Modelling of methane production in a sewer network

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Presenter
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Outline

• Introduction

• Data collection

• Results

• Conclusions
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Pressure sewer (Rising main)

Gravity sewer

Sewers

Modified from Jiang (2010)
Methane measurement in sewers

(A) Dependency of CH₄ Production on HRT

(B) Gas Phase Methane Measurement (Melbourne)

Collected from a few sites with intermittent manual sampling during very short periods

GWRC (2010)
Sewers are highly dynamic and complex systems

Even with online sensors, it is not feasible for long-term quantification over a large number of sampling sites along extensive sewer networks.

Sharma et al. (2008), Liu et al. (2015) and Corowa Shire
SeweX model

• Predicts spatial and temporal variations of various compounds/characteristics of interests/concern
  – Hydrogen sulfide (both in liquid and gas phases)
  – pH considering all organic and inorganic acids and bases

• Effect of H₂S control strategies
  – Chemical dosage (O₂, NO₃⁻, Fe²⁺/Fe³⁺, Mg(OH)₂, caustic, FNA)
  – Ventilation

• Corrosion rate prediction
Processes Included in SeweX Model

- **H₂S adsorption** → **H₂SO₄ formation leading to concrete corrosion**

- **H₂S**
  - Gas Transport
  - **Gas transfer (Emission/Reaeration)**
  - **Air-water interface**

- **Biological Processes**
  - Sulfur Cycle, Carbon Cycle and Nitrogen Cycle under both aerobic and anaerobic conditions

- **Physico-Chemical Processes**
  - Chemical oxidation, precipitation, iron-pairing reactions (in progress), weak acid-base equilibrium

- **Wastewater**
- **Sediment**
- **Sewer Biofilm**
SeweX Model Validation for C27

[Graph showing total dissolved sulfide and pH over time with measured and simulation results]
SeweX model: The first model to predict the spatial and temporal variation in sewer methane concentration

- Predicts spatial and temporal variations of various compounds/characteristics of interests/concern
  - Hydrogen sulfide (both in liquid and gas phases)
  - Methane (both in liquid and gas phases)
  - pH considering all organic and inorganic acids and bases
- Effect of H₂S control strategies
  - Chemical dosage (O₂, NO₃⁻, Fe²⁺/Fe³⁺, Mg(OH)₂, caustic, FNA)
  - Ventilation
- Corrosion rate prediction
- VOSC prediction (under development)
- Algorithm for on-line chemical dosing control
Processes Included in Current SeweX Model

More online field measurement data are needed for better calibration and validation of the methane related kinetics.
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Field measurement site

Wastewater flow
Flow: 2840 m³/d
Average HRT: 9 h
Length: 4.4 km
Volume: 1071 m³
Principal of dissolved methane sensor

\[ C_s = \frac{(V_r - V_s) \cdot C_{g,eq} + V_s \cdot C_{w,eq}}{V_s} \]

\[ C_{w,eq} = H \cdot G \cdot T \cdot C_{g,eq} \]
Sensor performance

Graph a: CH₄ Sensor (% vol) vs. Time (min)

Graph b:溶解CH₄ (mg/L) vs. Dissolved CH₄ (mg/L)

Equation:

\[ y = 1.04x - 0.84 \]

\[ R^2 = 0.9991 \]
Data Collection

- Methane concentration
  - Online measurements during summer and early winter

- Sewer details

- Pump flow rate
  - SCADA data (pump run details)
  - Wet-well dimensions

- Wastewater characteristics
  - Historical measurement data
  - Average concentrations used

- Temperature
  - 28°C in summer
  - 25°C in early winter
Outline

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• Data collection

• Results: model calibration and validation

• Conclusions
Model calibration (summer data)
Model calibration (summer data)
Model validation (early winter data)
Model validation (early winter data)

- Measured values vs Model predictions for Dissolved Methane (mg/L) from 5 April 2014 to 5 May 2014.

- Early winter data is highlighted in the graph.

- The data shows fluctuations in Dissolved Methane concentrations with a comparison between measured and modeled values.
Model validation (early winter data)
Further Application of the Model

Sewer Properties
Length = 100 m (constant)
Pipe diameter = D mm
Pump run time = P (hours/day)
Average daily flow = Q (m$^3$/day), typical diurnal pattern to be applied
Temperature = T ($^\circ$C)
A range of the parameters to be determined and sets of sewer conditions to be developed

Network Data
Pipe length
Pipe diameter
Average daily flow
Pump run time (hours/day)
Temperature

Calibrated Sewer Model
Simulations to estimate methane production under each set of sewer conditions
Non-linear regression of the simulation results data to develop a correlation between the sewer parameters and the methane production, some parameters derived from the primary data might be needed
Methane production in each pipe section to obtain overall methane production in the entire network
Conclusions

• SeweX model was successfully calibrated and validated using long-term online methane measurement data in actual sewers.

• SeweX model can serve as an powerful tool for predicting methane formation in sewer networks.
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Thank you!