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Modelling of methane production in a sewer network

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Summary of key findings

An online methane sensor was employed to monitor methane level in the sewage at the end of a rising main for a period of 3 weeks during both winter and summer periods. Based on the sewer information and the pump station operation data, a model was setup for the sewer system. The SeweX model, capable of predicting methane generation in a sewer, was employed for this purpose. The model was calibrated and validated using the measured methane concentrations in summer and winter, respectively. The model was able to reproduce the variation in methane concentration reasonably well suggesting that the model can therefore be used as a tool for greenhouse gas accounting for the wastewater collection system.

Background and relevance

Sewer systems are an important and integral component of urban water infrastructure, which collects and transports wastewater from residential houses or industry to wastewater treatment plants (WWTPs). A small number of recent studies in sewer systems have shown significant methane production in sewers (Foley et., 2009; Guisasola et al., 2008). Liquid phase CH_4 concentrations of up to 20 to 25 mg/L have been measured in rising main sewers. Methane is a highly potent fugitive greenhouse gas (GHG) that contributes significantly to climate change. Depending upon the ventilation conditions, methane could also accumulate to high concentrations in sewer headspace. Gas phase methane concentrations of up to 50,000 ppmv, i.e. 5% by volume (vol), have been detected in the air of a gravity sewer in Australia. This is concerning because CH_4 is a highly volatile gas and displays a Lower Explosive Limit (LEL) of approximately 5% vol. Uncontrolled release of methane could cause an explosion when in contact with air in confined spaces such as sewers, and thus poses a serious safety risk. In addition, methane generation in sewers may consume a significant amount of soluble chemical oxygen demand (COD), which is detrimental to nutrient removal in downstream WWTPs.

However, due to the operational complexity of sewer systems and dynamic nature of methane emissions, it is impractical to estimate overall CH_4 emissions from large networks through either online or off-line measurements. Instead, mathematical modelling would provide an alternatively way to predict the extent of the problem.

Results

SeweX is a dynamic sewer model, describing in-sewer biological, chemical and physical processes (Sharma et al., 2008). It predicts both the temporal and spatial variations of wastewater composition, including sulfur compounds using sewer network configuration, pipe geometry, sewage characteristics and hydraulic data as inputs. Although the methane component has now been added to the SeweX model (Guisasola et al., 2009), the model originally calibrated using data collected from lab-scale experiments, has not been validated for a sewer network.

In this work, we have attempted to deploy the SeweX model to a network of rising main sewers in Gold Coast, Australia. The model was calibrated and validated using field data collected through continuous on-site methane measurement (Liu et al., 2015). The network comprises of six pumping stations feeding domestic sewage into a 4.4 km long rising main. The monitoring site was at the end of a rising main sewer network (Fig. 1). The pumping stations are operated in an ON/OFF manner with pump turned on when the sewage level in the wet well reached a pre-defined water level in the wet-well and turned off when water level falls to a pre-defined lower level of water. The network collects domestic wastewater with an average daily flow of 2840 m^3/d. The average hydraulic retention time (HRT) in this network is 9 hours.

The online methane sensor (Liu et al., 2015) was employed to monitor methane level in the sewage at the end of the rising main and the measurements were carried out continuously over a period of 3 weeks during both summer (January 2014) and early winter (May 2014). The dissolved methane concentrations in the upstream pumping stations were measured manually.

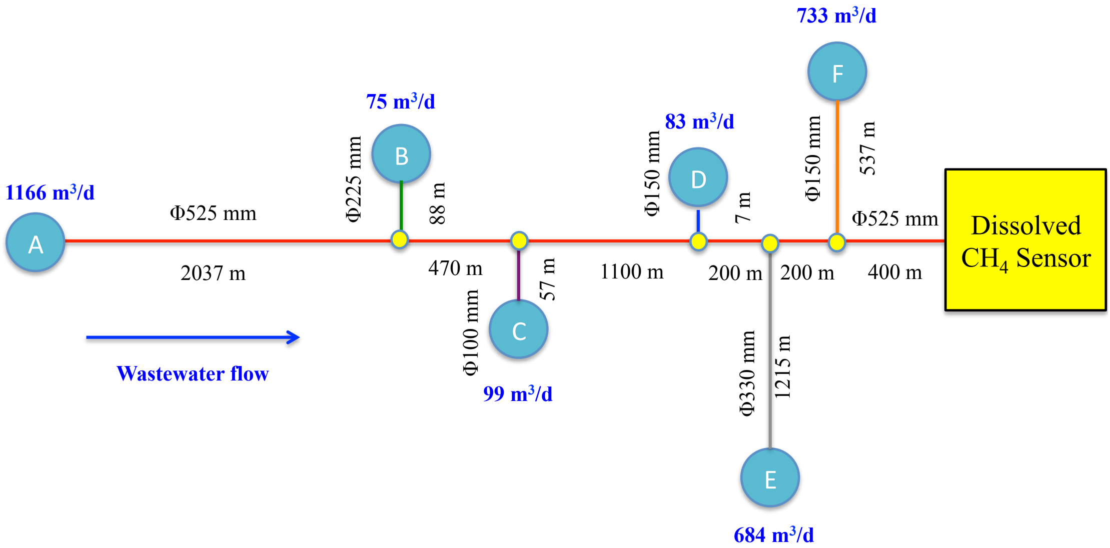

Figure 1. Details of the sewer network and the sensor location

The sewage flow rates during the sampling period was obtained using the pump station operation data (time when each of the pumping stations was switched on or off) recorded by supervisory control and data acquisition (SCADA) systems and the geometry of the pumping station wet wells.
Key parameters of the SeweX model were adjusted manually to produce the best fit between the model predicted and the field measured methane concentrations during the summer period. The calibrated model was then validated using the data obtained from the winter monitoring.

A comparison of the model-predicted and measured methane concentrations for a period over 3 weeks is shown in Fig. 2. The model is able to reproduce the variations in methane concentrations reasonably well. The dissolved CH_4 concentrations varied from 5 to 15 mg/L with an average concentration of 9.1 mg/L. The profile also displayed a clear diurnal pattern (see inset, Fig. 2), with higher dissolved CH_4 concentrations during night-time and lower concentrations during daytime, caused by the diurnal variation of HRT in the network. The short-term (e.g. within an hour) variation was caused by the intermittent pump operations. Fig. 3 shows the variation of dissolved sulfide concentration at the end of the sewer system. It is worthwhile to note the highly dynamic methane and dissolved sulfide concentrations at the end of the network, which was caused by the intermittent pump operation.

Discussion

The online dissolved methane measurement data enabled the determination of reliable model parameters as demonstrated by the good fit between the measured data and the model predicted results. The calibrated model was then used to validate the methane production in the same system during early winter. The validation results will be included in the presentation. The SeweX model presented here can be employed to any sewer network to determine methane production in the sewer system and this will serve as a useful tool for greenhouse gas accounting for the wastewater collection system.

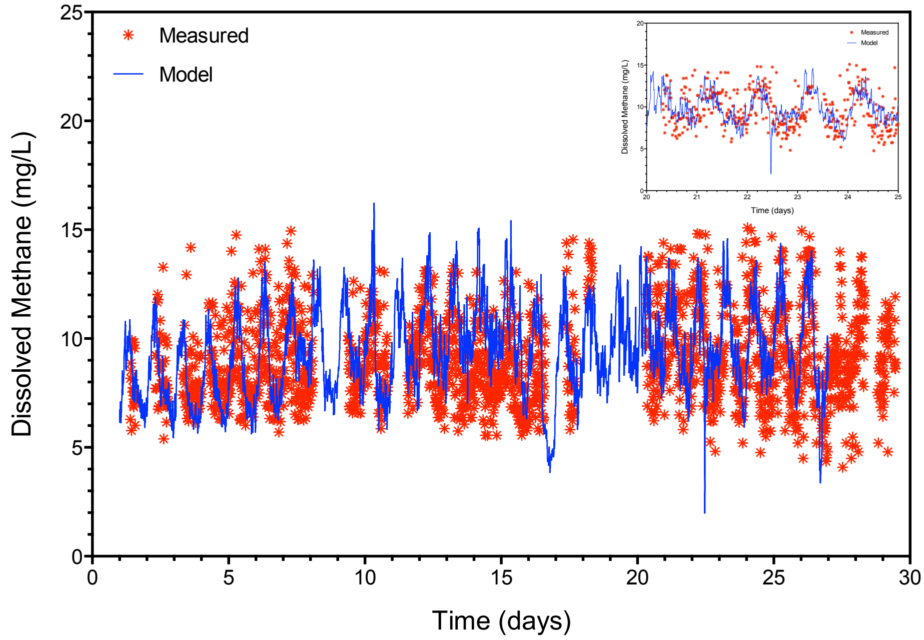

Figure 2. Details of the sewer network and the sensor location

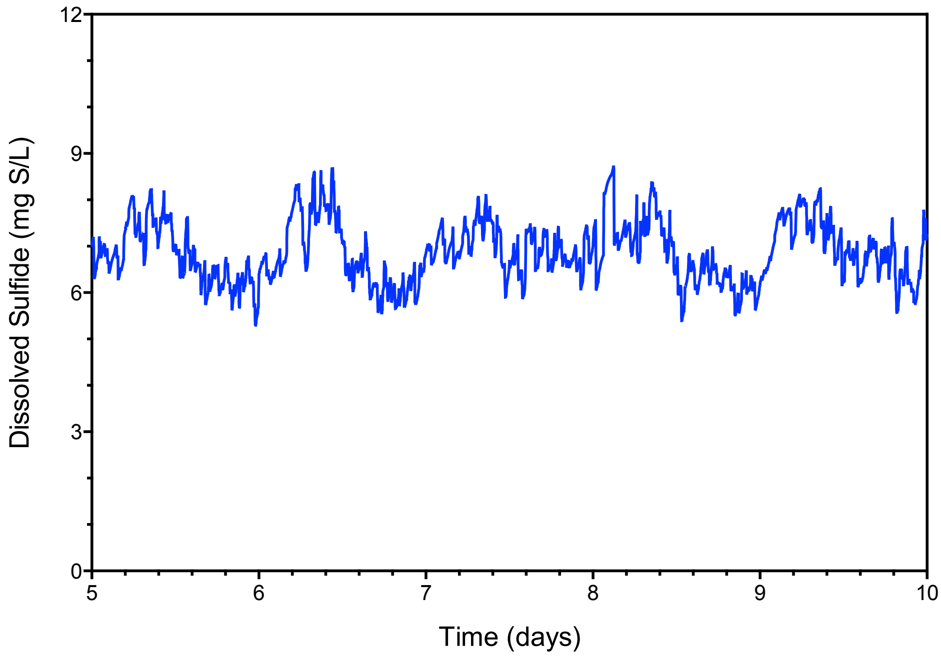

Figure 3. Details of the sewer network and the sensor location

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