Managing The Wastewater Transport And Treatment System As An Integrated System In Terms Of Water Quality

Lisha Guo[1], Riccardo Boiocchi[1], Zachary Scott[2], John Walton[2], Domenico Santoro[3], Elsayed Elbeshbishy[1], Peter Vanrolleghem[4]

[1]Ryerson University, [2]USP Technologies, [3]Trojan Technologies, [4]Laval University

INTRODUCTION

Because of city expansion and population growth, large-scale construction and development of modern sewage collection systems started more than one century ago. As its name states, the main role of the collection system is to collect domestic and industrial sewage from households and factories and transport collected sewage downstream to a sewage treatment plant (STP). In this traditional end-of-pipe technology, pollutants are considered to be removed or reduced by physical and biochemical methods merely at the STP. However, recent research and emerging trends show that the boundary of biochemical treatment of sewage should not only be constrained to the STP but also be pushed upward into the sewage collection system. A vision that uses the sewer as a bioreactor and technologies involving integrated management of collection system and STP are becoming popular.

Due to those emerging requirements, a research project was launched in July 2017 to investigate the interaction between the collection system and STP and to explore new tools and approaches for integrated management by using computer modelling and experimental methods. The scope of this project is illustrated in Figure 1. The study on the collection system is focused on how in-sewer biochemical reactions change sewage composition and how chemical dosing can alter the sewer environment to achieve a desired nutrient removal. For the STP, the study focus includes chemically enhanced primary treatment (CEPT) and plant-wide performance assessment.

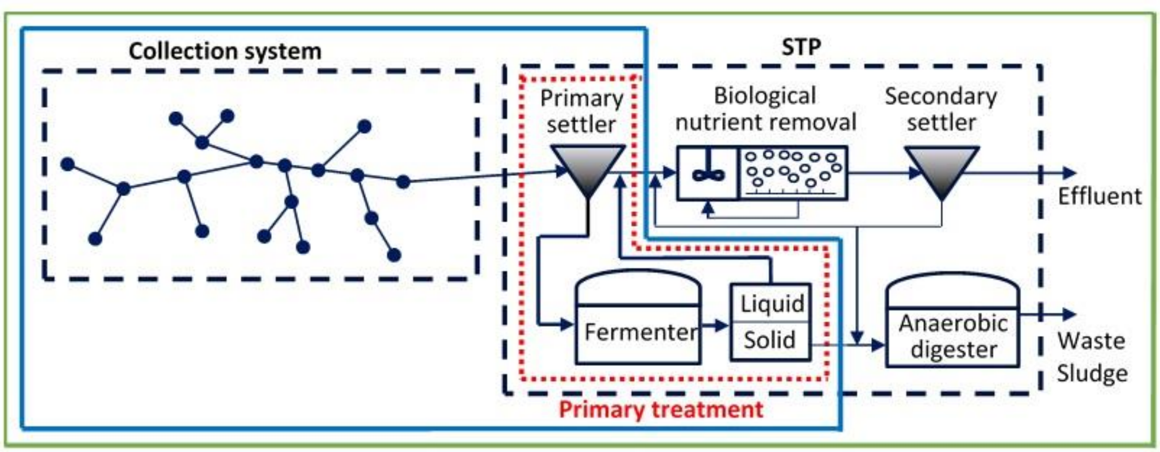

Figure 1 Scope of the integrated system in this study

In the first stage of the study, the investigation shed light on a smaller scope focusing on the collection system and primary treatment, i.e. the blue box in Figure 1. The goal is to optimize the collection system and primary treatment to optimize biological nutrient removal (BNR) at the

STP. The study of this stage does not represent the fully integrated management of collection system and STP, but inspires new technologies in engineering practice on how to operate the collection system and primary treatment for maximizing BNR. Then, the ultimate goal of the project is to optimize the overall gain of the collection system-STP integrated system (the green box in Figure 1), with considerations on nutrient removal and recovery and cost of operation and chemical dosing. The project is still in progress and work is ongoing. Preliminary results regarding collection system modelling were shown in a previous submission (Guo et al., 2018), which showed applications of a new modelling tool in real cases. This abstract focuses on collection system modelling under changing sewer environment and integrated management of collection system and STP. Methodologies used in the study are presented and more results are expected in the coming weeks.

STUDIED INTEGRATED SYSTEM

This study looks into a collection system that consists of three force mains and a STP that is located just after the collection system. The force main collection system and the STP compose an integrated system where different control strategies and operation conditions are tested in order to optimize the overall performance of the whole system.

A new sewage treatment technology is being tested in the collection system where high-strength oxygen is dosed to trigger nitrification and denitrification in force mains. This study uses modelling and experimental methods to investigate the influence of sewer oxygen dosing on STP operation, sewage composition and VFA production and nitrogen removal and to find a strategy that can achieve a trade-off between those aspects and an optimal gain for the entire integrated system.

INTEGRATED MODELLING

In collection systems, bacteria live in both bulk water that flows through sewer pipes and in a slime layer (i.e. biofilm) that adheres to the inner wall of the pipes. Research showed that biofilms play a key role in sewers (Hvitved-Jacobsen et al., 2013). Besides the discussion related to the microbiology, it is clear that in a collection system the retention time of bacteria in the bulk water is equal or close to hydraulic retention time, because they travel downstream with the sewage, whereas the bacteria in the biofilm, adhering to the pipe, stay longer in sewers and therefore are more adapted to the sewer environment.

In this study, a simple model, which considers both mixed cultures and biofilms (Rauch et al., 1999), is used to simulate biochemical reactions of the studied force main system, especially under high-strength oxygen dosing that will change sewer environment from anaerobic conditions to partially aerobic and anoxic conditions.

For the STP, Benchmark Simulation Model No.2 (BSM2) is used as a basis, but the research focus of this study is laid on primary treatment, i.e. the part in the red box in Figure 1. Therefore, instead of using the unreactive primary clarifier model as in BSM2, which only considers physic separation between liquid and solid, this study deploys a reactive primary clarifier model in order to model the biochemical and physico-chemical reactions occurring in a primary clarifier. Moreover, besides an anaerobic digester that is already included in BSM2, a fermenter model is added to simulate the treatment of primary clarifier sludge to generate BNR-stimulating VFAs. With those modifications, this STP model allows to investigate the effect of CEPT and the influence of chemical dosing in the collection system on primary treatment and the overall performance of STP.

The collection system model and the STP model compose an integrated model that focuses on nutrient removal and recovery processes and system-wide assessment.

EXPERIMENT

On the one hand, experiments provide real data for model calibration and validation. On the other hand, a model survey offers suggestions and instructions for experimental design. The final decision on the selection of operational control strategies or chemical dosing strategies depends on a careful analysis of both experimental and modelling results. The cooperation between experimental activities and modelling is shown in Figure 2.

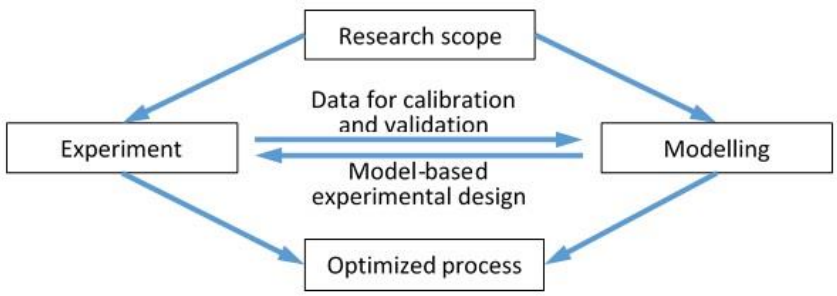

Figure 2 Cooperation of experimentation and modelling

CONCLUSION

In this study, modelling and experimental approaches are used to study an integrated system that consists of a three-force-mains collection system and a CEPT-enhanced STP. A simple model with mixed culture and biofilm is used to simulate biochemical reactions in sewers. This model describes the change of the sewer environment and bacteria species composition under chemical dosing. For STP modelling, BSM2 is extended in terms of CETP, including a reactive primary clarifier and a primary sludge fermenter. An overall evaluation on the integrated system of collection system and STP is carried out to assess system-wide nutrient removal and recovery and cost. New technologies for the purpose of nutrient removal and recovery are tested based on experimental and modelling studies.

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