1. Control algorithm for dosing oxygen in sewers

1.1 Background

Oxygen is one of the most used chemicals for the control of sulfide production. Oxygen relies on sulfide oxidation, both chemical and biological, as the mechanism for H_2S control.

Further information can be obtained as follows:

- Effects of oxygen dosing:
  - **Paper:** *Gutierrez, O., Mohanakrishnan, J., Sharma, K.R., Meyer, R.L., Keller, J. and Yuan, Z. (2008) Evaluation of oxygen injection as a means of controlling sulfide production in a sewer system. Water Research 42(17), 4549-4561.*

1.2 Control Strategy

1.2.1 Dosing Location

A suitable location for oxygen dosing (x) can be theoretically determined from Equation 1.

$$x = \frac{\pi \cdot D \cdot L \cdot (4r_{B,ox} + r_{C,ox} \cdot D) - 4(TDS_0 - TDS_f) \cdot Q_L}{\pi \cdot D \cdot (4r_B + 4r_{B,ox} + r_{C,ox} \cdot D)} \qquad (1)$$

Where D is the pipe diameter (m), L is the pipe length (m), r_B the sulfide production rate of the biofilm (gS/m^2▪d), $r_{B,ox}$ the biological sulfide oxidation rate of the biofilm (gS/m^2▪d), $r_{C,ox}$ the volumetric chemical sulfide oxidation rate (gS/m^2▪d), TDS_0 the total dissolved sulfide at the beginning of the rising main (g/m^3), TDS_f the total dissolved sulfide at the end of the rising main (g/m^3) and Q_L is the sewage flow (m^3/d).

1.2.2 Dosing rate

Assuming an oxygen dosing station located in a downstream section, close to the rising main discharge point, oxygen dosage for an optimised dosing depend on two factors:

- The amount of sulfide produced upstream that needs to be oxidised

- The oxygen that will be consumed by heterotrophic bacteria during the transport time between the dosing location and the discharge/control point.

1.2.2.1 Sulfide produced upstream

Sulfide concentration at the dosing location can be measured using a S::CAN UV/VIS spectrometer. If online measurement is unavailable, typical sulfide profiles can be estimated based on HRT as illustrated in Figure 1.

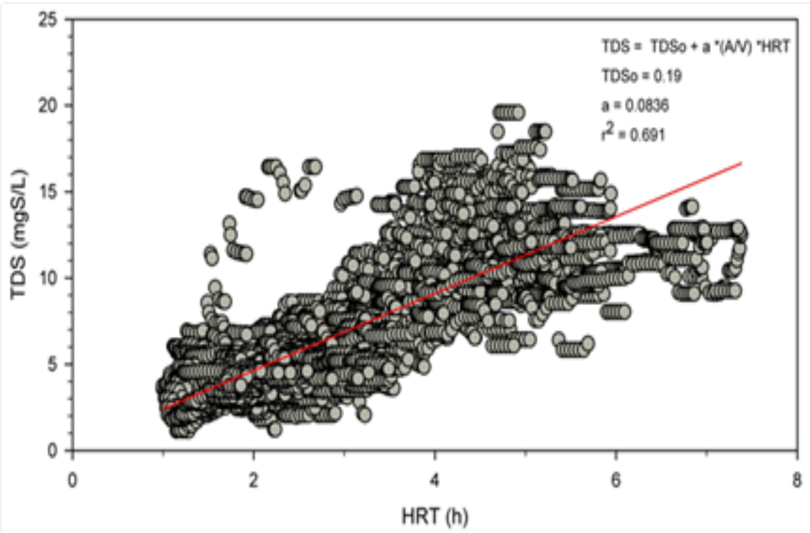

Figure 1. Total dissolved sulfide vs. hydraulic retention time.

The amount of oxygen required for sulfide oxidation to sulfite is 1.5 $gO_2/gS\text{-}S^2$, whereas 2 $gO_2/gS\text{-}S^2$ are required to convert sulfide to sulfate according to equation 2 and 3.

$$2.S^{2-} + \frac{3}{2}O_2 \rightarrow SO_3^{2-} \qquad (2)$$

$$SO_3^{2-} + \frac{1}{2}O_2 \rightarrow SO_4^{2-} \qquad (3)$$

1.2.2.2 Heterotrophic oxygen consumption downstream

Oxygen consumption rate by heterotrophic bacteria can be modelled using a Monod kinetic according to the following equation:

$$\frac{d(S_{O_2})}{dt} = -r_{area} \cdot \frac{A}{V} = -r_{area,\max} \cdot \frac{A}{V} \cdot \frac{S_{O_2}}{K_{O_2} + S_{O_2}} \qquad (3)$$

Where r_{area} is heterotrophic oxygen consumption rate of the biofilm (mg N/L); $r_{area,max}$ is the maximum oxygen consumption rate of the biofilm; S_{O_2} is the oxygen concentration in the boundary layer of biofilm (mg N/L) and K_{O_2} is the half-saturation substrate limitation constant for oxygen in the biofilm.

For a given pipe diameter and retention time, the amount of oxygen to be dosed to reach the desired concentration at the discharge point can be estimated by equation 3 using a Newton iteration method.

Due to the intermittent operation pattern of sewer pumping stations, the effects of quiescent periods on oxygen consumption rate is also taken into consideration (Figure 2).

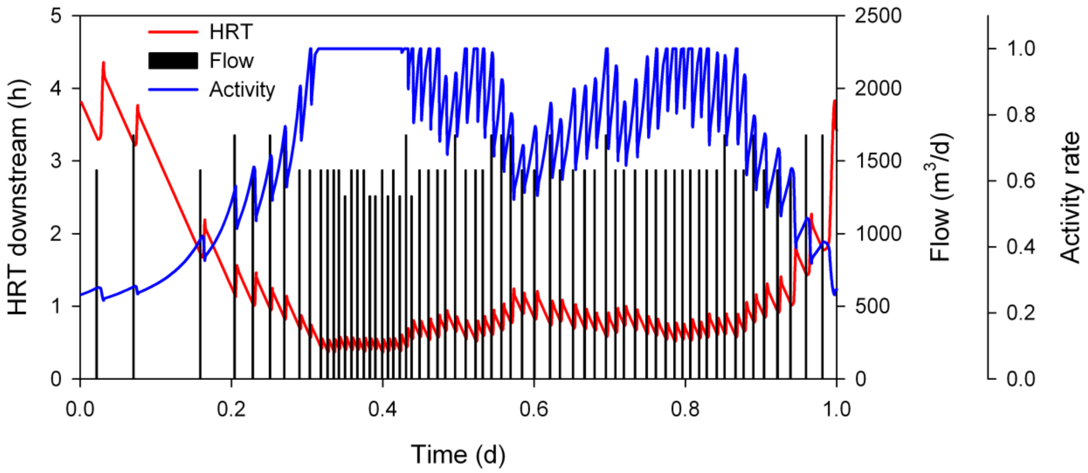

Figure 2. Pumping profile, HRT downstream and activity corrected by quiescent conditions.

1.2.2.3 Future flow prediction

The heterotrophic oxygen consumption depends on the time the wastewater will be spend in the last section of the pipe. This can be estimated using typical HRT profiles (simple). Otherwise, future flow can be predicted based on ARMA models.

1.2.2.4 Feedback Loop

A feedback loop could be implemented to adjust the dosing based on weekly average of dissolved oxygen concentration at the discharge point. This would require additional instrumentation to measure dissolved oxygen online.

1.2.3 Control scheme

The control algorithm for the optimised dosing of oxygen is composed of a feedforward and a feedback loop. The feedforward loop will predict the amount of oxygen required to oxidise sulfide produced upstream the dosing location and ensure aerobic conditions of sewage until its discharge. In addition, the feedback loop can adjust the dosing based on the overall performance. A scheme of the control algorithm is depicted in Figure 3.

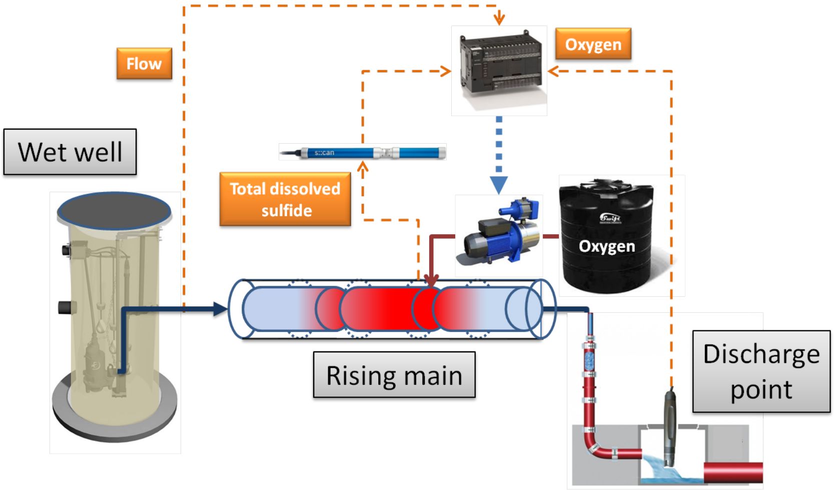

Figure 3. Control algorithm scheme for oxygen dosing.

1.3 Case studies

Oxygen dosing in the Cowie Creek sewer system (Barwon water) in Geelong, Australia