WATER RESEARCH 70 (2015) 350–359

Available online at www.sciencedirect.com

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# Sulfide and methane production in sewer sediments

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ARTICLE INFO

*Article history:*
Received 28 July 2014
Received in revised form
7 December 2014
Accepted 9 December 2014
Available online 17 December 2014

*Keywords:*
Sewer
Sediment
Sulfide
Methane
Microbial profiling
Modelling

ABSTRACT

Recent studies have demonstrated significant sulfide and methane production by sewer biofilms, particularly in rising mains. Sewer sediments in gravity sewers are also biologically active; however, their contribution to biological transformations in sewers is poorly understood at present. In this study, sediments collected from a gravity sewer were cultivated in a laboratory reactor fed with real wastewater for more than one year to obtain intact sediments. Batch test results show significant sulfide production with an average rate of $9.20 \pm 0.39$ g S/m$^2$·d from the sediments, which is significantly higher than the areal rate of sewer biofilms. In contrast, the average methane production rate is $1.56 \pm 0.14$ g $CH_4$/m$^2$·d at 20 °C, which is comparable to the areal rate of sewer biofilms. These results clearly show that the contributions of sewer sediments to sulfide and methane production cannot be ignored when evaluating sewer emissions. Microsensor and pore water measurements of sulfide, sulfate and methane in the sediments, microbial profiling along the depth of the sediments and mathematical modelling reveal that sulfide production takes place near the sediment surface due to the limited penetration of sulfate. In comparison, methane production occurs in a much deeper zone below the surface likely due to the better penetration of soluble organic carbon. Modelling results illustrate the dependency of sulfide and methane productions on the bulk sulfate and soluble organic carbon concentrations can be well described with half-order kinetics.

## 1. Introduction

Sewer systems are an important and integral component of urban water infrastructure, which collects and transports wastewater from residential houses or industry to treatment and disposal. According to the operational nature, sewer systems can be divided into fully-filled pressure sewers (anaerobic), and partially-filled gravity sewers, where re-aeration takes place.

The production and emission of hydrogen sulfide has since long been identified as a major cause of odor and corrosion in sewer systems (Boon, 1995), which incurs large costs to the water industry due to assets depreciation and mitigation measures (WERF, 2007). Sulfide build-up in sewers is commonly found in pressure sewers as well as in gravity

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http://dx.doi.org/10.1016/j.watres.2014.12.019
0043-1354/

sewers with low slope and deposits (Nielsen et al., 1998). Recent studies also demonstrated that methane, a highly potent greenhouse gas that greatly contributes to climate change, is also significantly produced in pressure mains by methanogenic archaea (MA) within the sewer biofilm (Foley et al., 2009; Guisasola et al., 2008; Shah et al., 2011).

Over the years, most of the studies on sulfide and methane production in sewers have focused on sewer biofilms, particularly those in rising mains. These studies demonstrated that sulfide is generated in significant amounts from biofilms in anaerobic pressure sewers (Pomeroy, 1959; Sharma et al., 2008) primarily due to the biological sulfate reduction process mediated by sulfate reducing bacteria (SRB), which grow in the biofilm attached to the walls of rising mains. MA have also been reported with a high activity in sewer biofilms of rising mains, which would consume significant amounts of soluble organic carbon (Guisasola et al., 2008). SRB and MA have been previously hypothesized to co-exist in anaerobic sewer biofilms but reside in different zones of sewer biofilm (Guisasola et al., 2008).

Sediments settled in gravity sewers are also believed to be biologically active (Schmitt and Seyfried, 1992), and would also contribute to sulfide and methane production. However, research in gravity sewers to date has mainly focussed on physical processes such as the sewer sediment deposition, erosion and transport (Banasiak et al., 2005; Gasperi et al., 2010; Rodríguez et al., 2012). It has been reported that the sediment deposition rate ranges from 30 to 500 g per meter length of sewer per day (Ashley et al., 2003). Ashley and Verbanck (1996) also revealed that sediment transport in sewers was influenced by the sewer cross-sectional shape, sediment supply and hydraulic conditions, as well as the relationship between sediment erosion and shear stresses. Mathematical models have been proposed to predict these physical processes (Ashley et al., 2003; Bertrand-Krajewski et al., 1993; Mouri and Oki, 2010; Skipworth et al., 1999). In comparison, little effort has been dedicated to the biological reactions in the sediment despite several studies recognizing their significance (Ashley et al., 2003). Schmitt and Seyfried (1992) demonstrated that the sulfate reduction rates in sewer sediment could be ca. 80% higher than that in sewer biofilms. In fact, with plentiful supply of biodegradable organic carbon, sewer sediment could have great potentials to produce sulfide and methane biologically.

The significant knowledge gaps related to the biological transformations within the sewer sediment are currently limiting our ability to model sulfide and methane production in gravity sewers. To our knowledge, the in-sediment biological reactions are being modelled as biofilm processes in most of the sewer models such as the WATS (Hvitved-Jacobsen et al., 1998) and the SeweX (Sharma et al., 2008) models. The validity of such an assumption is currently unknown.

The aim of this study is to understand the sulfide and methane production processes in gravity sewer sediment, and to propose models to describe these processes. Sediments collected from a real gravity sewer were cultivated in a laboratory sediment reactor mimicking gravity sewer conditions over a period of one year to achieve steady-state performance. A comprehensive evaluation of the in-sediment sulfide and methane production processes was then carried out through integrating batch production tests, microsensor and pore water measurements of sulfide, sulfate and methane in the sediment, microbial community profiling along the depth of the sediment and detailed mathematical modelling. Empirical models were then proposed and calibrated for the prediction of sulfide and methane production in sewer sediment.

## 2. Materials and methods

### 2.1. *Reactor set-up, sediment collection and system operation*

A laboratory reactor system was specifically designed to mimic gravity sewer conditions and to cultivate sediment (Fig. 1). The reactor had a working volume of 3.2 L (2.7 L and 0.5 L for the liquid and gas phase, respectively), with a diameter of 140 mm and a height of 210 mm. The bottom part contained an additional cylinder vessel (120 mm diameter and 60 mm depth) as the sediment carrier aimed at keeping the

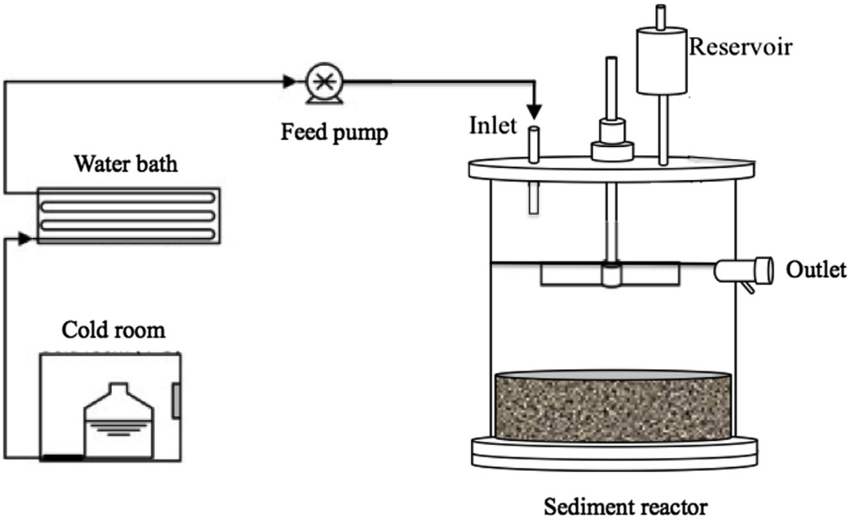

**Fig. 1 – Schematic diagram of the sediment reactor.**