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Calibration and validation of a phenomenological influent pollutant disturbance scenario generator using full-scale data

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ABSTRACT

The objective of this paper is to demonstrate the full-scale feasibility of the phenomenological dynamic influent pollutant disturbance scenario generator (DIPDSG) that was originally used to create the influent data of the International Water Association (IWA) Benchmark Simulation Model No. 2 (BSM2). In this study, the influent characteristics of two large Scandinavian treatment facilities are studied for a period of two years. A step-wise procedure based on adjusting the most sensitive parameters at different time scales is followed to calibrate/validate the DIPDSG model blocks for: 1) flow rate; 2) pollutants (carbon, nitrogen); 3) temperature; and, 4) transport. Simulation results show that the model successfully describes daily/weekly and seasonal variations and the effect of rainfall and snow melting on the influent flow rate, pollutant concentrations and temperature profiles. Furthermore, additional phenomena such as size and accumulation/flush of particulates of/in the upstream catchment and sewer system are incorporated in the simulated time series. Finally, this study is complemented with: 1) the generation of additional future scenarios showing the effects of different rainfall patterns (climate change) or influent biodegradability (process uncertainty) on the generated time series; 2) a demonstration of how to reduce the cost/workload of measuring campaigns by filling the gaps due to missing data in the influent profiles; and, 3) a critical discussion of the presented results balancing model structure/calibration procedure complexity and prediction capabilities.

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Nomenclature

α_i Fraction of a given ASM1 state variable, where i can be S_I (α_{SI}), S_S (α_{SS}), X_I (α_{XI}), X_S (α_{XS}) and X_{BH} (α_{XBH})
A_1 Surface area of the variable volume tank ('Soil' model block) [m^2]
aH A parameter determining the direct contribution of rainfall falling on impermeable surfaces in the catchment area to the flow rate in the sewer ('Rain generator' model block) [%]
ASMs Activated Sludge Models
BSM1 Benchmark Simulation Model No.1
BSM2 Benchmark Simulation Model No.2
COD Chemical Oxygen Demand
COD_{part} Particulate COD
$COD_{part\_gperPEperd}$ COD_{part} load per person equivalent per day ('Households pollutants' model block) [(g COD pe^{-1}) d^{-1}]
$COD_{part\_Ind\_kgperd}$ COD_{part} load from industry per day ('Industry pollutants' model block) [kg COD d^{-1}]
COD_{sol} Soluble COD
$COD_{sol\_gperPEperd}$ COD_{sol} load per person equivalent per day ('Households pollutants' model block) [(g COD pe^{-1}) d^{-1}]
$COD_{sol\_Ind\_kgperd}$ COD_{sol} load from industry per day ('Industry pollutants' model block) [kg COD d^{-1}]
COD_{tot} Total COD
FFfraction Fraction of TSS that can settle in the sewer ('First flush effect' model block) [–]
G_{rain_Temp} Proportional gain to adjust the temperature after a rain event ('Temperature' model block) [–]
G_{snow_Temp} Proportional gain to adjust the temperature after a snow event ('Temperature' model block) [–]
InfBias Mean value of the sine wave signal for generating seasonal effects due to infiltration ('Seasonal correction factor' model block) [m^3 d^{-1}]
IWA International Water Association
K_{down} Gain for adjusting the flow rate to downstream aquifers ('Soil' model block) [m d^{-1}]
K_{inf} Infiltration gain ('Soil' model block) [$m^{2.5}$ d^{-1}]
M_{max} Maximum mass of stored sediment in the sewer system ('First flush effect' model block) [kg]
MC Monte Carlo simulation technique
N_{tot} Total *N* concentration [g N m^{-3}]
N_{org} Total organic *N* concentration [g N m^{-3}]
PE Person equivalent ('Households' model block) [–]
$Q_{Ind\_weekday}$ Average wastewater flow rate from industry on normal weekdays (Monday to Thursday) ('Industry' model block) [m^3 d^{-1}]
Q_{lim} Flow rate limit triggering a first flush effect ('First flush effect' model block) [m^3 d^{-1}]
Qpermm Flow rate per mm rain ('Rain generator' model block) [m^3 mm^{-1}]
Qpercm Flow rate per cm of snow ('Rain generator' model block) [m^3 cm^{-1}]
QperPE Wastewater flow rate per person equivalent ('Households' model block) [m^3 d^{-1} PE^{-1}]
S_U Inert soluble COD [g COD m^{-3}]
NH_{4Ind_kgperd} S_{NHX} load from industry per day ('Industry pollutants' model block) [kg N d^{-1}]
$NH_{4gperPEperd}$ S_{NHX} load per person equivalent per day ('Households pollutants' model block) [(g N pe^{-1}) d^{-1}]
S_B Readily biodegradable COD [g COD m^{-3}]
Subareas A parameter that forms a measure of the size of the catchment area. It will determine the number of variable volume tanks in series that will be used for describing the sewer system ('Sewer' model block) [–]
TKN Total Kjeldahl nitrogen [g N m^{-3}]
T_{Amp} Seasonal temperature variation, amplitude ('Temperature' model block) [°C]
T_{Bias} Seasonal temperature variation, average ('Temperature' model block) [°C]
Td_{Amp} Daily temperature variation, amplitude ('Temperature' model block) [°C]
Td_{Freq} Daily temperature variation, frequency ('Temperature' model block) [rad d^{-1}]
Td_{Phase} Daily temperature variation, phase shift ('Temperature' model block) [rad]
T_{Freq} Seasonal temperature variation, frequency ('Temperature' model block) [rad d^{-1}]
$TKN_{gperPEperd}$ *TKN* load per person equivalent per day ('Households pollutants' model block) [(g N pe^{-1}) d^{-1}]
TKN_{Ind_kgperd} TKN load from industry per day ('Industry pollutants' model block) [kg N d^{-1}]
T_{Phase} Seasonal temperature variation, phase shift ('Temperature' model block) [rad]
TSS Total suspended solids concentration [g.m^{-3}]
WWTP Wastewater treatment plant
X_{ANO} Autotrophic biomass [g COD m^{-3}]
X_{OHO} Heterotrophic biomass [g COD m^{-3}]
X_U Inert particulate COD [g COD m^{-3}]
$XC_{B,N}$ Particulate organic nitrogen [g N m^{-3}]
XC_B Slowly biodegradable particulate COD [g COD m^{-3}]
WWTP1 Data set for WWTP1 (Bromma, Stockholm, Sweden)
WWTP2 Data set for WWTP2 (Lynetten, Copenhagen, Denmark)