulant dose to meet the demand of particles and natural organic matter (NOM) present in the raw water. Sub-optimal coagulant dosing will lead to decreased removal of oocysts (Xu *et al.*, 2006) and NOM while over-dosing will incur increased OPEX for chemicals as well as sludge treatment and disposal. The correct coagulant mixing and careful control of coagulation chemistry are also essential requirements.

Jar testing is currently the most widely-used process for determination of optimal alum dose rates. However this process is highly time-consuming for operators, and does not allow adjustment of alum dose rates to keep pace with rapidly changing raw water quality. This issue was to some degree addressed by the development of an alum dose prediction model as part of the former CRC for Water Quality and Treatment Research Program (CRCWQ&T) (van Leeuwen *et al*., 2005). The key advantage of this model is that it utilises relatively simple water quality input data to generate dose predictions, and as such is very useable operationally. This model has been successfully used for a number of years as an offline coagulation dose prediction tool (van Leeuwen et al., 2009).

The original mEnCo software ran on a personal computer (PC) using Visual Basic and has been converted to an Excel platform. It requires raw water turbidity, colour and UVabs@254 nm as input data (van Leeuwen *et al*., 2005). These are easily obtained from analysis of raw water grab samples at the WTP laboratory. Values for these parameters are manually entered into the software on the PC to produce coagulation predictions. Recently a new model has been developed that used the sample input parameters WTC-Coag™.

The operator is able to use one of two coagulation modes.

- Enhanced coagulation refers to near maximum removal of DOC for a selected coagulation pH. The WTC-Coag™ predicted alum dose for enhanced coagulation achieves a DOC removal rate with coagulant dosing of -0.015 (ΔDOC/ΔAlum). This represents a reduction of 0.15 mg/L DOC with an increase in alum dose of 10 mg/L.
- The user specified removal coagulation refers to the alum dose required to remove a specified percentage removal of DOC that can be removed by alum coagulation (coagulable DOC).

Operators at the Metropolitan Adelaide WTPs have found the coagulation dosing prediction (CDP) software to be a useful tool for coagulation optimisation. The software is generic and does not require prior calibration for use at a WTP.

A need to improve the control of alum dosing in response to unstable raw water quality prompted the development of an online and automatic Predictive Alum Dose Control System (PADCS). The PADCS predicts the required alum dose in real time allowing more proactive operational responses.

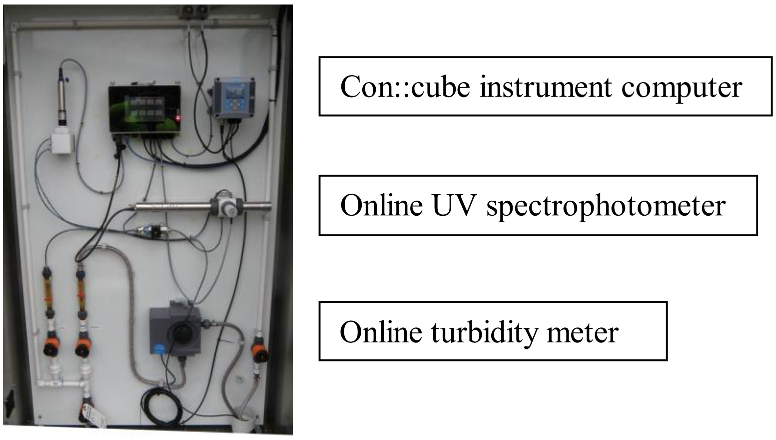
Online instruments were procured to measure UVabs@254 nm and colour. The WTC-Coag™ algorithm was programmed to run on a programmable logic controller (PLC) using inputs from the online water quality analysers and to allow multiple alum dose predictions to be made. Implementation of online PADCS was trialled at two Metropolitan WTPs; one, implementation Site 1 (IS1) primarily receiving water from a reservoir source, the other, implementation Site 2 (IS2) receiving water alternately from a reservoir and the River Murray (via the Mannum-Adelaide pipeline - MAPL).

2.0 DISCUSSION

2.1 Site Preparation and Instrument Configuration

Online instruments were mounted in a waterproof cabinet to receive water from the raw water inflow pipe at each implementation site (e.g. IS1 Figure 1). Turbidity data was acquired for model input by an online turbidity meter. An online UV spectrophotometer (s::can spectro::lyser) was installed onsite for the measurement of UVabs@254 nm and colour. The spectrophotometer measured absorbance in the UV-Visible spectrum (200-700nm) at 2 minute intervals. The s::can spectro::lyser model (path-length) was selected by reviewing historical water quality and grab sample testing data. The measurement quality relies on the use of a suitable spectrolyser with the correct path-length. The selection of path-length is based on water quality with larger path-length provides higher sensitive measurement; however, it also has a narrower dynamic range when water quality varies. Therefore initial testing prior to purchase is very important.

Output parameter data from the online instruments was received by a PLC where the alum dose prediction algorithm was calculated. From the PLC both the raw instrument outputs and coagulant dose predictions were sent to an internal database for remote access.



<u>**Figure 1:**</u> ***Onsite instrument configuration IS1***

2.2 Optimisation of Online Water Quality Measurements

The spectro::lyser measures absorbance in the UV-Visible spectrum 200-700nm, and unlike the standard laboratory method it does not possess any physical filtration step prior to absorbance measurement. 'Raw' absorbance readings are calibrated to represent 'true' or solid free absorbance readings using a solids compensation algorithm. This compensation tool was initially used to generate UVabs@254 nm and colour output measurements. However, comparison between these outputs and periodic grab samples revealed some discrepancy between field and laboratory values (Figure 2).

Hence, local calibration (performed by the instrument supplier) was required to allow the online values to match correctly with laboratory readings. Ensuring this match occurred was highly important, as the alum dose prediction model was developed using laboratory values. Both IS1 and IS2 had local calibration performed to improve data output, however discrepancies between the field and lab measurements were far greater at IS2.

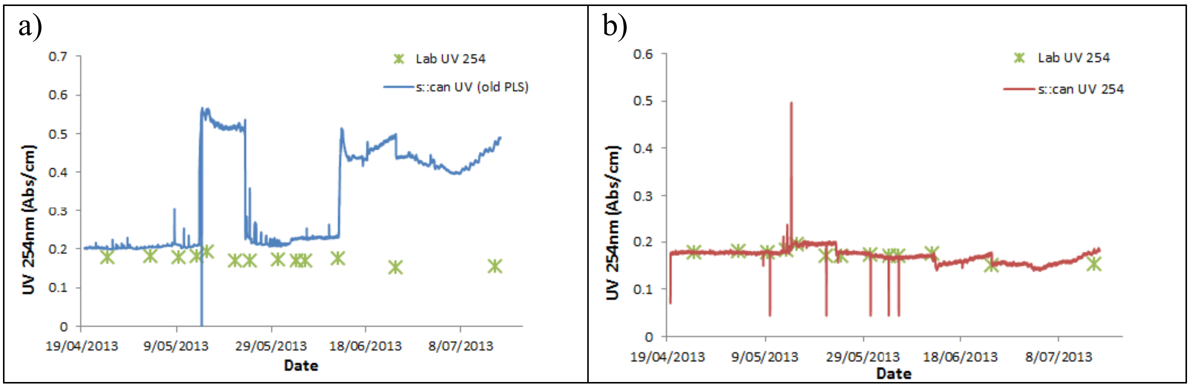


Figure 2: ***Online UV absorbance readings at IS2 a) before and b) after local calibration***

Differences between the online and laboratory UVabs@254 nm and colour readings were greatest at IS2 during periods where inflow water was from the MAPL. River Murray water has a very high turbidity compared to most raw water sources, and is known to contain a high proportion of fine colloidal material. It appears this material impacted the UV absorbance and colour readings to a large degree; the in-built solid compensation was not able to adequately remove impact from this material. A custom built algorithm will be required for this type of water.

2.3 Performance of Online Alum Dose Prediction

A new software model Water Treatment Control–Coagulation™ (WTC-Coag™) has been developed. Where the model has not been previously applied at a WTP, some preliminary work should be undertaken to determine how the plant dose relates to model predictions over time. An effective way to achieve this is to trend weekly model predictions at several percentage removals (for instance 80%, 85%, 90% and 95%), against actual plant dose. It is probable that the prediction trend provided by the model will match the trend exhibited by the plant when trended over a reasonable operational period (i.e. 6 months). The percent removal prediction that is closest to the actual dose applied routinely at the plant can be used as a target set point for future coagulation operational control. Where unexpected changes in water quality conditions occur at a site, or where existing water quality conditions fall outside the 'average' range of water quality predicted by the model, there is now functionality available to adjust the model prediction. An example is the use of the turbidity weighting factor (default is weighted at 100%) to account for different types of particulate material present not previously observed.

During the initial implementation, little variation was observed in the alum dosing requirements and alum dose rates at IS1, making assessment of the new PADCS challenging (data not shown). At IS2 however, variations in alum dose prediction coincided with alum dose changes observed at the WTP (Figure 3). They also closely matched offline alum dose predictions generated using laboratory data.

The PADCS at IS2 was successful in detecting a period of lower alum demand not reflected in plant dosing until several days after the drop in demand occurred (Figure 3).

This demonstrates the potential value of the PADCS to operations; detection of lower alum demands may allow faster operational response (decrease in alum dose rate), generating chemical cost savings.

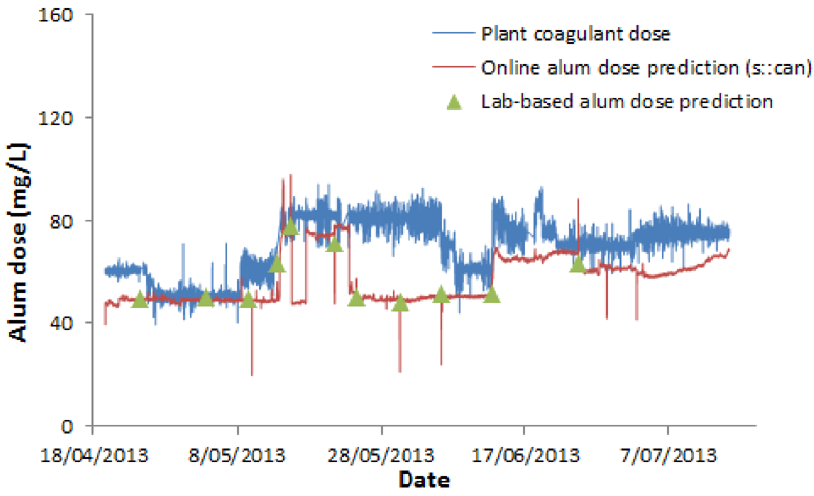


Figure 3: ***Online alum dose prediction at IS2***

2.4 Development of Quality Control Procedures

A sensitivity analysis was performed on the alum dose prediction inputs (i.e. UV_{254}, colour and turbidity), so that quality control procedures for the PADCS could be developed. UV_{254} was found to be the key parameter controlling accuracy of the online alum dose prediction (referenced against predictions based on grab samples). It was found that to generate an online alum dose prediction within 5 mg/L offline laboratory sample prediction, UV_{254} needed to be +/-10% of the laboratory value. Comparatively, colour and turbidity were of much lower importance controlling the predictive alum output, with variations up to 30% of these parameters allowed before the alum dose prediction was significantly affected (>5mg/L difference) (Figure 4).

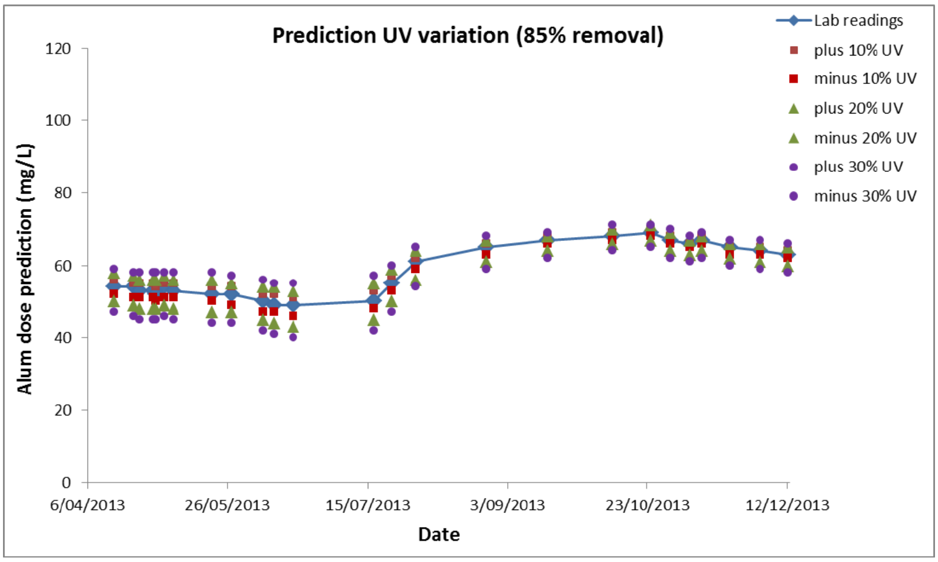


Figure 4: ***Example of predicted alum dose against simulated UV_{254} variation.***

3.0 CONCLUSION

This work demonstrated that implementation of PADCS may significantly improve optimisation of the coagulant dosing step at conventional water treatment plants. In particular, where decreases in coagulant demand are detected, there is potential for chemical cost savings through utilisation of the online data and allowing the plant operator to manage a short term water quality changes.

4.0 ACKNOWLEDGEMENTS

This work was supported by the South Australia Water as part of a capital project. The authors would like to thank Chas Allen, Project Manager, for his effort and support of this work. Also thanks DCM Process Control for providing support to develop the solid compensation algorithm.

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