Control of Sulphides in Sewers & Wastewater Treatment Plants via Groundwater Treatment Plant Coagulant & Sludge

Noah Cahill

Brendan Graham, Einar Fridjonsson
Chemical Engineering
The University of Western Australia

Peter Spencer
CEED Client: Water Corporation

Abstract

Sewer networks and wastewater treatment plants (WWTP) are under threat from the elevated presence of sulphides within wastewater, which enhance the issues of sulphide induced concrete corrosion and odour control. Current strategies for sulphide control are expensive due to the requirement for continuous chemical dosing and thus, identifying an alternative low-cost method is essential. This paper presents an investigation into the feasibility of reducing sulphide levels within wastewater by switching to an alternative non sulphate-based coagulant and by dosing iron-rich drinking water sludge (DWS) within the sewer network. Through conducting a mass balance and modelling within SeweX, it is estimated that dosing the available DWS within the sewer network will reduce the concentration of H_2S *by 19%. Additionally, it is revealed that switching to a non sulphate-based coagulant will not influence sulphide generation within the sewer network. Cost savings on chemical consumption of up to $380,000 per year may be realised by switching coagulant to polyaluminium chloride at the groundwater treatment plants (GWTP), with future works required to determine the optimal dosage and cost savings at scale.*

1. Introduction

The elevated presence of sulphides within wastewater creates a major problem in sewer networks and wastewater treatment plants (WWTPs) through the generation of hydrogen sulphide gas and sulphide induced concrete corrosion. Sulphides are produced via the reduction of sulphate under anaerobic conditions and at Water Corporation, elevated sulphide levels are hypothesised to be in part attributed to the use of alum ($Al_2(SO_4)_3{\cdot}14H_2O$) at the groundwater treatment plants (GWTPs) (Apgar et al., 2007). In addition to significant corrosion mitigation and sewer rehabilitation costs, the elevated presence of sulphides within wastewater leads to increased operating expenditures associated with increased chemical consumption in odour control scrubbers and biogas scrubbers utilised for energy recovery.

Current practices used to control sewer corrosion and odour problems utilise chemical dosing to control sulphide generation via precipitation or oxidation. Dosing iron salts effectively controls dissolved sulphides through forming highly insoluble precipitates, whilst the addition of oxygen, which Water Corporation has previously utilized is extensively used to prevent anaerobic conditions from prevailing (Oviedo et al., 2012; Water Corporation, 2014).

For effective sulphide control continuous dosing is required, which incurs high operational costs and thus, seeking a low cost alternative is imperitive (Shrestha et al., 2020). In this context, Water Corporation is investigating the potential to reduce sulphide levels by using an alternative coagulant at the GWTPs and by repurposing the produced, iron-rich drinking water sludge (DWS) within the sewer network. Switching to an alternative, non sulphate-based coagulant such as poly aluminium chlorohydrate (PAC) at the GWTPs has the potential to reduce the sulphate levels within the wastewater by 60%, whilst utilizing the iron-rich sludge will promote both a circular management approach to coagulant usage and the precipitation of metal sulphides within the sewer network (Pikaar et al., 2013; Sun et al., 2015). The objective of this project is to assess the practicality and economic feasibility of these potential solutions and provide a recommendation on whether they should be pursued in the future.

2. Process

The research project has been broken down into 4 stages as shown in Table 1.

Stage	Description	Alternative Coagulant	Iron Sludge
1	Sulphate mass balance to quantify sulphate reduction in wastewater when using an alternative coagulant.	✓	
2	SeweX modelling to quantify the associated reduction in sulphide from the new sulphate levels.	✓	
3	Drinking water sludge mass balance to determine sulphide reduction in wastewater via precipitation with iron.		✓
4	Cost benefit analysis to assess the economic feasibility.	✓	✓

Table 1 Summary of the 4 major tasks and the solution each stage applies to.

2.1 Stage 1: Sulphate Mass Balance of End-to-End Process

Under the current operating conditions, a sulphate mass balance has been completed across the end-to-end process, shown in Figure 1. Using real flow data and the average sulphate concentration at each sampling point, the contribution of alum and the source water to the sulphate levels within the wastewater can be estimated. Using these contributions, a simple mass balance has estimated the contribution of the catchment, which will enable an approximation of the sulphate levels entering the WWTP, under the scenario where a non-sulphate based coagulant is utilised at the GWTPs.

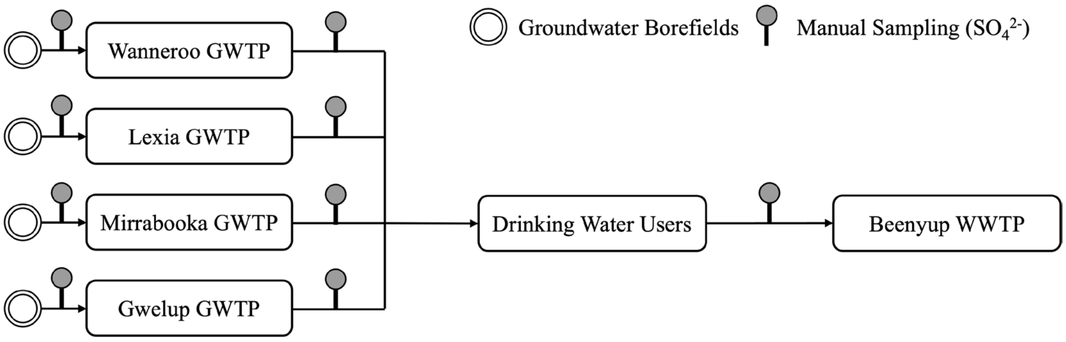

Figure 1 The end-to-end sulphate mass balance, revealing the locations of manual sampling points used to obtain sulphate concentrations (mg/L).

2.2 Stage 2: SeweX Modelling to Quantify Associated Sulphide Reduction

With the new sulphate levels determined from Stage 1, the SeweX model has been utilised to quantify the potential reduction in sulphides that may result from using a non sulphate-based coagulant at the GWTPs. The inputs to the SeweX model have been developed using real data provided by Water Corporation, with an illustration of the SeweX model available in Figure 2.

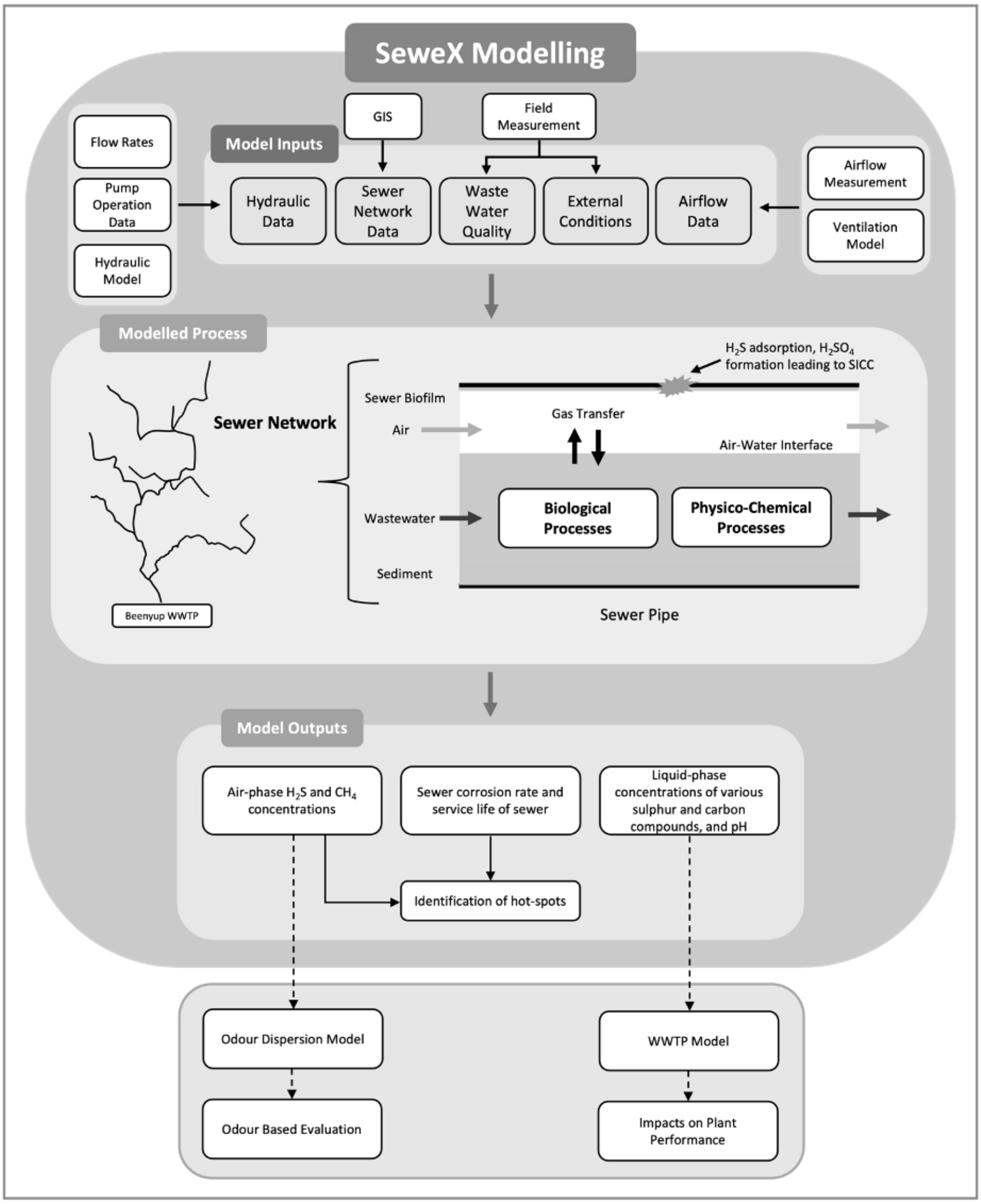

Figure 2 Overview of the SeweX modelling framework (Sharma et al., 2015).

2.3 Stage 3: Drinking Water Sludge Mass Balance

To conduct this mass balance, the mass of sludge produced from each GWTP, and its average iron content is required, along with the average dissolved sulphide concentration within the wastewater, which has been obtained from SeweX. Additionally, the efficacy of iron to precipitate sulphides out of solution is required, which will be inferred via a literature review. Using these values, the degree of sulphide precipitation that will occur through dosing the DWS within the sewer network can be estimated.

2.4 Stage 4: Cost Benefit Analysis

The change in operating expenditure and the cost savings that may be realised through the implementation of both solutions must be estimated. For the alternative coagulant method, the dosage required to provide an equivalent coagulation performance to alum must be identified. Using these dosages and the chemical costs, the change in operating costs can be estimated. For the DWS method, the change in operating costs associated with disposal and additional pumping must also be estimated. The areas in which Water Corporation has the potential to realise financial benefits through these solutions are available in Table 2.

Potential Saving	Methodology
Concrete Corrosion	Estimate the average rate of concrete corrosion at the reduced sulphide levels using literature and SeweX. Quantify the increase in asset lifetime and the associated cost savings using Water Corporation Data.
Chemical Dosage	Quantify the reduction in lime (GWTP), caustic soda and sodium hypochlorite (WWTP) dosages based off the new conditions.
Maintenance Frequency	Estimate the maintenance frequency required for the reduced sulphide levels, based on the current frequency.

Table 2 Areas for potential cost savings through reducing sulphide levels and the methodology for quantifying them.

3. Results and Discussion

3.1 Alternative Coagulant Method

Under current operating conditions (baseline case), the average sulphate concentration entering the WWTP is 77 mg/L. Approximately 22% of this sulphate is attributed to the use of alum at the GWTPs and thus, the concentration of sulphate within the wastewater is estimated as 60 ± 3 mg/L, should an alternative coagulant be used. In comparing the SeweX results for the generation of hydrogen sulphide gas within the sewer network from the two cases in Figure 3, it is evident that the change in sulphate concentration has a negligible impact on sulphide generation. This result is consistent with available literature as above a concentration of 5 to 15 mg/L, sulphate becomes a non-limiting substrate for sulphide generation (Apgar et al., 2007).

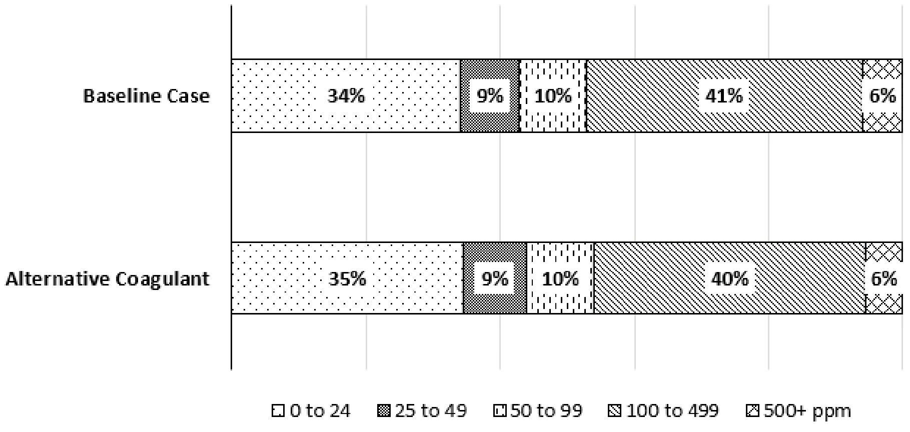

Figure 3 Percentage of sewer network exposed to hydrogen sulphide gas concentrations under baseline (77 mg/L) and alt. coagulant (60 mg/L).

Although using an alternative coagulant will not reduce the generation of sulphides within the network, it will potentially provide Water Corporation with significant savings on chemical consumption. Figure 4 below illustrates the potential savings that could be realized through using polyaluminium chloride (PAC), aluminium chlorohydrate (ACH) and ferric chloride, based off optimal dosages obtained from jar testing in 2021. The results indicate that both ACH and PAC could provide potential savings on chemical consumption, with PAC providing savings of up to $380,000 per year. As alum is a relatively cheap coagulant with a price of 0.22 $/kg, only minor savings on coagulant consumption are possible with PAC. The majority of the potential savings are attributed to the reduced consumption of lime (CaO) utilized for pH correction, as smaller dosages are required when used in conjunction with ACH or PAC. This is due to their higher pH of 4.5, compared to alum which has a pH of approximately 2.

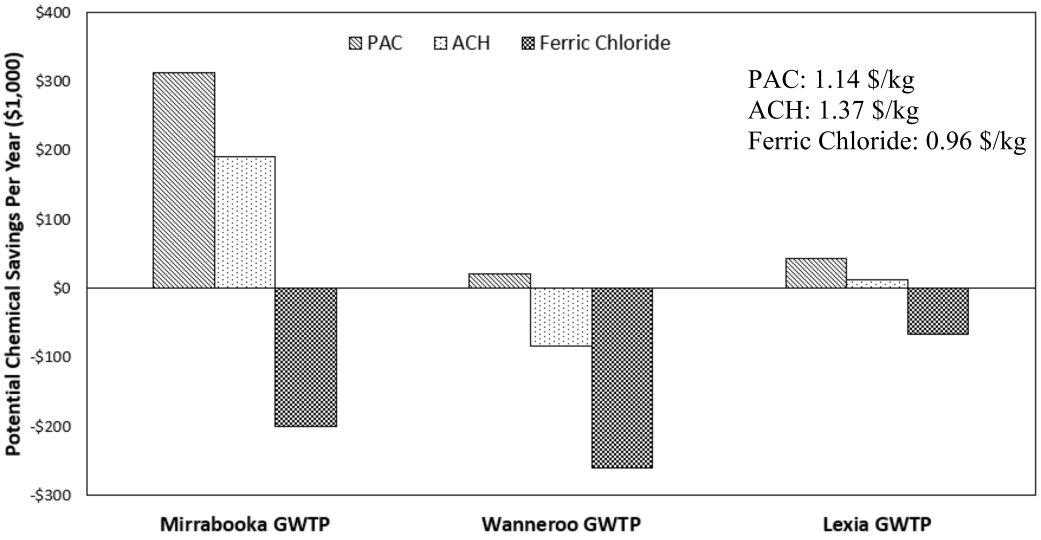

Figure 4 Potential cost savings from utilizing an alternative coagulant to alum at three GWTPs.

3.2 Drinking Water Sludge Method

Between the Gwelup and Mirrabooka GWTPs, approximately 2,800 tonnes of DWS with an iron content ranging from 129 to 475 g/kg is produced each year. Using this information and the average concentration of dissolved sulphides within the sewer network of 3.26 mg/L from SeweX, it is estimated that 20.7% of the sulphide will precipitate with the available iron. This has been estimated using an iron to sulphide molar ratio (Fe:S) of 0.5 obtained from literature and assumes that only 20% of the sewer network will be exposed to the iron sludge (Shrestha et al., 2020; Sun et al., 2015). The associated reduction in hydrogen sulphide gas is approximately 19%, with the results of the mass balance available in Table 3.

Parameter	Baseline Case	Iron Sludge Case	Reduction
Dissolved Sulphide (mg/L)	3.26	2.59	20.7%
Hydrogen Sulphide (ppm)	327	265	19.0%

Table 3 Reduction of the average dissolved sulphide and hydrogen sulphide gas concentration within the sewer network when iron sludge is dosed.

Intermittent dosing of iron sludge does not have a long lasting inhibitory effect on the sulphate reducing bacteria within the sewer biofilm, thus continuous dosing will be required for effective control. For practical purposes, the iron sludge will be dosed to the network in the form of a slurry via the backwash recovery streams at both the Gwelup and Mirrabooka GWTPs.

4. Conclusions and Future Work

The results from the alternative coagulant method reveal that utilising a non sulphate-based coagulant will not influence the generation of sulphides within the sewer network, as sulphate is not a non-limiting substrate at the concentrations present. Switching to PAC however, has the potential to provide savings on chemical consumption at the GWTPs of up to $380,000 per year due to the reduction in lime consumption required for pH correction. Future works will consist of conducting a plant trial with PAC to further determine the optimal dosage and assess the cost savings at scale.

It is estimated that dosing the iron-rich DWS within the sewer network will result in a reduction of the dissolved sulphide and hydrogen sulphide gas concentrations by 21% and 19% respectively. Further work required consists of finalizing the cost benefit analysis for this method, which includes quantifying the changes in operating costs and the potential savings this reduction may incur.

5. Acknowledgements

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6. References

Apgar, D., Witherspoon, J., Easter, C., Bassrai, S., Dillon, C., Torres, E., Corsi, R., Forbes, B., Quigley, C., Ward, M., Morton, R., Weiss, J., Bowker, R., Davidson, S., Wolstenholme, P., Joyce, J., & Stuetz, R. (2007). *Minimization of Odours and Corrosion in Collection Systems Phase 1*. I. Publishing.

Oviedo, E. R., Johnson, D., & Shipley, H. (2012). Evaluation of hydrogen sulphide concentration and control in a sewer system. *Environmental technology*, *33*(10), 1207-1215. https://doi.org/10.1080/09593330.2011.618932

Pikaar, I., Sharma, K., Hu, S., Gernjak, W., Keller, J., & Yuan, Z. (2013). *Sewer Corrosion: How Avoidable is This Billion Dollar Problem*

Sharma, K., Jiang, G., Ganigue, R., Cesca, J., Yuan, Z., & Vuong, L. (2015). Sewex modelling to support corrosion and odour management in sewers. *Water (Melbourne)*, *42*(7), 71-78.

Shrestha, S., Kulandaivelu, J., Sharma, K., Jiang, G., & Yuan, Z. (2020). Effects of dosing iron- and alum-containing waterworks sludge on sulfide and phosphate removal in a pilot sewer. *Chemical engineering journal (Lausanne, Switzerland : 1996)*, *387*, 124073. https://doi.org/10.1016/j.cej.2020.124073

Sun, J., Pikaar, I., Sharma, K. R., Keller, J., & Yuan, Z. (2015). Feasibility of sulfide control in sewers by reuse of iron rich drinking water treatment sludge. *Water research (Oxford)*, *71*, 150-159. https://doi.org/10.1016/j.watres.2014.12.044

Water Corporation. (2014). *Effectiveness and Benefit of Oxygen Dissolvers in the Water Corporations Wastewater Collection System.*