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Predictive control of ferrous chloride dosing to minimise corrosion & odour in Bellambi system

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Summary of key findings

This paper presents a ferrous chloride dosing control algorithm to achieve optimal corrosion and odour control in sewer networks. The trial at Bellambi successfully demonstrated the benefits of predictive feed-forward control, including the ARMA model for predicting the wastewater flow rate. Predictive ferrous chloride dosing control not only improved the efficiency of the dosing, it also improved the effectiveness by being adaptive to actual flow rates. The result was a tighter control on total dissolved sulphide (TDS) with reduced chemical usage.

Introduction

The Sewer Corrosion and Odour Research (SCORe) program is a five-year, $20 million major initiative funded by the Australian Research Council (ARC) and many Australian water utilities along with partners from overseas. The program aimed to improve the management of corrosion and odour in wastewater systems. A sub project of this program, SP5, focused on the automatically controlled dosing of chemicals into sewers for corrosion and odour control. The University of Queensland research team as the research partner of SP5 delivered this study in collaboration with Sydney Water, an industry partner of the SCORe project.

Ferrous Chloride is one chemical that has been used effectively in controlling odour and corrosion (Zhang et al 2010). Presently Sydney Water uses approximately 20,000 tonnes per year of ferrous chloride to remove hydrogen sulphides in wastewater during its transport to wastewater treatment plants. The chemistry of this reaction is complex, but is most commonly simplified to the equation:

$$Fe^{2+}_{(aq)} + S^{2-}_{(aq)} \leftrightarrow FeS_{(s)}$$

There are many forms of iron sulphide, of which pyrite, pyrrhotite and marcasite may be the end products. These forms of iron sulphide have different stoichiometry of iron to sulphide. When aiming at lower total dissolved sulphide (TDS) levels, higher ratios need to be applied (WERF 2007).

The SCORe project had developed a sulphide model, called the SeweX model (Sharma et al. 2008), which can be used to relate hydraulic retention time (HRT) to the level of sulphide generated in a wastewater rising main (RM). The model predicts sulphide production in sewer as a function of wastewater composition and flow rates, and also accounts for the precipitation of sulphide by ferrous chloride.

This project was to develop a ferrous chloride dosing control algorithm to achieve optimal corrosion and odour control. The stages in the project were: (1) develop a dosing control algorithm; (2) identify a site where the control algorithm could be tested; (3) apply the dosing control and verify the effectiveness of that control.

Methodology

Current practice for ferrous chloride dosing is to characterise the wastewater flow pattern and then determine the appropriate flow-paced dosing rate. The difficulty in optimising the dosing rate is that the ferrous chloride must target the ultimate sulphide generated in the rising main, and the sulphide generation is dependent on the HRT, among other factors, which in turn is dependent on the wastewater flow rate. It was determined that the accurate prediction of the HRT was the single most important factor for the automatic control of ferrous chloride dosing for sulphide control.

The HRT of a wastewater slug leaving a pumping station in the downstream pipes is determined by future rather than the current wastewater flows, as the wastewater slug under consideration is driven through the pipes by future wastewater slugs. To achieve this prediction of HRT and consequently determine the chemical dosing rate, an Auto Regressive Moving Average (ARMA) algorithm was applied to predict the future flow rate based on the current and past flow rates. The prediction of flow must cover the whole HRT of the system. This was achieved by using an iterative multistep prediction approach in which, historical and current flow rates are used as the starting point for the first step prediction, and the estimated values are used as an input for subsequent iterative prediction steps. The prediction stops when the algorithm attains the specified prediction time. For this study, it was determined that a 15 minute step size would give sufficient accuracy in predicted flow without tying down computing capacity. Consequently, 4 steps would be necessary for 1 hour ahead prediction. Under non-limiting substrate conditions, there is a linear relationship between the HRT of the wastewater in the pipe and the amount of sulphide produced. In this respect, sulphide concentration can be estimated through the HRT, which can be calculated based on the ARMA-predicted future flow.

The Bellambi rising main is over 9 km long with a HRT of 3 to 8 hours for average dry weather flow. The wet well of the Bellambi pumping station is at a stormwater flow treatment plant and the discharge is at the Wollongong Wastewater Recycling Plant (WRP). Ferrous chloride is used at the Bellambi pumping station to control sulphide and the existing dosing control uses an hourly-adjusted pre-set flow pattern (Nguyen et al 2009). The sulphide generation rate was well investigated for the rising main and so it was the site chosen to trial the control algorithm.

Background monitoring was conducted in September 2011 to characterise the sewage, sulphide generation rate and effectiveness of the existing dosing strategy. The key parameters for monitoring were time series TDS, pH and Temperature. Grab sampling was also done for the offline measurement of the TDS (to confirm the online measured time series TDS), and the dissolved iron to characterise the extent of over dosing, if any. The feed-forward control algorithm based on the ARMA model was then converted into PLC code and uploaded into the Supervisory Control and Data Acquisition (SCADA) and the monitoring repeated in September 2013.

Results and findings

The major change brought about by the change in dosing control was the increased sensitivity, in that the dosing rate was adjusted every 15 minutes, through the use of the feed-forward control algorithm, instead of being fixed for an hour with the use of pre-set dosing rates. The next benefit was that the dosing was able to respond to increased flow rates in the rising main, which result in shorter HRT and consequently lower TDS generation and lower dosage requirement. Likewise, reduced flows, that result in higher HRT and increased dosing requirement were also responded to on a 15 minute basis, reducing the variation in resultant TDS, and this reduced variability improved the resultant TDS. As an example, Figure 1 shows the comparison of the dosing rate of the profiled dose and feed-forward control dose.

Table 1 summarises the results of the trial in a comparative table. In effect, the feed-forward controlled dosing resulted in much more closely controlled TDS, whilst achieving a reduction in dosage of approximately 25%.

Another finding was that the pH was not significantly reduced. Although the pH results tabled are all within the error band, it stands to reason that when less acidic chemical is used (ferrous chloride is acidic), then pH is less likely to be repressed. Previous research has demonstrated that ferrous sulphide precipitation is more effective at higher pH level. Also, less of the dissolved sulphide is in the most volatile H_2S form at higher pH, leading to reduced transfer of sulphides to the gas phase.

Conclusion

The Predictive Ferrous Chloride Dosing Trial at Bellambi successfully demonstrated the benefits of predictive feed-forward control, including the ARMA model for predicting the wastewater flow rate. Predictive ferrous chloride dosing control not only improved the efficiency of the dosing, it also improved the effectiveness by being adaptive to actual flow rates. The result was a tighter control on TDS with reduced chemical usage.

The effectiveness of iron salts in capturing sulphides through precipitation is known to be very sensitive to pH, and the addition of iron salts generally suppresses pH, which reduces the effectiveness of the dosing. For this reason there is a limitation to the effectiveness of over dosing iron salts, and a considerable benefit in targeted dosing.

Table 1 Summary of experimental findings

Parameters	No-dosing*	Profiled dosing	Feed-forward dosing
Sewage flow (L/sec)	292 ± 30	244 ± 25	240 ± 25
pH	7.4 ± 0.2	7.3 ± 0.2	7.4 ± 0.2
Average TDS (mgS/L)	1.65	0.13	0.07
90% TDS (mgS/L)	3.08	0.46	0.23
Iron dosage (L/day)	0	433	318

*Data from previous study (Nguyen et al. 2009).

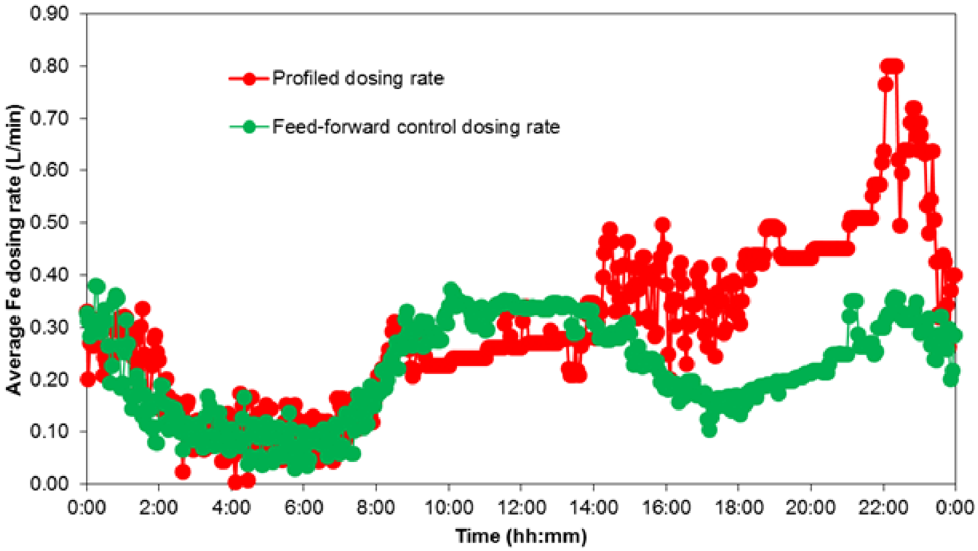

Figure 1 Comparison of the dosing rates: Flow Profile dosing vs. Feed Forward dosing

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Bio: José González is a Technical Specialist at Sydney Water. He has been involved with developing and implementing Sydney Water's Corrosion and Odour Strategy since 2007 and participated in Sydney Water's contribution to the ARC SCORe project.