Solving Sewerage Odour Problems
The Noosa Experience

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1. SUMMARY

Noosa's economy relies on its multimillion dollar tourist industry. In the past ten years Noosa Council has expended millions of dollars on works to prevent sewerage overflows into its river, lakes and beaches and to eliminate sewerage odour. Whilst overflows have been virtually eliminated, sewerage odour problems have continued to plague Council….. until now.

Noosa Shire Council currently operates and maintains 110 sewerage pump stations and over 430 km of sewerage main. Persistent hydrogen sulphide or rotten egg gas odour and related concrete corrosion problems have been experienced over many years throughout the sewerage collection network.

Council has previously used or evaluated many different odour and corrosion control methodologies to achieve asset protection and odour control objectives. Methodologies and technologies evaluated include:

- Precipitation of aqueous sulfide as insoluble compounds – Ferric and Ferrous Chloride.
- Oxidising the sulfide to sulfate - Hydrogen Peroxide, Oxygen and Air injection

Other technologies evaluated included:

- Bacteria,
- Enzymes,
- Hot Air Induction
- Odour Masking Chemicals
- Activated carbon filters

Costly pipeline and manhole renovation as a result of hydrogen sulphide related acid corrosion in recent years, together with the construction of a new multi million dollar sewerage project from Sunshine Beach to Peregian prompted Council to explore new strategies that achieve more effective odour and sewer corrosion control.

Noosa Shire Council subsequently commenced an evaluation of magnesium hydroxide liquid (marketed under the tradename name SulfaLock™ by Orica) in September 2002. Council were attracted by the non-hazardous nature of the product compared with previous chemicals used for odour control. However at the time, limited historical performance data was available documenting the performance of the product for sewer collection systems odour and corrosion control. Temporary dosing facilities were commissioned.

The performance of SulfaLock™ was assessed against the following objectives:

- ability to maintain mean and peak $H_2S_{(g)}$ levels below 1 and 4 ppm respectively
- dose rates and treatment costs.

The results obtained during the 18 month evaluation demonstrated that SulfaLock™ achieved Council's odour control objectives. Further, SulfaLock exceeded the performance, in terms of reducing peak and average sulphide levels, of any of the other technology previously used or evaluated and at comparable or lower costs.

Noosa Shire Council have decided to adopt SulfaLock™ for odour control throughout its sewerage collection system. Council are currently proceeding with the construction of permanent facilities at new sites and replacement or modification of existing chemical dosing facilities to facilitate SulfaLock™ use.

Considerable operational experience has been achieved by overcoming problems associated with the storage, dosing and dosing control strategies. The learning obtained during the trial has been captured and used in the design of the new storage and dosing installations.

2. INTRODUCTION

2.1 SULFALOCK™ (MAGNESIUM HYDROXIDE LIQUID)– PRODUCT DESCRIPTION

Magnesium hydroxide, $Mg(OH)_2$, is a relatively slow reacting weak base. At 60 % w/w $Mg(OH)_2$, it is also the active ingredient in Orica's SulfaLock™ product. Its low viscosity, high concentration, stability to settling and non-hazardous classification allow the product to be stored and dosed as a liquid eliminating solids handling and dangerous goods issues.

2.2 ODOUR CONTROL MECHANISM

SulfaLock™ reduces hydrogen sulphide odour via three mechanisms:

- Elevating pH thereby retarding sulphate reducing bacterial activity in the slime layer and thereby reducing the conversion sulphates to sulphides.
- Elevating pH to around 8.5 thereby increasing the solubility of hydrogen sulphide preventing its escape as a gas.
- Forming stable magnesium sulphide complex which lock up dissolved sulphides.

These mechanisms are described in detail below.

2.2.1 REDUCTION IN GENERATION OF HYDROGEN SULPHIDE GAS

The sewage pH has a significant impact on the generation of gaseous hydrogen sulphide. This is due to the varying proportions of H_2S, HS^- and S^{2-} present as dissolved sulphide in the sewage. It is the H_2S species (gaseous hydrogen sulphide) that forms the foul rotten egg gas odour. The proportions of the species are dependent on the sewage pH according to Figure 1.

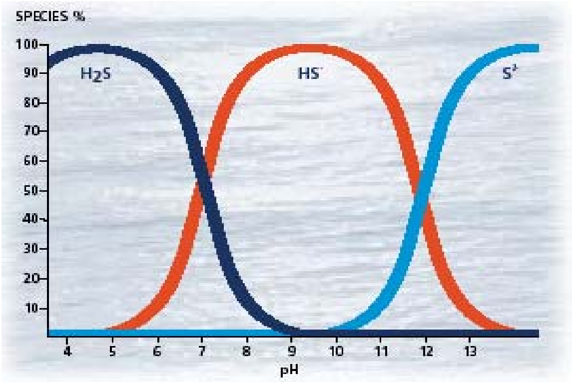


Figure 1: Sulphide speciation chemistry as a function of pH

According to Henry's Law, reducing dissolved H_2S results in a direct decrease in the equilibrium concentration of H_2S in the atmosphere ($H_2S_{(g)}$). At a pH of 7.0, approximately 50% of the sulphides are present as dissolved hydrogen sulphide gas and the other 50% present as the bisulphide ion (HS^-). As wastewater pH is increased, equilibrium shifts rapidly to the right. This dramatically increases the solubility of hydrogen sulphide and the formation of HS^-. The bisulphide ion, unlike hydrogen sulphide, cannot escape from solution to the atmosphere and cause odour problems and asset corrosion.

$$H_2S_{(gas)} \Leftrightarrow H_2S_{(aq)} \Leftrightarrow H^+_{(aq)} + HS^-_{(aq)} \Leftrightarrow H^+_{(aq)} + S^{2-}_{(aq)}$$

$$\text{lower pH} \Leftrightarrow \text{higher pH}$$

At pH 8.0, only around 8% of the sulphides are present as dissolved hydrogen sulphide gas, and at pH 9, hydrogen sulphide levels drop to less than 1% - a significant reduction in the likelihood of hydrogen sulphide gas being released to atmosphere. An adjustment in pH to 8.5 can correspond to a 95% reduction in sulphide odour.

In theory, any alkali can be added to sewage to achieve this. However in a sewer system, highly soluble alkali's are consumed immediately and therefore do not sustain the elevated pH for very long. This is especially true if the treated sewage is subject to re-acidification as a result of high retention times, high BOD content or simply dilution with untreated and lower pH flows within the network. In practice, using highly soluble alkali to achieve a pH of around 8.5 at some distance along a rising main requires an initial pH adjustment to well in excess of pH 9.

Magnesium hydroxide raises pH of sewage via the controlled release of hydroxyl (OH^-) ions:

$$Mg(OH)_2 \Leftrightarrow Mg^{2+} + 2OH^-$$

A useful chemical property of magnesium hydroxide is that the addition of $Mg(OH)_2$ to water cannot result in a pH in excess of pH 9 - 9.5, no matter how much of the material is added. Exceeding pH 9 in sewers is known to cause problems including carbonate precipitation, sludge generation and ammonia gas release. Notably, pH 9 is the upper limit specified in many trade waste discharge agreements and is close to the maximum tolerance of aerobic and anaerobic digester bacteria. This self buffering feature allows a sewer to be loaded with residual or unreacted alkalinity. This residual component is available in the event that re-acidification occur. This makes magnesium hydroxide liquid ideal for use in applications subject to extreme pH depression, ie industrial areas where sewer systems receive high BOD loadings and in those systems with extended detention times. It can also allow long reaches of sewer to be treated using a single dose point. This can be important in systems where only a single dose point is possible for reasons such as limited access to the sewer or aesthetics. Further, minimising dose points can avoid the costs associated with the maintenance and operation of numerous chemical dosing installations.

2.2.2 RETARDING SULPHATE REDUCING BACTERIAL ACTIVITY

The second mechanism by which SulfaLock™ reduces hydrogen sulphide gas is its direct impact on the biofilm or slime layer present is sewers. Raising wastewater pH retards sulphate reducing bacterial (SRB) activity in the slime layer. SRB present in the slime layer are responsible for reduction of sulphate to sulphide. The optimal pH range for SRB has been reported to be near pH 6.6 – 7.5 (*The Bergey's Manual of Determinative Bacteriology, 1993*). SulfaLock produces a pH environment that is sub-optimal for SRB, thus decreasing populations and sulphide generating ability. Consequently, continuous addition of SulfaLock to wastewater results in less sulphate reduction and therefore significantly reduced odours.

2.2.3 LOCKING UP DISSOLVED SULPHIDES

The magnesium ion (Mg^{2+}) that generated from the dissociation of magnesium hydroxide in solution, is also known to associate or bind with dissolved sulphides. The magnesium is cationic and reacts directly with sulphides. This results in the formation of species that do not readily dissociate to hydrogen sulphide in the absence of strongly acidic conditions.

2.2.4 TREATMENT PLANT CONSIDERATIONS

The increased alkalinity and buffering capacity provided by magnesium hydroxide can help to avoid low pH excursions within in the treatment plant, leading to improved control of the pH in the treatment process and nitrification.

Higher pH wastewater can reduce both odour and the alkali requirement at the treatment plant. It is anticipated that all of the magnesium hydroxide introduced into the collection system for odour control will be have dissolved prior to the WTP.

Importantly, the use of SulfaLock does not contribute sodium to the waste water. This can be important where treated wastewater is directly reused for irrigation or discharged to water bodies which are subsequently used for irrigation.

3. SCOPE OF TRIAL

3.1 TESTING METHODOLOGY

Hydrogen sulphide and pH levels were monitored concurrently at various discharge points within each system. The system and the tests points is shown in Figure 2.

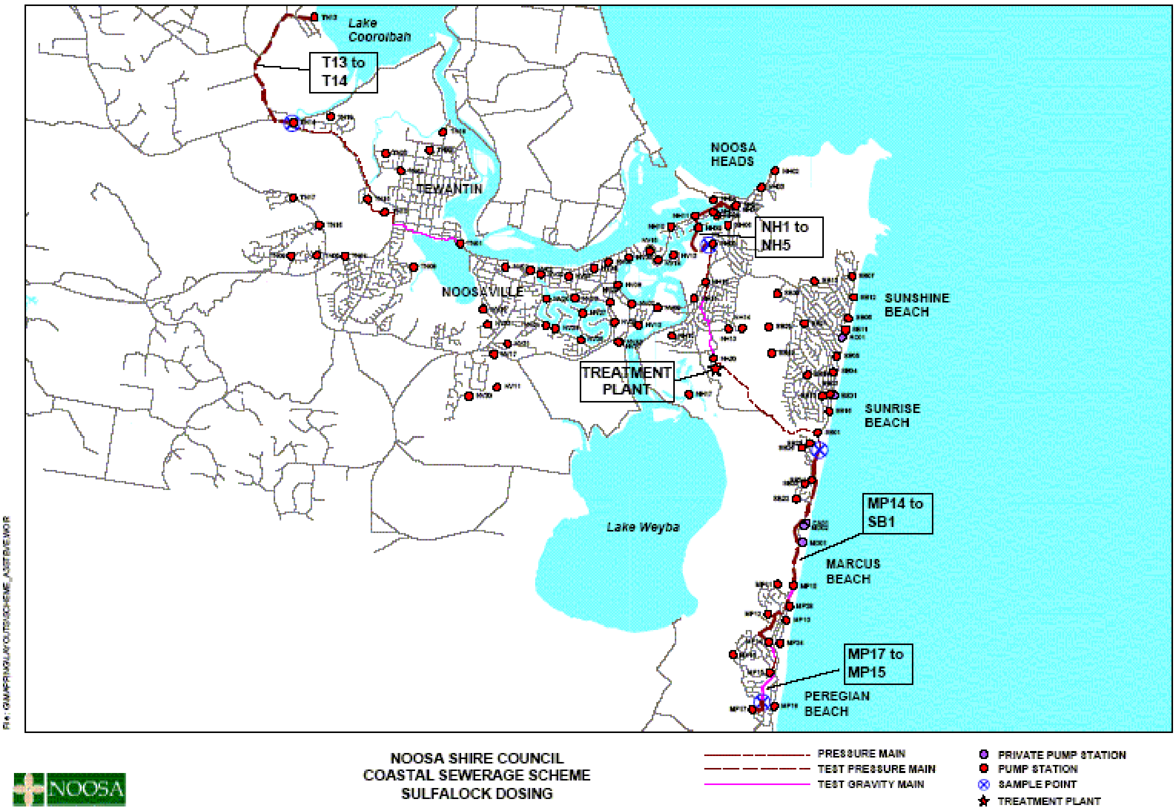


Figure 2. Schematic of the Noosa Shire Council sewer network.

Rising mains treated with SulfaLock™, Hydrogen Sulphide and pH data collection points are shown in Figure 2 above using the following equipment:

- $H_2S_{(g)}$ levels - 'Apptek' infra red data communication link Odaloggers
- A TPS model WP80 pH meter and data logger with an Ionode IJ44 Intermediate Junction pH probe with 10 metre cable was used to measure pH in the downstream pump station wet wells of interest.
- Odalog graphical user interface software for result presentation and analysis.

3.2 DOSING METHOD AND CONTROL STRATEGY

Where applied, SulfaLock™ was dosed at the head pump station and directly into the station wet well. The chemical dose rate used was initially adjusted to maintain a pH above 8.3. pH and $H_2S_{(g)}$ levels were monitored and then optimised.

To ensure accuracy of data, pump station pump cycle volumes and rates were confirmed by volumetric drawdown testing. Average daily system and station flows were then determined by SCADA interrogation and monitored regularly. This data was used to modify magnesium hydroxide dose rate adjustment. SulfaLock™ volume used was recorded daily on site by operations staff and data collated with test results. Dose rates were incrementally increased at minimum weekly duration's until minimum $H_2S_{(g)}$ levels were attained in each system.

4. RESULTS AND DISCUSSION

Following 18 months evaluation of magnesium hydroxide, average and peak hydrogen sulphide gas levels in a number of its sewerage systems are consistently maintained below 1 and 4 ppm. These levels are lower than that achieved using other odour control strategies either trialed or used and at comparable or lower costs. A sample of results obtained are shown in Table 1 and Figures 3, 4, 5 and 6.

Table 1. System details, untreated and treated $H_2S_{(g)}$ concentrations.

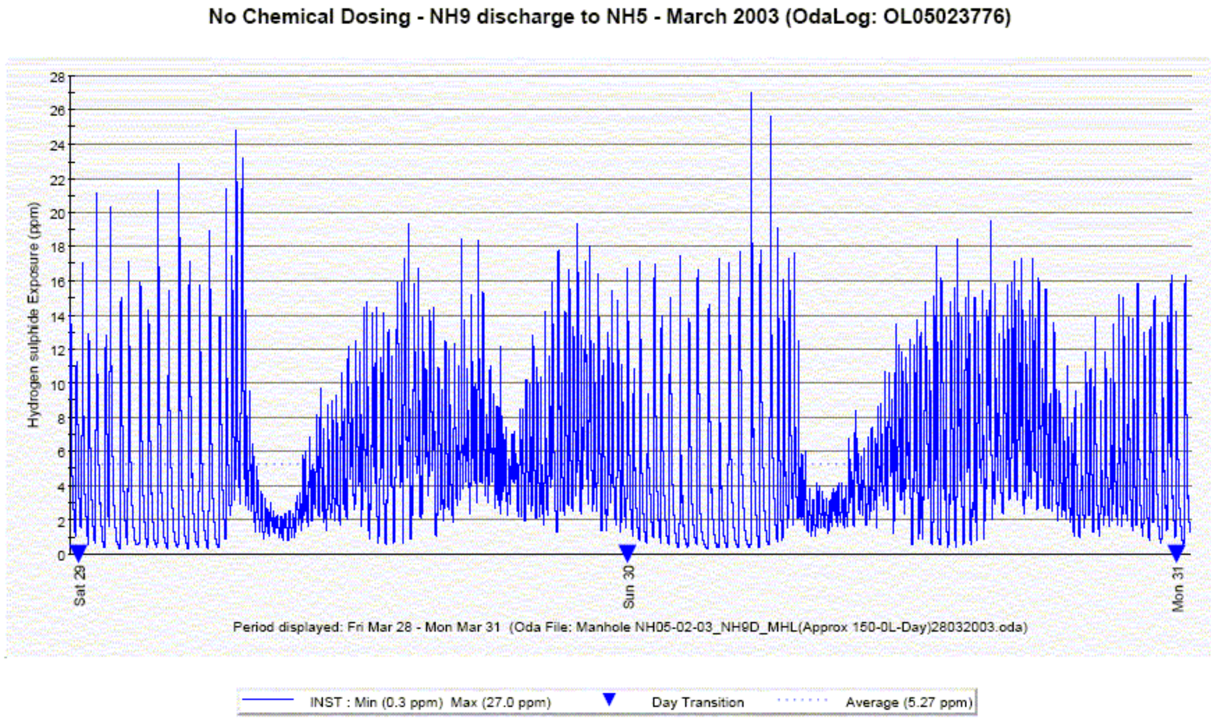
- System - Daily Flow - Detention Time	$H_2S_{(g)}$ Level No Dosing		$H_2S_{(g)}$ Levels SulfaLock™ Dosing		% Reduction Achieved	
	Average	Peak	Average	Peak	Average	Peak
- NH1 to NH5 - 1.1 ML/day - 2.6 hrs	5.3	27.0	0.6	0.9	89	97
- MP14 to SB1 - 0.3 ML/day - 18 hrs	49	193	0.5	2.2	99	99
- T13 to T14 - 0.03 ML/day - 19.2 hrs	42	115	1.2	4.1	97	96
- MP17 to MP15 - 0.03 ML/day - 11.4 hrs	15	228	0.09	0.8	99	99

The NH1 to NH5 rising main carries some 1.1 ML per day and has an average retention time of 2.6 hrs. Without any treatment, $H_2S_{(g)}$ peaks and daily averages of 27 and 5.3 ppm were observed. Treatment of this rising main with SulfaLock™ at a dose rate of 175 L per day elevated pH to an average 8.3 and reduced mean and peak levels by 97 and 89 % respectively. Greater reductions in mean and peak $H_2S_{(g)}$ levels were observed in the MP14 to SB1, MP14 to SB1 and T13 to T14 rising mains.

It was generally found that significant reduction in $H_2S_{(g)}$ levels are achieved by increasing and maintaining sewage pH between pH 8.3 - 8.5.

The above sections of the Noosa sewerage network are sub-sections of longer systems currently treated. At 2.1 ML/day, the total volume of sewage treated using SulfaLock™ constitutes about 20% of the total daily sewage volume.

Based on the results of its trials, Council have decided to adopt SulfaLock™ and replace all of its existing chemical dosing systems for odour control and increase the volume treated to 6ML/day or 60 % of the total volume over the next 2 years. The construction of permanent dosing facilities at new sites and replacement or modification of existing chemical dosing facilities to suit the product is currently under way.



No Chemical - Pump Breakdown

Figure 3. $H_2S_{(g)}$ NH1 to NH5 – No Treatment

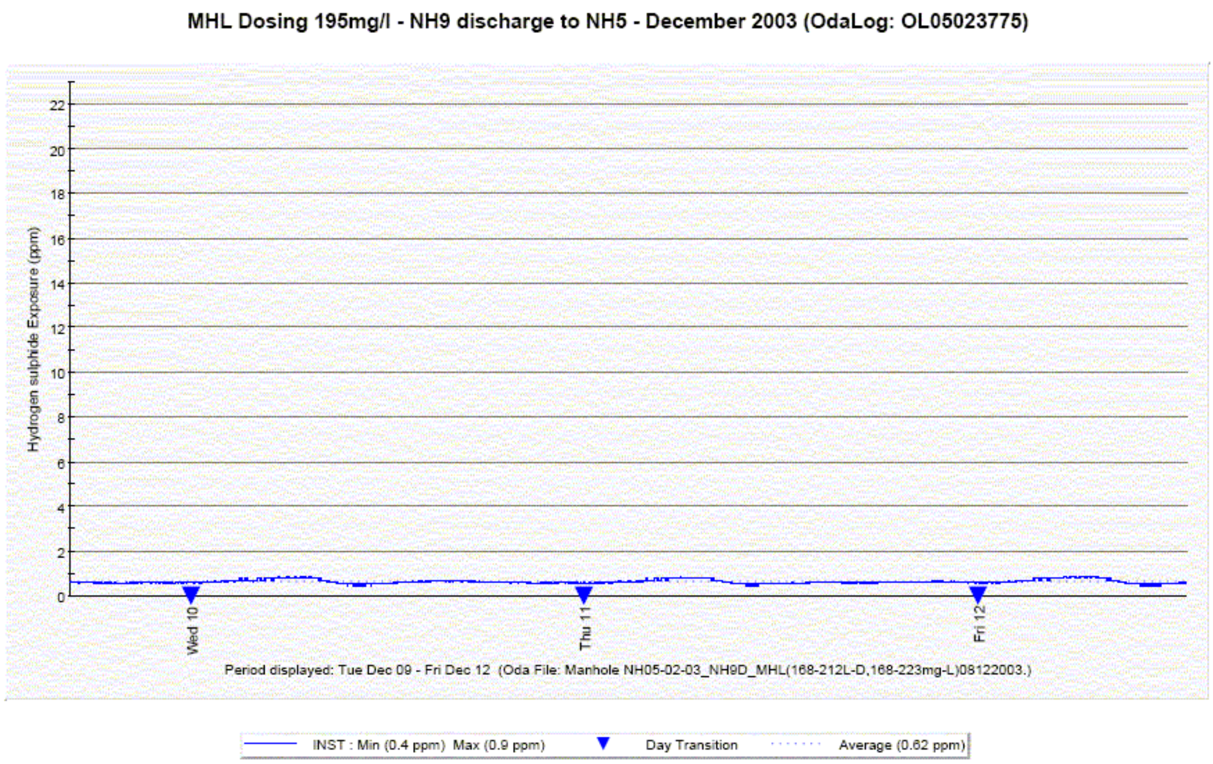


Figure 4 $H_2S_{(g)}$ NH1 to NH5 – Treated with SulfaLock™

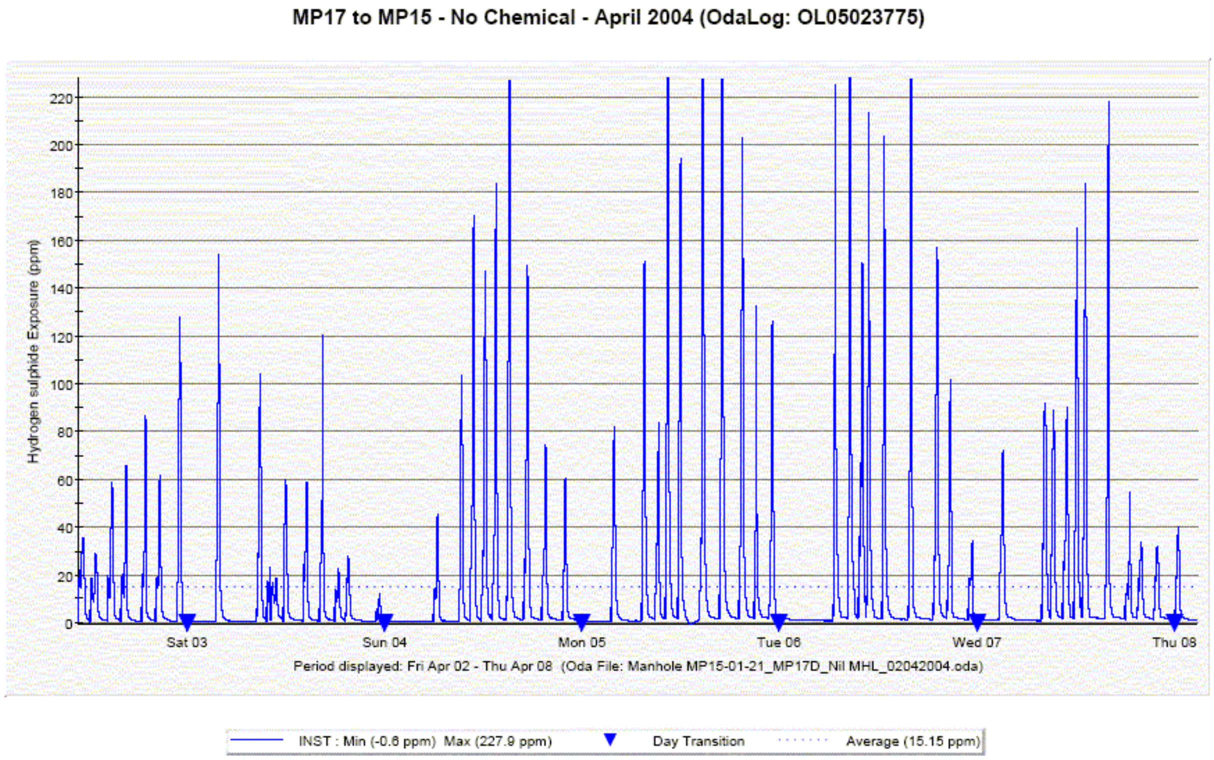


Figure 5. $H_2S_{(g)}$ MP17 to MP15 – No Treatment

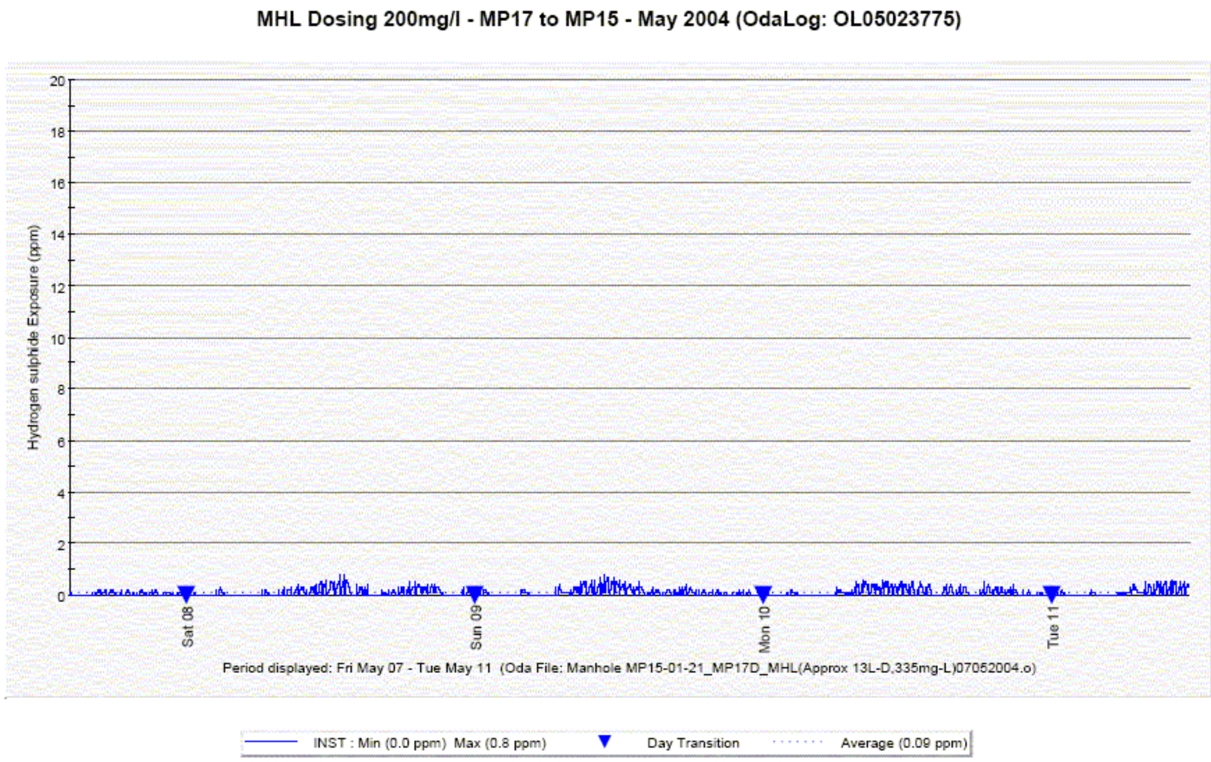


Figure 6. $H_2S_{(g)}$ MP17 to MP15 – Treated with SulfaLock™

5. GENERAL LEARNING

5.1 DOSE RATES

The SulfaLock™ dose rates required to achieve the very high $H_2S_{(g)}$ reduction in excess of 95% were found to vary for different systems. Dose rates were found to depend mainly on detention time of sewage in pressure mains with dose rates increasing with increasing transit time.

Noosa Shire Council have found the dose rate required to achieve odour reductions in the order of 98 % for shorter Rising Mains systems nearing ultimate design capacity to be 126 to 133 L product per million litres sewage (190 to 200 mg/L). Optimum dose rate for longer (5 km plus) pressure mains system where longer detention times are present was found to be 180 L/ML (265 mg/L) of sewage treated.

Higher interim dose rates have been found to be required for satisfactory odour control where daily flows are significantly less than design levels, ie where detention times are abnormally high. This scenario is typically observed upon the commissioning of new systems servicing new housing estate development or backlog housing connection periods.

5.2 CHEMICAL DOSING AND DOSING CONTROL

Dosing magnesium hydroxide into the wet well or station control manhole was found to provide the most consistent mixing of the product with sewage. To maximise mixing time, chemical was dosed into the well at the end of a pump cycle.

Single speed magnesium hydroxide dosing pumps were utilised. Variation in chemical dose rate was achieved by varying the dosing pump run-time. The number of wet well pump cycles was generally set for each system to equal or exceed those occurring at a downstream pump station (by adjusting wet well pump operating levels) ensuring that all downstream sewage was effectively dosed.

Sewerage pump station operation at Noosa is controlled by PLC. SulfaLock dosing pump start and run-time logic has been incorporated into the PLC programs. Additional logic has also been included to increase dose rate at night to allow for diurnal variations in detention time. Variables (ie dosing pump runtime, percentage night increase) are simply modified by Laptop PC access to register values in the PLC programs. This control system is reliable, consistent and easily managed.

5.3 RECOMMENDED Dosing Facility Equipment / Configuration

Council experienced many problems in the early stages of the evaluation period. The main problems were associated with product dosing resulting from the use of pumps unsuited to the product (diaphragm pumps) and the development of appropriate dosing regimes . The following observations and recommendations are based on Noosa Shire Council's experience and may not be the only viable solutions or methods.

5.2.1 DOSING PUMPS

Due to the viscosity, particulate nature and density of SulfaLock, peristaltic pumps were found to provide the most reliable delivery of chemical from on site storage to the wet well. For simplicity and maintenance flexibility, pump functionality was kept to a minimum and thus single speed peristaltic pumps operated at 18rpm using a 0.37Kw motor and 15 mm internal diameter hoses have been used universally and have been found them to provide very reliable and robust service.

5.2.2 PRODUCT STORAGE

Noosa Shire Council have located storage and dosing facilities within masonry or steel sheds, chain-wire compounds or in underground pits.

After evaluating various shaped storage vessels, Council has chosen to use 1200 x 1200 footprint galvanised steel framed polyethylene bulk containers with a 40 degree conical base for on-site product storage for storage and dosing. The tanks have a flat top and a manhole allowing full access to the tank to facilitate cleaning. It is anticipated that the conical base eliminates the need for mechanical stirrers, which have found to be necessary for flat bottomed bulk containers. These are available in various volumes from 1000 L up to 2800 L and may be custom manufactured in smaller sizes from 200L up to 1000L .

Council have decided to used linked smaller tanks wherever possible rather than a single large tank to provide maintenance flexibility. Total storage volume is designed to suit bulk delivery frequency and anticipated system product requirement. Noosa has arranged a fortnightly bulk delivery and have designed installations to ensure that product is consumed within four weeks of delivery.

5.3 OTHER

Recommended dosing delivery hose diameter is 20mm. The length of dosing delivery hose should be kept to a minimum by locating the dosing pump and chemical storage facility as close to the chemical discharge point as possible.

Facilities should incorporate bunding to contain spillage during delivery operations and to facilitate washdown of spilled product to sewer. All hoses, pipes and containers in contact with magnesium hydroxide should be kept clean and regularly flushed with fresh water during and after periodic use. Spilled product dries chalky white, looks unattractive to the public and is difficult to remove.

6. CONCLUSIONS

The results obtained during the 18 month evaluation demonstrated that SulfaLock™ could be used to achieved Noosa Shire Councils odour control objectives at comparable or lower costs than alternatives used or trialed previously. Where sewage pH was maintained at pH 8.3 or higher, mean and peak $H_2S_{(g)}$ levels were maintained at, or well below the 1 and 4 ppm target levels, often constituting reductions of up to 99 %.

Well designed storage and dosing systems (peristaltic pumps and conical product storage tanks of appropriate size) effectively eliminated dosing issues and ensured reliable chemical dosing.

Noosa Shire Council have decided to adopt SulfaLock™ for odour control throughout its sewerage collection system. Council are currently proceeding with the construction of permanent facilities at new sites and replacement or modification of existing chemical dosing facilities to facilitate SulfaLock™ use.

Whilst not yet quantified, the reduced $H_2S_{(g)}$ levels in those systems treated with SulfaLock™ is anticipated to significantly reduce the rate and extent of concrete corrosion and therefore extend asset life.

6.1 SulfaLock™ (Magnesium hydroxide liquid) - Advantages / Disadvantages

In the view of Noosa Shire Council, the main advantages of using SulfaLock™ over the alternatives used or trialed previously include:

Advantages

- Safety of operations and maintenance staff in handling,
- Minimises potential for environmental harm and injury to the public
- Less stringent transport and delivery safety conditions,
- Increased control of odour levels with stable and consistent results,
- Dosing method and equipment simplicity,
- Re-dosing usually not required as product does not oxidise or vent out,
- Introduction of alkalinity beneficial for WTP operation,
- Cost.

Disadvantages:

- Limited shelf and storage life of the product,
- Specialised pump and storage containers required,
- More labour intensive,
- Can be messy compared with other more hazardous chemicals.