Advanced assessment of Sulfide and Methane emissions from sewers of Mediterranean cities

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Abstract
Production and build-up of sulfide and methane in wastewater collections systems cause several detrimental effects including odour nuisance, health hazards due to its toxicity and corrosion of pipes and inlet structures of sewage treatment plants. On the other hand methane is a greenhouse gas significantly contributing to global warming. Despite these major impacts, sewer-produced sulfide and methane are yet to be considered in the management of Mediterranean Urban Water Systems. This work aims to study the production of sulfide and methane from combined sewers exposed to Mediterranean climate conditions. The study methodology combines extensive experimental work on real sewers with advanced mathematical modelling. The objective is to carry out the first combined quantification of sulfide and methane from Mediterranean sewers and also to provide advanced management tools that include control of sewer emissions for optimal operation of urban water systems. Initial monitoring results and future tasks are presented.

Keywords
Sulfide, Methane, Sewer systems, Advanced control strategies, Mediterranean climate conditions.

INTRODUCTION

Sewer systems are an integrated and very important component of the urban wastewater and stormwater management. By design their primary function is the conveyance of wastewaters and or/stormwater to treatment plants or directly to the receiving waters. The nature of the wastewater, however, leads to a range of complex chemical and biochemical transformations.

When anaerobic conditions prevail in a sewer system, the sulfate present in the wastewater is reduced to sulfide (H_2S) by microorganisms (collectively called sulfate reducing bacteria-SRB). The build-up of H_2S in the sewer atmosphere causes major detrimental effects such as i) malodour in the neighbourhood of the sewer system, ii) health hazards due to H_2S toxicity, and iii) corrosion of the sewer system and the inlet zones in wastewater treatment plants (Boon, 1995; Boon et al., 1998). Therefore, H_2S accumulation results in profound impacts on the structural integrity of the sewer system, their surrounding environment and the performance and cost of the downstream wastewater treatment plants (WWTP) (Thistlethwayte, 1972; Hvitved-Jacobsen, 2002). The cost of remediation or replacement of corroded sewer systems is very high for large systems, in the order of several hundreds to several thousands € per metre depending on pipe diameter and depth.

But hydrogen sulfide is not the only detrimental compound produced in sewer systems. Recent studies indicated that build-up of methane in sewer systems could occur in certain conditions (Guisasola et al., 2008; Foley et al., 2009). In addition of being explosive at low concentrations, methane is one of the main greenhouse gas contributors to global warming with a lifespan of about 12 years and a global warming potential of roughly 21–23 times higher than carbon dioxide. To date, methane production from sewer systems has been largely overlooked. It seems that total GHG emissions from wastewater systems could be underestimated. The latest report from the Intergovernmental Panel on Climate Change (IPCC) concerning greenhouse emissions did not consider methane production from closed or underground sewer systems (IPCC et al., 2006), despite some indications that domestic sewage is one of the anthropogenic methane sources (Minami and Takata, 1997).

In the Mediterranean context, sulfide and methane emissions from sewers are yet to be considered in the integral management of Urban Water Systems (UWS) despite the impacts at local and global scale described above. With relatively mild rainy winters and dry-warm summers (Martinez et al., 2010), the Mediterranean region is likely to suffer from sewer detrimental emissions in the coming years. Indeed most climate change models conclude that the Mediterranean region will be more affected by summer droughts, higher flood frequency and higher temperatures (Meehl and Tebaldi, 2004; Barceló and Sabater, 2010). Those are trigger factors for sewer emissions, with bacterial activity increasing with temperature and quality of wastewater diminishing due to water scarcity. Therefore the wastewater industry is facing the critical challenge of operating at the highest treatment standards and simultaneously reduce its carbon-footprint to achieve greenhouse gas neutral operation.

This work consists in the first comprehensive study to quantify the production of sulfide and methane from combined sewers in the Mediterranean area. This task is regarded as the first step necessary to then develop the best H_2S and CH_4 control strategies from UWS. Outcomes of this study will provide optimal operational strategies to wastewater managers that are currently operating their assets with partial knowledge of the impacts produced by sewers.

METHODOLOGY

This work combines extensive experimental work on field sewer systems with advanced modelling using the UQ-Sewer model (Sharma et al., 2008). Field works are carried out in the municipality of l'Escala, in the Costa Brava Region, top North-East of Spain (Figure 1). L'Escala is a touristic town with sulfide-related problems due to a number of anaerobic rising main pipes with long sewage hydraulic retention time (HRT) and a warm-mild climate. The field sites are characterised in terms of sulfide and methane emissions both in the liquid and gas phase by means of comprehensive sampling campaigns. Measurements focus on sulphurous and carbon compounds from both liquid and gas phase under dry weather conditions. Advanced in-situ online methods are used for sulfide and methane detection in order to monitor the dynamics of the sewers (Gutierrez et al., 2010). Gas phase H_2S was analysed by means of a Oddaloger® from Apptek International onsite detector. Other chemical analysis (Sulfate, COD and volatile fatty acids) are performed by off-line grab samples latter analysed at the ICRA analytical laboratories. The characterisation is carried out at relevant points, mainly WWTP inlets and sewer hotspots, where significant emissions problems are expected (Figure 1.).

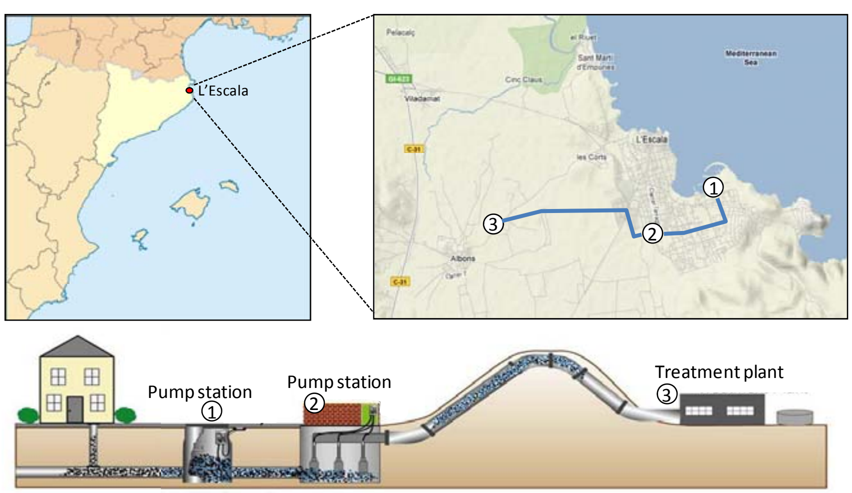

Figure 1. Location and scheme of l'Escala Urban Wastewater System with monitoring locations: ①&②: Pump stations; ③: Wastewater Treatment plant inlet.

Field data collected is used to run to the UQ-Sewer Model (Sharma et al., 2008). The UQ-Sewer Model is an advanced wastewater-network model capable of predicting dynamic biological carbon and sulfur transformations that lead to H_2S and CH_4 formation. The model is a dynamic model which takes into account the biochemical processes (aerobic, anaerobic and anoxic) occurring in a biofilm and bulk liquid, chemical processes such as sulphide oxidation and precipitation and chemical equilibrium reactions leading to pH prediction, and physical processes such as liquid gas mass transfer. Some of the processes are not applicable to rising main sewers, as no headspace exists. The input of the model are sewer system characteristics such as network layout, pipe sizes, length and slope (only in the case of gravity main), feed wastewater characteristics, and hydraulic characteristics such as variation of flow and the corresponding changes in flow velocity and the depth. In addition to this, temperature data is also required. The model has been recently upgraded to predict CH_4 formation in rising mains (Guisasola et al., 2009). The UQ-Sewer model consists of a reliable tool to formulate accurate predictions of sulfide and methane production in sewer systems, which is absolutely necessary to establish the appropriate strategies for optimal sewer management.

RESULTS AND FUTURE TASKS

Figure 1 shows the model predictions of H_2S concentration in the sewage as it moves from the pump stations (1,2) to the wastewater treatment plant (3). The 24h profile indicates how the H_2S build up occurs within the anaerobic pipes, starting from an average concentration of 3.9mgS-H_2S/L (Point 1) and reaching up to 13.4 mgS-H_2S/L at the inlet of WWTP (Point 3).

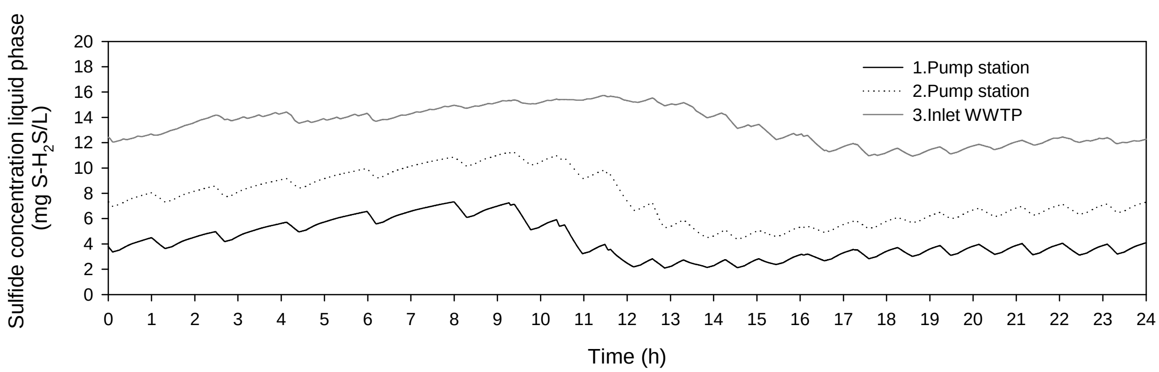

Figure 1. 24h profiles of Sulfide concentration predicted by the UQ sewer model in the different sections of the l'Escala UWS.

Measurement of H_2S in the gas phase in Points 1 and 3 also showed an increasing trend in H_2S concentration from the initial pump station to the WWTP inlet (Figure 2). H_2S monitored in the initial pumping station was significantly lower than in the inlet of WWTP. H_2S was released to the gas phase due to its stripping from the liquid phase during pump events as plug flow pattern. Therefore, the increasing H_2S liquid-concentrations plus the turbulent discharge produced several peaks higher than 80 ppm per day at the WWTP inlet.

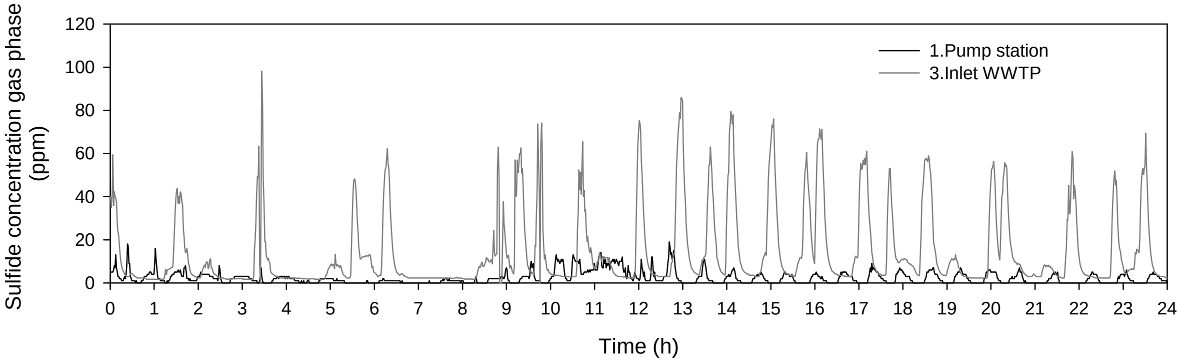

Figure 2. 24h profiles of H_2S measured concentrations in the gas phase of points 1 and 3 of l'Escala UWS.

With regards to the methane formation, the model predicts a considerable build-up of CH_4 in the liquid phase through the sewer system, reaching around of 30mgCH_4-COD/L·day at the inlet of the WWTP. However these results remain to be confirmed by the experimental campaigns currently being carried out. Full information will be included in the final conference paper.

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