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Feasibility of sulfide control in sewers by reuse of iron rich drinking water treatment sludge

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ABSTRACT

Dosage of iron salt is the most commonly used method for sulfide control in sewer networks but incurs high chemical costs. In this study, we experimentally investigate the feasibility of using iron rich drinking water treatment sludge for sulfide control in sewers. A lab-scale rising main sewer biofilm reactor was used. The sulfide concentration in the effluent decreased from 15.5 to 19.8 mgS/L (without dosing) to below 0.7–2.3 mgS/L at a sludge dosing rate achieving an iron to total dissolved inorganic sulfur molar ratio (Fe:S) of 1:1, with further removal of sulfide possible by prolonging the reaction time. In fact, batch tests revealed an Fe consumption to sulfide removal ratio of 0.5 ± 0.02 (mole:mole), suggesting the possible occurrence of other reactions involving the removal of sulfide. Modelling revealed that the reaction between iron in sludge and sulfide has reaction orders of 0.65 ± 0.01 and 0.77 ± 0.02 with respect to the Fe and sulfide concentrations, respectively. The addition of sludge slightly increased the total chemical oxidation demand (tCOD) concentration (by approximately 12%) as expected, but decreased the soluble chemical oxidation demand (sCOD) concentration and methane formation by 7% and 20%, respectively. Some phosphate removal (13%) was also observed at the sludge dosing rate of 1:1 (Fe:S), which is beneficial to nutrient removal from the wastewater. Overall, this study suggests that dosing iron-rich drinking water sludge to sewers could be an effective strategy for sulfide removal in sewer systems, which would also reduce the sludge disposal costs for drinking water treatment works. However, its potential side-effects on sewer sedimentation and on the wastewater treatment plant effluent remain to be investigated.

1. Introduction

Hydrogen sulfide generation is a major problem in sewer management. It causes sewer corrosion, odour nuisance and health risks to sewer workers (WERF, 2007). It has an enormous economic impact due to the need for rehabilitation or replacement of corroded sewer pipes and the need for hydrogen sulfide control strategies (Brongers et al., 2002; Sydney et al., 1996; WERF, 2007). Methods to control

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hydrogen sulfide in sewer networks normally involve the addition of large amounts of chemicals for either the mitigation of hydrogen sulfide after its formation or by controlling hydrogen sulfide generation through suppressing sulfate reduction, as described in detail by Zhang et al. (2008) and Ganigué et al. (2011). Iron salts are commonly used chemicals for sulfide control, which remove sulfide by oxidation and/or precipitation. A recent industry survey showed that iron salts comprise ~66% of the total amount of chemicals dosed for sulfide control in Australia (Ganigué et al., 2011). Although iron dosage is an effective sulfide control method, it requires continuous addition, which incurs high chemical costs (Ganigué et al., 2011; Jiang et al., 2011). Therefore, a cheaper source of iron is highly desirable for the water industry.

Iron salts are also used in large amounts and play an essential role in the production of drinking water, for the removal of natural organic material (NOM), colour and turbidity (Henderson et al., 2009). Its use results in the production of large amounts of iron rich drinking water treatment sludge, which requires handling and ultimately disposal through e.g. landfill (Dentel, 1991). If coagulants could be successfully recovered and reused, this would enable a significant reduction in chemical usage during water treatment processes. Therefore, several studies investigated the feasibility of recovery and direct reuse at drinking water treatment plants, as reviewed by Babatunde and Zhao (2007) and Keeley et al. (2012). Various studies showed that it is feasible to recover coagulants, but the obtained quality of the recovered coagulant (e.g. the presence of NOM and heavy metals) in most cases did not allow for direct reuse in the drinking water treatment process (Keeley et al., 2012). Therefore, several studies aimed to increase the product quality of the recovered coagulant to enable direct reuse in the drinking water treatment process, using approaches such as Donnan dialysis (Prakash et al., 2004; Prakash and Sengupta, 2003, 2005), liquid ion exchange (Sthapak et al., 2008) and ion exchange with a cation resin (Petruzzelli et al., 2000). Although these studies achieved a sufficient product quality for direct re-use, their practical implementation remains restricted due to their unfavorable process economics compared to the use of fresh coagulants (Keeley et al., 2012).

Considering the high iron concentration in drinking water sludge (in case iron salts are used as coagulants), it has the potential to be beneficially reused in sewer networks for sulfide control. In comparison to reuse for drinking water production, the product quality in terms of the presence of organics and trace amount of metals is far less restrictive in a wastewater context. The latter would allow for disposal of drinking water treatment sludge to sewers. Indeed, discharge of drinking water treatment sludge to sewer networks is a common practice by many water utilities world-wide (Keeley et al., 2014). For example, 9% and 25% of the total sludge produced in drinking water treatment is discharged into sewers in the United States and in the United Kingdom, respectively (Keeley et al., 2014; Walsh, 2009). However, the rationale for such sewer discharges is simply finding the most economic disposal route for the produced drinking water sludge (Keeley et al., 2014; Miyanoshita et al., 2009), rather than potential beneficial reuse. Although most water utilities use aluminium based coagulants, the use of iron salts are also commonly used (Pikaar et al., 2014). However, to the author's best knowledge, a possible role of iron-rich drinking water sludge for sulfide control in sewer networks has not been studied in detail to date. If a positive role is confirmed, it may have a major impact on urban water management.

This study aims to experimentally evaluate the potential of iron rich drinking water treatment sludge (hereinafter refer as to “iron sludge”) for sulfide control in sewer networks. To do so, iron sludge was added to a simulated rising main. Online measurement was used to enable continuous monitoring of the dissolved sulfide concentrations. Subsequently, batch tests were performed to determine the stoichiometry and kinetics of the reaction between sulfide and the iron in sludge. A kinetic expression of the reaction was proposed based on the batch tests results.

2. Materials and methods

2.1. *Sludge source and characteristics*

The iron sludge was obtained from a local drinking water treatment plant (DWTP) (Australia), where $FeCl_3$ was dosed as the coagulant. The main characteristics of the sludge are shown in Table 1. Iron was the predominant component of metals in the sludge with a concentration of 155 ± 3.4 g/kg dry mass (DM).

2.2. *Lab-scale sewer system and operation*

A 0.75 L gas-tight cylindrical reactor, made of Perspex™, was set up to mimic a pressure sewer pipe (Fig. 1A). The inner diameter of the reactor was 80 mm with a height of 149 mm, resulting in an area to volume ratio (A/V) of 70.9 m^{-1}. Biofilms developed on the wall and the inner surface of the reactor lids. Mixing was continuously provided by a magnetic stirrer (Heidolph MR3000) at 250 rpm under the reactor, so there was no biofilm growing on the bottom in the reactor. Previous

Table 1 – Characteristics of iron sludge used in this study.

Parameter	Value	Parameter	Value	Parameter	Value
TS (g/L)	64.20 ± 1.31	Ni (mg/g DM)	0.04 ± 0.001	S (mg/g DM)	1.49 ± 0.03
VS (g/L)	22.10 ± 1.23	Pb (mg/g DM)	0.09 ± 0.002	TKN (mg/g DM)	11.87 ± 0.20
Fe (mg/g DM)	155.0 ± 3.40	Zn (mg/g DM)	0.14 ± 0.003	TKP (mg/g DM)	1.12 ± 0.05
Al (mg/g DM)	9.03 ± 0.28	Cu (mg/g DM)	0.03 ± 0.001	tCOD (mg/g DM)	352.0 ± 9.0
Mn (mg/g DM)	3.58 ± 0.08	Cd (mg/g DM)	0.01 ± 0.0002	sCOD (mg/g DM)	3.08 ± 0.09

DM: dry mass.