Detection of Exfiltration in Sewer Systems with Tracers

Stegeman, Bram; Langeveld, Jeroen; Bogaard, Thom; Clemens, François

DOI
10.1007/978-3-319-99867-1_141

Publication date
2019

Document Version
Final published version

Published in
New Trends in Urban Drainage Modelling - UDM 2018

Citation (APA)
Stegeman, B., Langeveld, J., Bogaard, T., & Clemens, F. (2019). Detection of Exfiltration in Sewer Systems with Tracers. In G. Mannina (Ed.), *New Trends in Urban Drainage Modelling - UDM 2018* (pp. 820-824). (Green Energy and Technology). Springer. https://doi.org/10.1007/978-3-319-99867-1_141

Detection of Exfiltration in Sewer Systems with Tracers

Bram Stegeman[1(✉)], Jeroen Langeveld[1,2], Thom Bogaard[1], and François Clemens[1,3]

[1] Water Management Department, Delft University of Technology, Delft, The Netherlands
b.stegeman@tudelft.nl
[2] Partners4UrbanWater, Nijmegen, The Netherlands
[3] Deltares, Delft, The Netherlands

Abstract. Due to the ageing of our underground wastewater infrastructure, leakage of sewers and pressure mains and subsequent infiltration or exfiltration are becoming an increasingly important issue. Herein, we present a novel method to detect and potentially quantify exfiltration from sewer systems under variable flow conditions; the DEST method. The DEST method is based on the principle of setting up a mass balance of a tracer substance. At an upstream point a tracer is injected in a sewer with a constant rate for a certain period, subsequently downstream high frequent time discrete grab samples are combined with discharge measurements to complete the mass balance. The method is applied on a sewer section in Loenen (NL) to investigate its feasibility. Two different tracers are used; Lithium chloride and Deuterium. Preliminary results indicate that both tracers show similar behaviour at the downstream measurement point. Final lab results are expected at the end of March, allowing in depth analysis of the experimental results with a focus on the measurement uncertainty.

Keywords: Exfiltration · Tracer · Leakage · Sewer · Field experiments DEST

1 Introduction

Due to the ageing of our underground wastewater infrastructure, leakage of sewers and pressure mains and subsequent infiltration or exfiltration are becoming an increasingly important issue. Infiltration of groundwater in sewers below the groundwater level could lead to an unnecessary high hydraulic influent load of wastewater treatment works and a decreased treatment efficiency. Infiltration of groundwater might also result in sewer collapse, due to the ingress of soil into the sewer and the subsequent undermining of roads (Stanić et al. 2014). Exfiltration from gravity sewers and pressure mains might also result in sewer collapse due to bedding erosion. In addition, exfiltration of sewage which contains pathogens and pharmaceuticals might have detrimental environmental effects and threaten groundwater quality used in drinking water production (Nakada et al. 2008). Even though many of these issues are well known, relatively little effort is spend by sewer operators to detect and repair leaks. This is

G. Mannina (Ed.): UDM 2018, GREEN, pp. 820–824, 2019.
https://doi.org/10.1007/978-3-319-99867-1_141

partly a result of a lack of suitable inspection techniques and incentives. However, current focus on Asset Management and risk reduction has initiated new research into potential methods to detect, locate and quantify leakage from sewage systems and pressure mains.

In past decades there has been an increased interest in the problem of sewer leakage. In the APUSS project methods based on tracer experiments have been developed to measure infiltration and exfiltration in sewer systems. Exfiltration is measured in a reach with a pulse dosing method (QUEST) or a continuous dosing method (QUEST-C) (Rieckermann et al. 2007). Since the need for a discharge measurement is canceled out, both methods produce most reliable results under steady flow conditions.

This is also why, ideally, these methods are applied in trunk sewers with a constant flow, sufficient length and no inflows. However, exfiltration also may occur in sewer networks with inflows and QUEST-C cannot be applied to this type of situations. Therefore an alternative method with tracers is developed and tested.

The proposed paper addresses the results of multiple field tests with the novel DEST (Detection of exfiltration with tracers) method to detect and potentially quantify exfiltration under variable flow conditions.

2 Materials and Methods

2.1 Exfiltration Quantification and Detection with Tracers

The principle of the DEST method is applying a mass balance of a tracer in a sewer reach or system (see Fig. 1). At a certain upstream point in the sewer system a well-known mass of tracer is injected. Consequently, the conservative tracer mixes with the sewer flow and exfiltration will result in a decrease of tracer mass. To complete the balance, downstream at the reach or system under investigation, the remaining tracer mass is determined. To this end, discharge is measured with an *Electromagnetic Flow Meter* and high frequent time discrete samples of wastewater are collected for lab analysis of the tracer substance.

Exfiltration is calculated by comparing the injected mass ($mass_{in}$) with the remaining mass ($mass_{out}$). The injected mass is the product of the dosed volume (V_{in}) and concentration (C_{in}). The remaining mass is derived from the discharge (Q) and concentration (C), corrected background concentration (C_0) at time t. Exfiltration can be defined as:

$$E = \frac{mass_{in} - mass_{out}}{mass_{in}} = 1 - \frac{\int Q(t)(C(t) - C_0(t))dt}{V_{in}C_{in}} \tag{1}$$

When there is no additional sewer inflow between the injection and measurement point, formula 1 can be used to quantify the exfiltration.

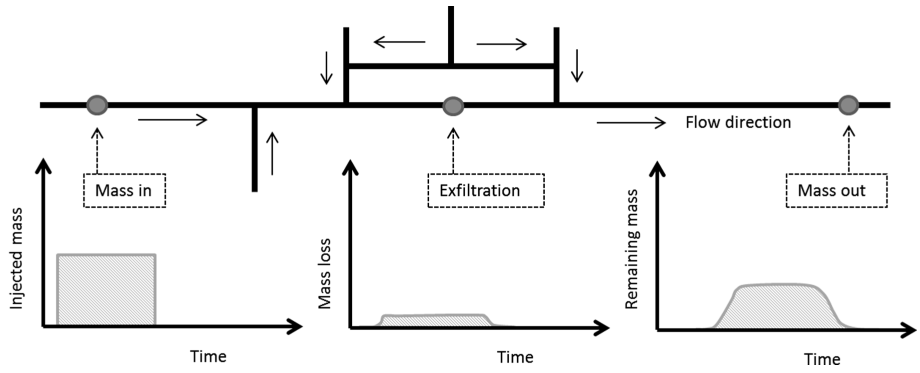

Fig. 1. Conceptual scheme of DEST experiment.

2.2 Case Study: Loenen (NL)

The DEST method is applied in a sewer section in Loenen to investigate its feasibility. A description of this catchment can be found in Van Bijnen et al (2012). The investigated reach is about 640 m long with consecutively a diameter of 1250 and 500 mm. At 70 m downstream from the dosing point there is a lateral inflow. Infiltration is also likely to occur. The investigation reach is the main sewer towards the pumping station with an average slope of 2.3‰. Groundwater level measurements confirm that the investigated reach is located below groundwater level. Consequently, exfiltration due to leakage can be excluded for this sewer, making it a suitable location for the experiment.

2.3 Experimental Setup

In total 6 field experiments have been conducted. At the start of each experiment samples were collected to determine the background concentrations. At 3 out of 6 experiments an artificial exfiltration was introduced. At 247 m downstream from the dosing point a peristaltic pump in combination with a wastewater collection vessel (1000 L) was installed. Subsequently the extracted volume was measured, and after mixing 3 samples were collected.

At the dosing point two tracers (Lithium chloride (LiCl) and Deuterium (^2H)) were injected in the sewer system using a peristaltic pump. The dosage rate was approximately 240 ml/min and the dosage time varied between 41 and 43 min. The experiments had a dosed Li^+ concentration of around 10,5 g/L and around 13 g/L (4 out of 6). The $^2\delta$ value of the 6 vessels need to be determined.

At the downstream measurement point a local bypass was created. The conduit was closed with a metal valve and a submergible pump with variable discharge was installed. At this point a pressure and conductivity sensor were also installed. The discharge from the diverted flow was measured and simultaneously time discrete samples were taken. The sampling interval is 5 s and composite samples are collected every 150 s. The samples were filtered and analysed with an ICP-OES for Li^+ and with a laser absorption spectrometer.

The start and stop of a single experimental run was initiated by two types of markers: one based on visual observation; ping-pong balls (5 white balls for the start and 5 pink balls for the stop). When these balls arrived at the artificial exfiltration location the pump was switched on or off. During the first two experiments these balls did not arrive at the downstream measurement point. Likely as a result of a submerged pipe at a manhole. Therefore, at the remaining experiments a pulse dose of NaCl solution (around 170 g/l table salt) before the start and after the stop of the tracer dosing has been used as a marker. This resulting increase in conductivity was used as a sampling start and stop indicator.

3 Results and Discussion

3.1 Downstream Tracer Values

Figure 2 presents the lithium concentration and $^{2}\delta$ values in time for experiments 1 and 2 at the downstream measurement point. The correlation between the two time series in both experiments is $R^2 > 0.998$.

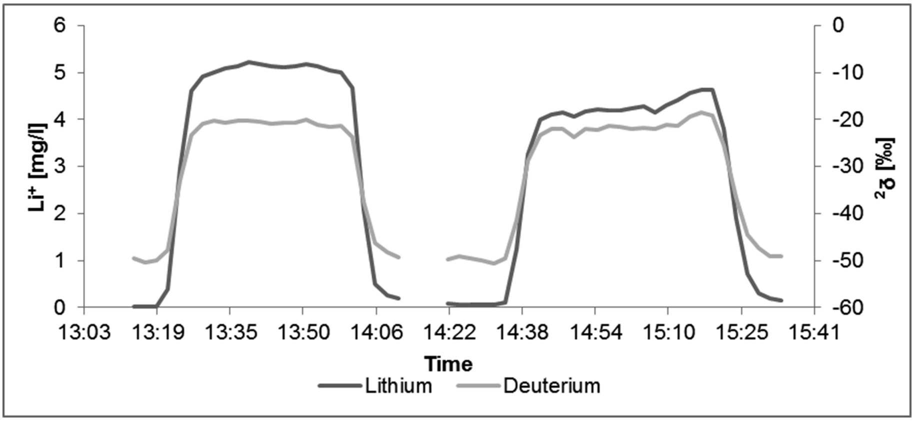

Fig. 2. Lithium and Deuterium time series for experiment 1 and 2 at downstream measurement point.

3.2 Expected Results

At the time of writing of the abstract, not all lab analyses have been finished. They will be available at the end of March. Once all data will be available, the data analysis will focus on the measurement uncertainty. This will include the analysis uncertainty of Li^+ and ^2H measurements and possible variability in background values. The uncertainty of the discharge measurements also has to be evaluated, in combination with sample volume and time of sampling. Since time series are used, the autocorrelation also have to be investigated. The influence of a long concentration tail and the resulting initial higher background concentration on an experiment will be quantified. The same holds for the observed small leakage at the closed valve.

4 Conclusions

The novel DEST (Detection of exfiltration with tracers) method to detect exfiltration in sewer systems has been tested on its feasibility in a field research. Two different tracers were applied; Lithium chloride and Deuterium. Results indicate that both tracers show similar behaviour at the downstream measurement point.

References

Nakada, N., Kiri, K., Shinohara, H., Harada, A., Kuroda, K., Takizawa, S., Takada, H.: Evaluation of pharmaceuticals and personal care products as water-soluble molecular markers of sewage. Environ. Sci. Technol. **42**, 6347–6353 (2008). https://doi.org/10.1021/es7030856

Rieckermann, J., Bareš, V., Kracht, O., Braun, D., Gujer, W.: Estimating sewer leakage from continuous tracer experiments. Water Res. **41**(9), 1960–1972 (2007). https://doi.org/10.1016/j.watres.2007.01.024

Stanić, N., Langeveld, J.G., Clemens, F.H.L.R.: HAZard and OPerability (HAZOP) analysis for identification of information requirements for sewer asset management. Struct. Infrastruct. Eng. **10**(11), 1345–1356 (2014). https://doi.org/10.1080/15732479.2013.807845

Van Bijnen, M., Korving, H., Clemens, F.: Impact of sewer condition on urban flooding: an uncertainty analysis based on field observations and Monte Carlo simulations on full hydrodynamic models. Water Sci. Technol. **65**(12), 2219–2227 (2012). https://doi.org/10.2166/wst.2012.134