INTEGRATED MODELLING AND OPERATION OF SEWER SYSTEMS AND WASTEWATER TREATMENTS, CONSIDERING RIVER WATER QUALITY

dr. MANFRED SCHÜTZE[1]

Abstract

This conference contribution aims to motivate the application of modelling and simulation of wastewater infrastructure. It also outlines some concepts of integrated modelling and assessment of sewer system, wastewater treatment plants and receiving water bodies and provides an outlook on very recent developments.

Keywords: energy, integrated assessment, modelling, river, sewer system, simulation, wastewater treatment plant.

1. INTRODUCTION

Wastewater engineers are responsible for critical, costly and important infrastructure. Thus, planning and operation of wastewater systems constitutes an important task and conveys significant responsibility. It is generally accepted that, when buying a car, it would be prudent to do a test drive prior to making any investment in purchasing that car (such as to identify strong and weak characteristics of the car, considering a large number of criteria such as purchase price, operational costs, demand on petrol, space, colour, …). However, this seems to be less the case when large infrastructure systems such as wastewater networks and wastewater treatment plants, are planned and operated.

The questions arises how a "test drive" of a wastewater infrastructure system could be done even before it is being built or refurbished? Here, modelling can assist – models, even if not calibrated and validated against data, can provide an estimate on the behaviour of the plant to be built. Design and operational options can be tested using the model, often leading to a better design of the plant and/or its better operation, resulting in considerable cost savings or reduction of energy consumption.

---

[1] Dr. Manfred Schütze, Department of Water and Energy, Institut für Automation und Kommunikation e. V. (ifak), Magdeburg, Germany.

Whilst models are applied for many years in water engineering and many simulators for individual components of the water system have emerged over time (such as BEMUS, KOSIM, SWMM, MOUSE/MIKE Urban, QUAL2, to name just a few), it is worthwhile to identify potential impediments of model application and be aware of recent developments. Modelling may become even more important as recent national and European guidelines will pose additional challenges.

This conference contribution aims to provide an overview of recent modelling developments, in particular with regard to integrated modelling of the components of wastewater systems, providing also some examples of model implementations in the Simba# simulator (ifak, 2022).

2. MODELLING MODULES

2.1. Sewer system modelling

Modelling of water flows and pollution in sewer systems has a long history. After rainfall-runoff modelling, flow modelling can be roughly grouped into two approaches: hydrological modelling and hydrodynamic modelling. Hydrological modelling, sometimes called conceptual modelling, is simplifying the flow processes using concepts of flow translation between subcatchments and employing concepts of reservoir cascades. On the other hand, hydrodynamic modelling is more detailed (and computationally more demanding) as it is based on the numerical solution of the Saint Venant differential equations. Table 1 summarises some commonly applied modelling approaches. As the Simba# simulator includes modules for almost all approaches mentioned, (almost) any combination of those mentioned in the table can be utilised within the Simba# simulator. Special routines allow the import of network data from GIS systems and the estimation of impervious areas from EU COPERNICUS satellite data.

Table 1: Various modelling approaches for sewer and river systems.

Process		**Potential modelling approaches**	
Rainfall-runoff	Constant runoff coefficient	Wetting losses, depression storage, etc.	Other (user-defined) approaches
Flow	Hydrologic (linear and non-linear reservoir cascades)	Diffusive-wave approximation	Fully hydrodynamic (full solution of Saint Venant equations)
Pollutant transport	None	Conventional (Continuously stirred tank reactors)	Lagrange ("water parcels"; no numerical dispersion effects)
Phys.-biochem. transformations	Simple sedimentation approach	Sedimentation and resuspension	Transformation processes of any complexity

2.2. Wastewater treatment plant modelling

For modelling the biochemical processes of wastewater treatment plants, the mathematical description of the Activated Sludge Models IWA has emerged as state of the art. These have been implemented in a number of simulation packages, including Simba#.

As an example, Figure 1 illustrates a simple dynamic model for wastewater treatment plants, which also can be used to model (and to optimise) operation of the plant. The various components of the model (clarification and aeration tanks) simulate the physical and biochemical transformation processes, using, in this example, the Activated Sludge Model No. 3 (Henze et al., 2000).

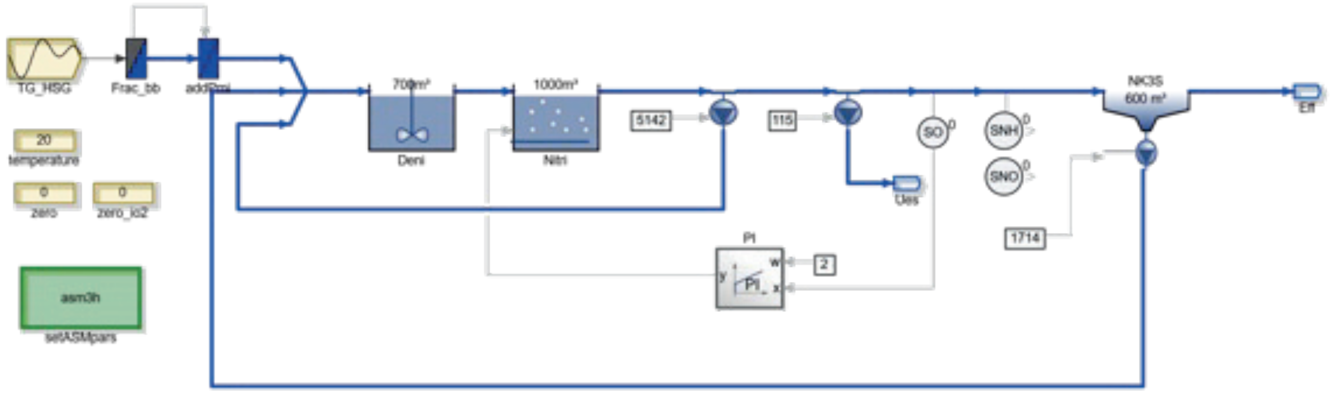

Figure 1: Example model of an activated sludge treatment plant.

A wide range of simulation modules allows to simulate and to analyse many different plant configurations and layouts and process control concepts (also including membrane-aerated bioreactors and many more). Conventional and advanced control concepts (also including model-based predictive control, see, for example, Alex, 2022) can be considered. Specific modules for aeration system components and energy balancing can be used to analyse energy efficiency of WWTPs, which becomes ever more important due to energy-labelling of WWTPs (CEN, 2021; DWA, 2016). All of these components allow to identify the best operational strategy for the specific conditions of any particular wastewater treatment plant. Such simulations can also provide useful information for detailed design and the operation of a plant. A common challenge in wastewater treatment modelling consists in the specification of the influent (flow and pollutants). However, methods derived from analyses of WWTPs from across Europe and also adapted to data-scarce conditions allow to specify WWTP influent information using data which are usually available anyway (Alex et al., 2020; Džubur, 2021).

2.3. River water quality modelling and assessment

Rivers (or, more generally, receiving water bodies) receive the discharges from sewer systems (Combined Sewer Overflows) and from WWTPs (treated wastewaters). These discharges, albeit being of quite different nature, can have important impacts on the water quality in the receiving water bodies. These discharges are of quite different nature (e.g. treatment plant effluents have usually lower contents of readily biodegradable organic matter (SS fraction of

Chemical Oxygen Demand) than combined sewer overflows) and their impacts are overlapping – thus making simple mixing calculations inappropriate in many cases. More recent guidelines (such as DWA, -A102 (2022), FWR (1998)) stipulate the evaluation of these impacts, usually related to Dissolved Oxygen and NH_4/NH_3 concentrations and a system of frequency-duration conditions of critical concentrations. Also the new EU Urban Wastewater Treatment Directive (EU, 2022) puts more emphasis on an integrated consideration than before. Whilst the River Water Quality Model of the IWA (RWQM) has been suggested as a rather comprehensive model, it is far too complex for practical applications. As a water quality model appropriate for such analysis of impacts of urban discharges, the Simple Water Quality Model (Schütze et al., 2011) has been suggested; it also now forms the base of the corresponding river water quality guidelines in the German Federal State of Hessen (HMUELV, 2012).

Figure 2 shows, as an illustration, an example from the literature (Schütze et al., 2017) of an integrated model where sewer system, WWTP and a simple river system are integrated in one single simulation model.

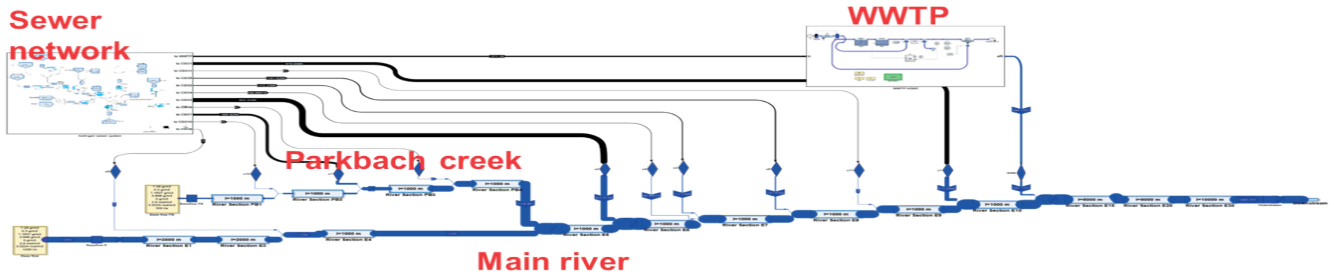

Figure 2: Integrated model of the Astlingen wastewater system.

A further step into modelling integration consists in the "Multi Solver" approach, integrating several solvers (so that each subsystem can use the numerical solution algorithm most appropriate to the subsystem) into one and the same simulation model. Figure 3 is an example of coupling drinking water and all components of the wastewater system (Schütze and Alex, 2022).

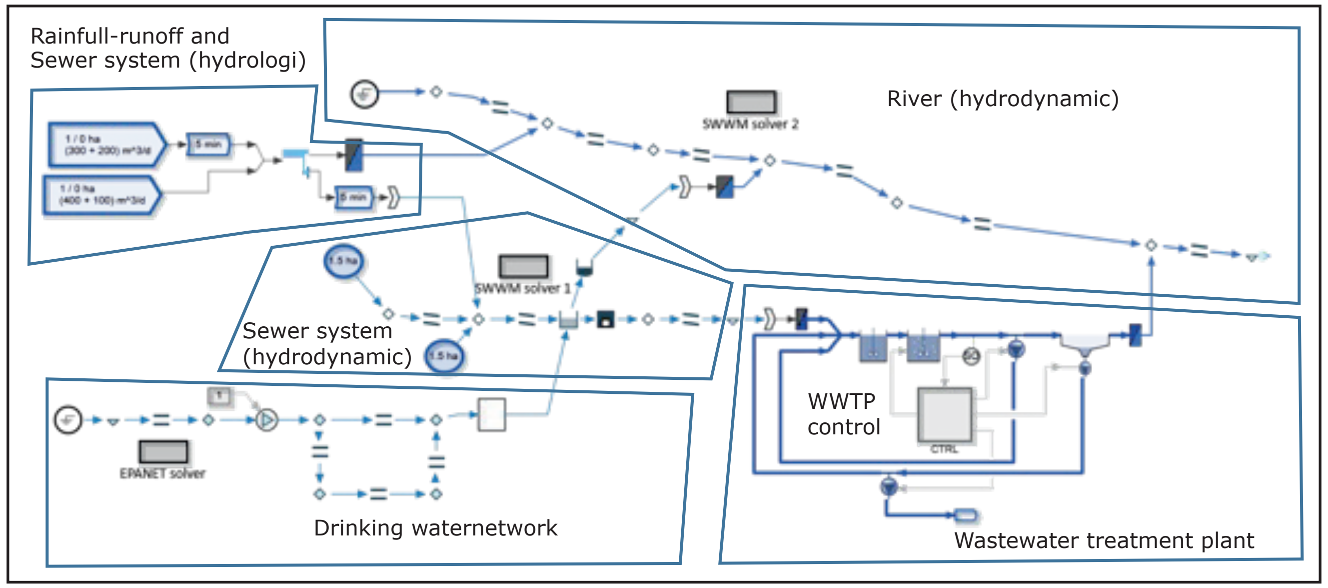

Figure 3: Multi-Solver simulator modelling different components of an urban water system using different solvers.

Source: Adapted from Schütze and Alex, 2022.

It is envisaged that such state-of-the-art modelling tools can assist water engineers in their important planning and operational tasks. Some general recommendations for integrated modelling are given in the HSG Integrated Modelling guidelines (see Muschalla et al., 2009).

REFERENCES

1. Alex, J., 2022. Design and runtime environment for model-based predictive controllers in water management. 13th IWA Conference on Instrumentation, Control & Automation - ICA 2022, Beijing/online, 17.-21. 10. 2022.
2. Alex, J., Förster, L. And Ogurek, M., 2020. Model Based Reconstruction Of WWTP Influent Data For Design, Evaluation And Simulation Studies. 13th IWA Specialised Conference on Design, Operation, and Economic of Large Wastewater Treatment Plants, Vienna.
3. CEN, 2021. CEN/TR 17614: Standard method for assessing and improving the energy efficiency of waste water treatment plants. Technical Committee 165, European Committee for Standardization, Brussels.
4. DWA, 2015. Arbeitsblatt A216: Energiecheck und Energieanalyse – Instrumente zur Energieoptimierung von Abwasseranlagen. German Water Association.
5. DWA/BWK, 2021. DWA-M 102/BWK-M 3 – Einleitung von Regenwetterabflüssen aus Siedlungsgebieten in Oberflächengewässer. German Water Association (DWA).
6. Džubur, A., 2021. Primjena dinamičkih simulacija na postrojenja za prečišćavanje komunalnih otpadnih voda sa aktivnim muljem. PhD thesis, University of Sarajevo.
7. EU, 2022. Proposal for directive concerning urban wastewater treatment. Available on: https://environment.ec.europa.eu/publications/proposal-revised-urban-wastewater-treatment-directive_en [26. 10. 2022].
8. FWR, 1998. Urban Pollution Management Manual. Foundation for Water Research. UK.
9. Henze, M., Gujer, W., Mino, T. and van Loosdrecht, M., 2000. Activated Sludge Models ASM1, ASM2, ASM2d and ASM3. IWA Scientific and Technical Reports, No. 9. IWA London.
10. HMUELV, 2012. Leitfaden zum Erkennen ökologisch kritischer Gewässerbelastungen durch Abwassereinleitungen. Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz. Available on: https://umwelt.hessen.de/sites/default/files/HMUELV/leitfaden_immissionsbetrachtung_stand_10-2012.pdf [17. 4. 2023].

11. ifak, 2022. Simulation system Simba#water. Version 5.0. Manual. Institut für Automation und Kommunikation e. V. Magdeburg. Available on: https://www.ifak.eu/en/products/simba-water [17. 4. 2023].
12. Muschalla, D., Schütze, M., Schroeder, K., Bach, M., Blumensaat, F., Gruber, G., Klepiszewski, K., Pabst, M., Pressl, A., Schindler, N., Solvi, A.-M. and Wiese, J., 2009. The HSG procedure for modelling integrated urban wastewater systems. Wat. Sci. Tech., 60, 8, 2065-2075.
13. Schütze, M. and Alex, J., 2022. A Multi-Domain Solver for integrated modelling. 12th Urban Drainage Mod. Conf.
14. Schütze, M., Ogurek, M. and Alex, J., 2017. Integrated modelling using a modern simulation framework; 14th Int. Conf. on Urban Drainage, Prague, 10. – 15.09.2017.
15. Schütze, M., Reussner, F. and Alex, J., 2011. SWQM - A simple river water quality model for assessment of urban wastewater discharges. 12th Intern. Conf. on Urban Drainage.
16. Shanahan, P., Borchardt, D., Henze, M., Rauch, W., Reichert, P., Somlyódy, L. and Vanrolleghem, P. A., 2001. River water quality model no. 1 (RWQM1): I. Modelling approach. Wat. Sci. Tech. 43, 5, 1-9.