Generation of diurnal variation for influent data for dynamic simulation

Motivation

Design guidelines for activated sludge (AS) plants that are based on static models such as the German DWA A131 (2000) are common practice in many countries. Over the last decades numerical models for activated sludge (AS) plants (Henze et al., 2000) have been becoming more popular and are generally used as a powerful tool to increase the detailed knowledge on the process and system behaviour, for optimisation studies (e.g. performance evaluation, operational optimisation, controller design, and conceptual process design), for training and teaching, and for model-based process control (Gernaey et al., 2004; Langergraber et al., 2004). Especially in German speaking countries numerical models are hardly used in the design process (Alex et al., 2007). The use of numerical models enables fine tuning of the plant design by including the evaluation of the dynamic behaviour as well as the design of control strategies.

To use dynamic simulation for the optimisation of design, diurnal variation of the influent data is required. If there are only few or no measurements available these influent data have to be generated. Gernaey et al. (2006) presented a method that is based on the pollutant load from each person in a catchment and considers also the layout of the sewer network. In this paper a simple approach to model diurnal variations that uses input data derived from the design of AS plants is presented. The aim is not to produce the exact diurnal variations that can be expected in reality, but to generate **input data for dynamic simulations with a realistic pattern for flow and concentrations in the case that no measured data are available**.

Model approach

The overall wastewater flows and concentrations are modeled as sum of different wastewater streams (infiltration water, nitrogen rich wastewater – i.e. urine with flush water, and domestic wastewater without urine). Rainwater is not considered in this paper but can incorporated easily.

Different wastewater streams are assumed to have **constant concentrations** and **variable flows**. Beside flow the concentrations for **COD, TKN and TP are considered**.

For the mathematical formulation of the periodic patterns **2nd-order Fourier series** are used. The three sources are mixed and finally moved through a plug-flow tank to describe the load retention in large sewer systems and optionally the primary clarifier.

Methods

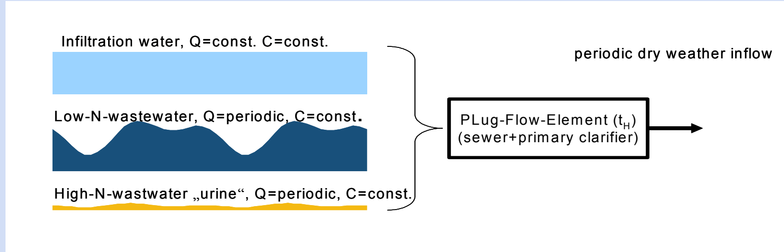
To describe the periodic flow pattern, four parameters are used: The minimum and maximum flow, Qmin and Qmax (described by the form parameters **fQ,min** and **fQ,max**) and the times when they occur, **tmin** and **tmax**, respectively. To describe nitrogen dynamics the following parameters are used: **fN,max** = ratio CTKN,max/CTKN,mean, **fmin,U** = % fraction of minimum urine flow rate to mean urine flow rate, and **dtN** TKN minimum and maximum relative to minimum and maximum of flow. Finally the hydraulic retention time of the water in the sewer system and primary clarifier **tPlug** is defined.

As a first step of implementation flows and concentrations have been fitted to measured data to derive general form parameters. Therefore measured data (flow, COD and TKN from two-hour composite samples from the influent of AS tanks) have been collected in total for more than 20 AS plants in Austria and Germany with plant sizes between 4'000 and 600'000 PE. The input data and the form parameters have then been used to generate the diurnal variation data.

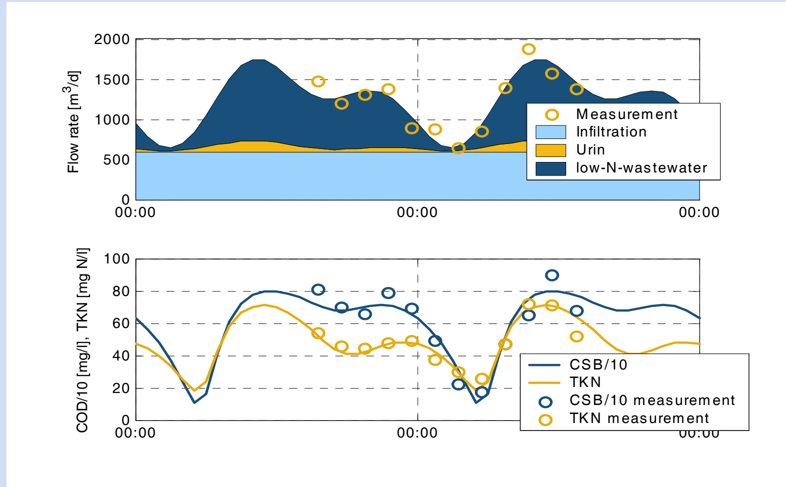
Based on the estimation of the form parameters for all data sets their dependence from the size of the AS plant (expressed as PE) has been investigated. A set of equations has been derived form correlations analysis for all form parameters (not shown). No dependency from the plant size could be found for fN,max and dtN; the parameters describing the behaviour of the TKN maximum. Table 1 gives calculated values for the form parameters using the equation derived for plant sizes from 5'000 to 400'000 PE.

Table 1. Form parameters for different plant sizes

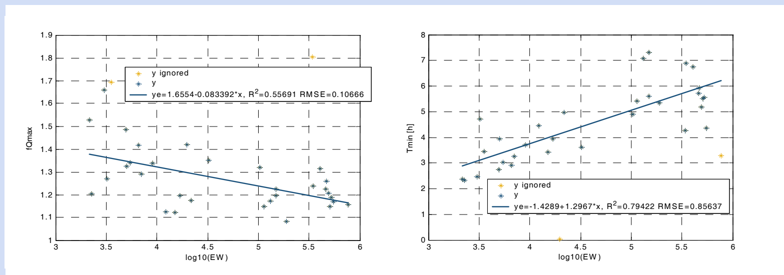
PE	5000	10000	20000	50000	100000	200000	400000	Generic
fQmin [-]	0.56	0.58	0.60	0.63	0.66	0.68	0.70	yes
tmin [h]	3.37	3.76	4.15	4.66	5.05	5.44	5.84	yes
fQmax [-]	*1.35*	*1.32*	*1.30*	*1.26*	*1.24*	*1.21*	*1.19*	no
tmax [h]	11.30	11.56	11.81	12.15	12.41	12.67	12.92	yes
fNmax [-]	*1.60*	*1.60*	*1.60*	*1.60*	*1.60*	*1.60*	*1.60*	no
fminU [-]	0.18	0.24	0.30	0.38	0.44	0.49	0.55	yes
dtN [h]	0.78	0.78	0.78	0.78	0.78	0.78	0.78	yes
tPlug [h]	*0.49*	*0.77*	*1.06*	*1.44*	*1.73*	*2.01*	*2.30*	no



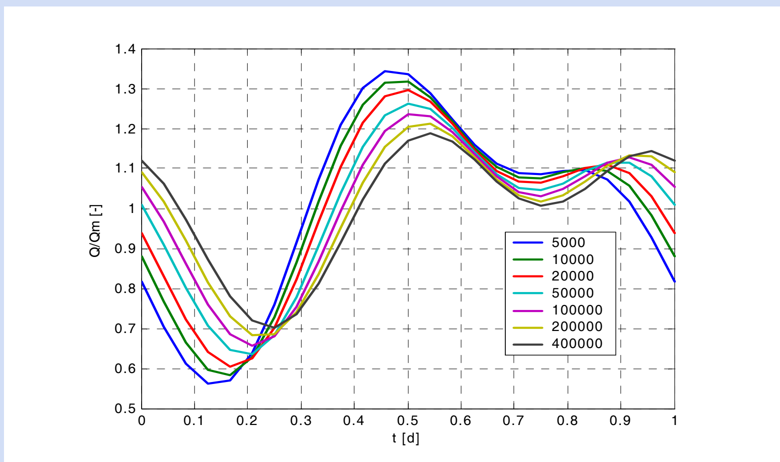
Model approach for periodic dry weather influent



Model fitted to one example data set (The form parameters (Qmin, tmin, Qmax, tmax, fN,max , fmin,U, dtN and tPlug) have been estimated by fitting the equations to the measured data of flow, COD and TKN. The total flow has been fitted to measured flow data. The Figure compares the measured and modelled flow and concentrations of COD and TKN for an AS plant. In general, a good fit to the measured data could be observed.)



Model parameter as function of PE (two examples, left: ratio of maximum flow rate/mean flow rate, right: time of minimum flow rate)



Typical flow pattern (function of PE)

Summary and conclusion

A simple method is presented to generate diurnal variations for input data for dynamic simulations in the case of no measured data are available. The input data required for the model are either available from the design process or simple to collect are:

- the daily influent dry weather flow and mean concentrations of COD, TKN and TP,
- the flow and concentrations of infiltration water and urine (with flush water),
- and the form parameters as summarised in Table 1 which are not generic (only fQmax, fNmax and tPlug).

By using this model, realistic diurnal variations for influent data for dynamic simulations can be generated. Having the objective – to produce realistic data sets – in mind the results show an excellent quality.

Alex et al. (2007) show how to get simulation results that are in compliance with the results from steady-state design models of AS plants. As an additional step this contribution links design of AS plants to fine tuning of planning using dynamic simulations by introducing a method to generate realistic influent data sets.

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G. Langergraber, N. Weissenbacher Institute of Sanitary Engineering and Water Pollution Control, University of Natural Resources and Applied Life Sciences, Vienna, Austria.
J. Alex ifak, Institut f. Automation und Kommunikation, Barleben, Germany.
D. Woerner iaks - Ingenieurbüro für Abfluss – Kläranlagen – Steuerung GmbH, Sonthofen, Germany.
M. Ahnert, Institute for Urban Water Management, TU Dresden, 01069 Dresden, Germany.
T. Frehmann Emschergenossenschaft/Lippeverband, Essen, Germany.
N. Halft Department of Environmental Engineering, RWTH Aachen, Germany.
I. Hobus WiW - Wupperverbandsgesellschaft für integrale Wasserwirtschaft mbH, Wuppertal, Germany.
M. Plattes Centre de Ressources des Technologies pour l'Environnement (CRTE), CRP Henri Tudor, Luxembourg.
V. Spering Institute of Sanitary Engineering and Waste Management (ISAH), University of Hanover, Hanover, Germany.
S. Winkler Vienna University of Technology, Institute of Water Quality, Resources and Waste Management, Vienna, Austria.

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