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Dosing free nitrous acid for sulfide control in sewers: Results of field trials in Australia

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ABSTRACT

Intermittent dosing of free nitrous acid (FNA), with or without the simultaneous dosing of hydrogen peroxide, is a new strategy developed recently for the control of sulfide production in sewers. Six-month field trials have been carried out in a rising main sewer in Australia (150 mm in diameter and 1080 m in length) to evaluate the performance of the strategy that was previously demonstrated in laboratory studies. In each trial, FNA was dosed at a pumping station for a period of 8 or 24 h, some with simultaneous hydrogen peroxide dosing. The sulfide control effectiveness was monitored by measuring, on-line, the dissolved sulfide concentration at a downstream location of the pipeline (828 m from the pumping station) and the gaseous H_2S concentration at the discharge manhole. Effective sulfide control was achieved in all nine consecutive trials, with sulfide production reduced by more than 80% in 10 days following each dose. Later trials achieved better control efficiency than the first few trials possibly due to the disrupting effects of FNA on sewer biofilms. This suggests that an initial strong dose (more chemical consumption) followed by maintenance dosing (less chemical consumption) could be a very cost-effective way to achieve consistent control efficiency. It was also found that heavy rainfall slowed the recovery of sulfide production after dosing, likely due to the dilution effects and reduced retention time. Overall, intermittent dose of FNA or FNA in combination with H_2O_2 was successfully demonstrated to be a cost-effective method for sulfide control in rising main sewers.

Abbreviations: ADWF, Average dry-weather flow; COD, Chemical oxygen demand; FNA, Free nitrous acid; H_2O_2, Hydrogen peroxide; HRT, Hydraulic retention time; SRB, Sulphate-reducing bacteria; WWTP, Wastewater treatment plant.

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1. Introduction

Hydrogen sulfide, produced by sulphate-reducing bacteria (SRB) in sewers under anaerobic conditions, is an important source of sewer odours, corrosion and health hazards (Pomeroy and Bowlus, 1946; US EPA, 1974; WERF, 2007). Sulfide released into the atmosphere through manholes or pumping stations may cause odour complaints from nearby residents. Also, hydrogen sulfide is toxic to human and animals (WHO, 2003). The generation of hydrogen sulfide from sewage and the transfer to the sewer atmosphere can cause serious concrete corrosion, creating major challenges to infrastructure management through reduced service life and high costs for sewer (US EPA, 1992).

Many chemical dosing technologies have been developed to prevent hydrogen sulfide production/emission in sewer systems (Ganigue et al., 2011; Zhang et al., 2008). There are four commonly used strategies:

1) Sulfide removal by oxidation through injection of air, oxygen, and nitrate (Gutierrez et al., 2008; Mohanakrishnan et al., 2009). Addition of stronger oxidants like hydrogen peroxide, ozone was also reported (US EPA, 1992);
2) Sulfide removal by precipitation through the addition of iron salts (Firer et al., 2008; Zhang et al., 2009a);
3) Reduction of H_2S transfer from liquid to air by pH elevation, typically through the use of magnesium hydroxide or lime (Gutierrez et al., 2009; Rees et al., 2003).
4) Prevention of sulfide generation by inhibiting the activities of sulphate-reducing bacteria or inactivating them through the use of inhibitors or biocides like caustic and molybdate (Predicala et al., 2008; Zhang et al., 2009b).

The first three types of strategies require continuous chemical addition in order to achieve effective sulfide control at all times, incurring high chemical consumption and operational costs (Jiang et al., 2011a). In contrast, biocides have the potential to disrupt the sulfide generating capacity of the sewer biofilm for extended periods following application. As a result, treatment with biocides may only need to be intermittent with the intervals between treatments determined by how rapidly the sulfide generating capacity recovers, i.e. the regrowth rate of SRB in biofilms.

Currently, caustic compounds are the most common biocidal agent used for sulfide control in sewers (Ganigue et al., 2011). Sodium hydroxide is added to wastewater to cause a pH shock (10–11) to suppress sulphate reduction activity in sewer biofilms. However, the effectiveness of caustic shock was limited in real applications with H_2S being reduced by 40–50% (O'Gorman et al., 2011; Tomar and Abdullah, 1994). In addition, costs of caustic shock are comparable to continuous dosing of oxidants or precipitants. Another SRB inhibitor, molybdate, was only demonstrated with pure cultures of SRB or for sulfide control in oil fields or anaerobic digesters (Kjellerup et al., 2005; Nemati et al., 2001; Tanaka and Lee, 1997). The persistence of molybdate in dosed water and the potential negative impacts on environment is still a significant concern.

Nitrite causes specific inhibition to dissimilatory sulphate reduction (Greene et al., 2006) and therefore an exposure of sewer biofilms to a high-level of nitrite over an extended period of time (weeks) caused a gradual decrease of the SRB population and hence the loss of biofilm activity (Jiang et al., 2010; Mohanakrishnan et al., 2008). Jiang et al. (2011b) further found that simultaneous addition of nitrite and acid deactivated sewer biofilm activity with an exposure time of 6–24 h. It was revealed that free nitrous acid (FNA or HNO_2) formed from nitrite at acidic conditions has a strong biocidal effect on anaerobic sewer biofilms, with the viable microbial cells in biofilms decreased from approximately 80% prior to FNA dosage to 5–15% after the biofilm was exposed to FNA at 0.2–0.3 mg HNO_2–N/L for 6–24 h.

Hydrogen peroxide, in combination with FNA, was found to enhance the microbial inactivation by 1-log (Jiang and Yuan, 2013), in comparison with FNA dosing alone. About 2-log of microbial inactivation was achieved when biofilms were exposed to FNA at 0.2 mgN/L or above and H_2O_2 at 30 mg/L or above for 6 h or longer. FNA was identified as the primary inactivation agent and H_2O_2 enhanced its efficiency. The intermediates of reactions between FNA and H_2O_2, such as peroxynitrite and nitrogen dioxide, were suggested to be responsible for the synergism between FNA and H_2O_2.

The strong biocidal effect of FNA on sewer biofilms implies that the simultaneous dosage of nitrite and acid could achieve rapid inactivation of SRB in sewer biofilms, making it possible to achieve sulfide control through intermittent FNA dosing. Through laboratory sewer reactor studies, Jiang et al. (2011a) showed that 12-h dosing of FNA at a concentration of 0.26 mg-N/L every 5 days could reduce the average sulfide production by >80%. The recovery time was doubled to approximately 10 days in another laboratory sewer reactor study by simultaneous addition of FNA and H_2O_2 due to the increased inactivation efficiency (Jiang and Yuan, 2013).

Although laboratory studies showed great promise of using FNA in sewers, the completely mixed nature in the lab-scale sewer reactors are different from real sewers, which are plug-flow systems. Therefore, biofilms at different locations in a sewer main may be exposed to FNA at different concentrations due to possible variations in nitrite and H_2O_2 concentrations and pH level during the transport of wastewater. Consequently, the effectiveness of FNA dosing on sulfide control in real sewers may be different from that previous observed in laboratory sewer reactors. In addition, previous laboratory studies were carried out with limited numbers of consecutive dosing, and hence the long-term effect of FNA dosing on sewer biofilm activities has not been assessed. It is possible that sewer biofilms develop resistance to FNA during repetitive dosing.

The primary aim of this study is to investigate the long-term effectiveness of FNA dosing, with and without simultaneous H_2O_2 dosing, in controlling sulfide production in full scale rising main sewers. Field trials were carried out at a rising main sewer with a diameter of 150 mm and a length of 1080 m. Different chemical combinations of FNA and hydrogen peroxide were added into the wet well at the pumping station for different dosing durations. Both dissolved sulfide in the downstream pipeline and H_2S gas in the discharge manhole were continuously monitored with online sensors, and were used as indicators of sulfide-producing