**Coupled Systems Mechanics,** *Vol. 9, No. 2 (2020) 111-123*
DOI: https://doi.org/10.12989/csm.2020.9.2.111 

# Daily influent variation for dynamic modeling of wastewater treatment plants

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*(Received January 11, 2020, Revised March 30, 2020, Accepted April 1, 2020)*

**Abstract.** Wastewater treatment plants (WWTPs) with activated sludge system are widely used throughout the most common technologies in the world. Most treatment plants require optimization of certain treatment processes using dynamic modeling. A lot of examples of dynamic simulations require reliable data base of diurnal variation of the inflow and typical concentrations of parameters such as Chemical Oxygen Demand (COD), Total Kjeldahl Nitrogen (TKN), etc. Such detailed data are not available, which leads to problems in the application of dynamic simulations. In many examples of plants, continuous flow measurements are only performed after the primary clarifier, whereas measurements from influent to the plant are missing, as is the case with the examples in this paper. In some cases, a simpler, faster and cheaper way can be applied to determine influent variations, such as the „HSG-Sim" method ("Hochschulgruppe Simulation"). "Hochschulgruppe Simulation" is a group of researchers from Germany, Austria, Switzerland, Luxembourg, Netherlands and Poland (see http://www.hsgsim.org). This paper presents a model for generating daily variations of inflow and concentration of municipal wastewater quality parameters, applied to several existing WWTPs in Bosnia and Herzegovina (B&H). The main goal of the applied method is to generate realistic influent data of the existing plants in B&H, in terms of flow and quality, without any prior comprehensive survey and measurements at the site. The examples of plants show the influence of overflow facilities on the dynamics of input flow and quality of wastewater, and a strong influence of the problems of the sewerage systems.

**Keywords:** municipal wastewater; input data; daily influent variation; HSG method; flow pattern generation; dynamic modeling

## 1. Introduction

Modeling approaches of wastewater treatment plants (WWTPs) can be static and dynamic. Both of these approaches have advantages and disadvantages. The former is faster to apply, it requires significantly less data (input parameters and boundary conditions), significantly lower funding for realization, etc. With the second approach, everything is more demanding.

If the goal is to achieve optimization of individual parts of plant or the entire system, a more detailed study of the wastewater treatment process and behavior of the plant by depending on the dynamics, etc., the priority is given to the second approach. The approaches and the differences between static and dynamic modeling are described in detail in the publications Alex *et al*. (2007)

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http://www.techno-press.org/?journal=csm&subpage=8 ISSN: 2234-2184 (Print), 2234-2192 (Online)

and Serdarevic and Dzubur (2016).

Standard procedures for dynamic modeling of WWTPs should lead to better quality assurance/quality control and confidence in the model output. It is not only important that the results of the model are applied in practice, it is also important that modeling approach is adapted to the necessary requirements. If the model predictions are reliable, model results are useful in practice. Some cases do not have enough defined input elements to be considered by more detailed approaches at all. This, of course, applies to other fields and research. The example of water treatment can be mentioned, where by setting lower level of parameters (which are defined by the legislation on water quality) a better quality of potable water is obtained, which results in higher treatment costs (Jusic and Milasinovic 2015). Another example is turbulent mixing in estuarine numerical models for two-layer shallow water flow (Kožar *et al*. 2018).

It is important to note that any modeling method used for simulation (in this case, flow and wastewater quality) should be checked. The starting process for the model calibration is usually adoption of default parameters which are recommended by previous research or provided with the model description. In addition to the validation, it is necessary to perform the verification of the method if quality data are available. It is only after the finalization of the validation and verification process that the method can be considered complete (Tasiopoulou *et al*. 2015).

Although dynamic modeling of WWTP is preferred, generally, the approaches to modeling differ depending on the application area. For example, the majority of North-American and European modelers use models in different ways. In Europe, dynamic models are most often used for process optimization, while in North-America most models are employed for design studies (Hauduc *et al*. 2009).

Modeling wastewater treatment can include: hydrodynamics, mass transfer, and kinetic aspects together or as partial segments. Simulation of fluid dynamics calculation (CFD) (Wang and Yan 2018) can also be used to obtain mass transfer data in the active sludge flow field. Such approaches are an integrated system between e.g., activated sludge models (ASMs), which they describe biological and chemical processes in reactors, and hydrodynamics.

Mathematical modeling of activated sludge systems has become a widely accepted tool for plant design and operation, training of process engineers and operators, and as research tool (Schutze *et al*. 2002). Dynamic modeling of WWTPs is performed using different methods, the most frequent being models with activated sludge (AS). The family of activated sludge models (ASM) is developed by the International Water Association (IWA). Some of these ASM models are: ASM1, ASM2, ASM2D, ASM3, etc. (Henze *et al*. 2000). There are also some other models based on Monod kinetics, which are described in detail by Gernaey *et al*. (2004). Monod kinetics have been usually used to study the growth rate of biomass in a bioreactor.

For both approaches - static and dynamic, guidelines on the procedure for implementing the modeling process are usually used. Thus, as example of a static approach, the German ATV-DVWK-A 131E (2000) standard can be used. This standard is commonly applied in practice in many European countries. However, there is an increasing need in European countries for the introduction of dynamic modeling already for the design of the plant. In this respect, in 2016, the already mentioned standard (Dimensioning of Single-Stage Activated Sludge Plants), which was based on previous research (Alex *et al*. 2007, 2009), was innovated.

The aim of this study was to prove that using dynamic simulations, the dimensioning according to ATV-DVWK-A 131E can be followed.

The most reliable way to implement dynamic modeling is by following some of the appropriate protocols. Since the modeling of wastewater treatment processes has become actual, several protocols and guidelines have been published, such as: STOWA, BIOMATH, WERF, HSG, GMP etc. All of these protocols were created with focus to different aspects of simulation projects and they were applied and quoted for years.

*Good modeling practice - GMP* (Rieger *et al*. 2013) is one of the most recent protocols, which is based on the interaction between modelers and the stakeholders. The differences of GMP to the above listed protocols relate mostly to: the design of measuring campaigns, using experimental methods in many steps and process of model calibration/validation (Rieger *et al.* 2013). The GMP protocol is implemented in five steps: 1) Project Definition, 2) Data Collection and Reconciliation, 3) Plant Model Set-up, 4) Calibration and Validation and 5) Simulation and Result Interpretation. The second step of this protocol includes the generation of diurnal variation for influent data for dynamic simulation and that is the topic of this paper.

## 2. Materials and methods

If dynamic processes are to be investigated and if they are used for fine tuning of the design of activated sludge plants, daily values of typical diurnal patterns might be required. Also, in order to optimize a WWTP by testing different management and maintenance plans, it is necessary to optimize daily variations of the influent flow and quality parameters.

There are at least three ways of determining the dynamic variation of flows and the quality of wastewater. One approach is monitoring with a two-hour composite sampler for at least 2 days (optimal for the whole week). The second way to determine the necessary daily variations is continuous monitoring of flow and quality parameters. This way is especially acceptable for cases which have planned continuous monitoring of these parameters during design and construction. Both of these ways for the oscillation determination require additional measurements of wastewater and quality parameters and also additional costs for their realization. And the third way is generation of diurnal variation for influent data. In the case of the mathematical modeling of WWTP, where there is insufficient input data for the influent available (continuous flow measurements and quality parameters or composite samples of them), an integrated method for generating input data can be used.

The method that can be applied for the third approach is the “HSG-Sim” method (“Hochschulgruppe Simulation”). The “HSG-Sim” method is an empirical method, which was developed on detailed data of a large number of existing plants (over 41 plants) in Germany and Austria (Langergraber *et al*. 2007, 2009, Spering *et al*. 2008). All these considered existing plants are with typical domestic wastewater and this method can be applied only under these conditions. This method is applied to generate the diurnal variation for influent data for dynamic simulation by using only input data on the plant (capacity, infiltration...) and quality parameters that are measured during the operation.

Therefore, the “HSG-Sim” method can be used to generate the input data for dynamic simulations with realistic pattern for flow and concentrations (Chemical oxygen demand - COD, Total Kjeldahl Nitrogen - TKN and Total Phosphorus - TP) in the case that no measured data are available (see Fig. 1).

As shown on the flowchart, the specific parameter values (total influent characteristics - Fig. 1) need to be set. These values represent the average daily values of the considered plant. The form parameters (step 1. - calculations field) that are as a function of the population equivalents (PE) (see Fig. 1- orange fields) need also to be set. Fractions and concentrations of infiltration water and urine

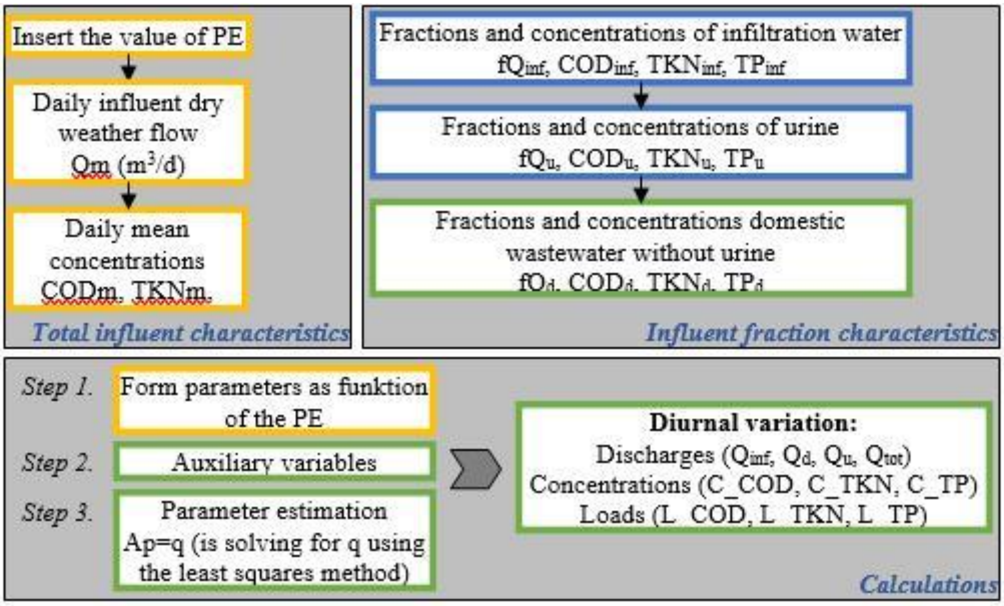


Fig. 1 Flowchart - “HSG-Sim” method application (according to Langergraber *et al*. 2007)

(blue fields) can be fine-tuned, although their default values are appropriate in most situations. And finally, the green fields represent the calculated fields, which do not change. All the above components/steps are described below in more detail.

Oscillations of flows and key quality parameters in domestic wastewater occur periodically. The oscillation period is usually one day.

In order for wastewater to be characterized in more detail, it needs to be divided into different components. They are different in quality compared one to the other (Gearney *et al*. 2006).

Therefore, the total flow (only for dry weather) consists of three different types of wastewater:

- infiltration water ($Q_{inf}$),
- urine flow ($Q_u$) and
- domestic wastewater without urine ($Q_d$).

These summarized wastewater components give a total flow of (municipal) wastewater plant. Rainwater is not considered in this model and design optimization is carried out for dry weather flows only. This approach considers the delay of wastewater in the sewage system as well as in the primary clarifier (Plug-Flow-Element) (Alex *et al*. 2015).

The wastewater flow to the plant can be described by the periodic harmonic function. Fourier series is used to define the inflow variation. With Fourier series, it is possible to present a periodic function as a sum of sine and cosine functions of various amplitudes, phases and frequencies (Kožar *et al.* 2018).

For the mathematical formulation of the periodic patterns 2nd-order Fourier series are used in the “HSG-Sim” approach. Certain parts of wastewater flows (Fig. 2) are described by Eqs. (1)-(3)

$$Q_{\inf}(t) = Q_{\inf} = const \tag{1}$$

$$Q_u(t) = Q_u + a_1 * \sin(\omega t) + a_2 * \cos(\omega t) + a_3 * \sin(2\omega t) + a_4 * \cos(2\omega t) \tag{2}$$

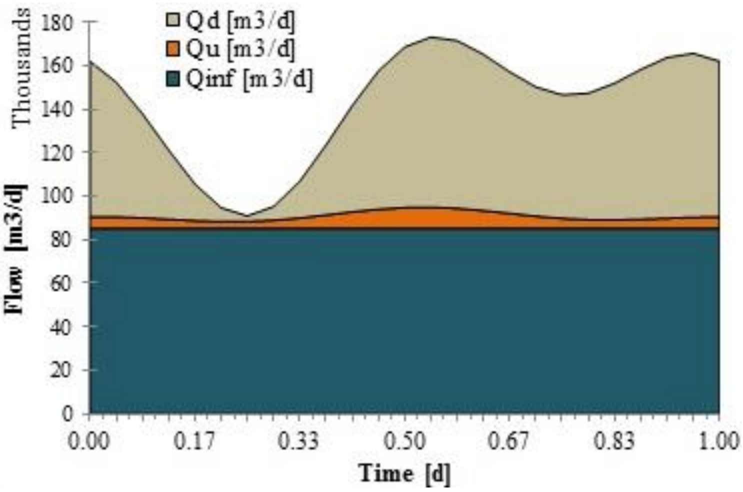


Fig. 2 Influent discharge, composed of three wastewater components (infiltration water ($Q_{inf}$), urine flow ($Q_u$) and domestic wastewater without urine ($Q_d$)

Table 1 Part of the second parameter set (Spering *et al*. 2008, Langergraber *et al*. 2009)

| Parameter/PE | 5.000 | 50.000 | 500.000 |
|---|---|---|---|
| $f_{Q,\min}$ (-) | 0.50 | 0.56 | 0.64 |
| $t_{\min}$ (h) | 3.31 | 4.64 | 5.97 |
| $f_{Q,\max}$ (-) | 1.40 | 1.32 | 1.22 |
| $t_{\max}$ (h) | 11.18 | 12.28 | 13.20 |
| $f_{N,\max}$ (-) | 1.60 | 1.60 | 1.60 |
| $f_{\min,U}$ (-) | 0.15 | 0.35 | 0.55 |
| $D_{tN}$ (h) | 0.67 | 0.59 | 0.51 |
| $t_{plug}$ (h) | 0.61 | 1.20 | 1.79 |

$$Q_d(t) = Q_d + b_1 * \sin(\omega t) + b_2 * \cos(\omega t) + b_3 * \sin(2\omega t) + b_4 * \cos(2\omega t) \tag{3}$$

where $\omega=2\pi/T$; $T$=1 day, $a_1$ ... $a_4$, $b_1$ ... $b_4$ are constant parameters (Langergraber *et al*. 2007).

The eight constant parameters can be obtained from four boundary conditions, where each of the extreme values occurs at a certain time:

- $Q_{\min} \leftrightarrow t_{\min}$ ($Q_{\min}$ described by the form parameters $f_{Q,\min}$),
- $Q_{\max} \leftrightarrow t_{\max}$ ($Q_{\max}$ described by the form parameters $f_{Q,\max}$),
- Minimum urine flow occurs at $t_{\min}$-$\Delta t_{N1}$,
- Maximum TKN concentration occurs at $t_{\max}$-$\Delta t_{N2}$.

The first two form parameters describe the periodic flow pattern, i.e., minimum and maximum flow ($Q_{\min}$ and $Q_{\max}$) and the times ($t_{\min}$ and $t_{\max}$) when they occur. The other two form parameters describe nitrogen dynamics (Langergraber *et al*. 2007).

The “HSG-Sim” method is implemented with a default set of parameters recommended from the research in the previous years. At the beginning of the research, a set of parameters (first parameter set) was obtained, based on the measured data of real plants (19) from Germany and Austria (Langergraber *et al*. 2007). The capacity of the plants was from 4.000 to 150.000 PE. Following the research, new published form parameters (second parameter set) are based on large number of plants (41), with capacity from 4.000 to 650.000 PE, and also from the same countries (Langergraber *et al*. 2009, Spering *et al*. 2008).

The first and second parameter sets are partially different. Considering that the second set of parameters is based on a large number of plants, the same is taken in the research of this paper. The form parameters for three different capacities of plants (which are essential for this research) are presented in Table 1.

The auxiliary variables by step 2 (see Fig. 1) are required for the next calculation, i.e., for determining the boundary conditions. The Eq. (4) is used to solve this problem.

$$A \times p = q \tag{4}$$

Where:

$A$ - matrix of range 8×8,

$p$ - constant parameters,

$q$ - boundary conditions.

The matrix $A$ is a rectangular matrix of type ($m$, $n$). Assuming that $A \epsilon R_n$, matrix $A$ has a form:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \tag{5}$$

The elements $a_{i1}$, …, $a_{in}$ are the $i$-th row and $a_{1j}$, …, $a_{mj}$ are $j$-th column. Because $m=n$, matrix $A$ is square matrix i.e., matrix of order $n$. In a short form, this matrix can be written as $A=[a_{ij}]$.

Since the unknown parameters are $a_1 \ldots a_4$ and $b_1 \ldots b_4$ (represented by the vector $p$), it is necessary to further apply the Eq. (6)

$$p = A^{-1} \times q \tag{6}$$

The equation is solved for $p$ using the least squares method. The vector $p$ in this case represents the constant parameter and should be calculated by the multiplication of the inverse matrix and the vector $q$.

To define multiplication between inverse matrix $A$ and vector $q$, the vector should be in the form of a column matrix. The matrix-vector product is only to define for the case when the number of columns in matrix $A$ is equal the number of rows in vector $q$.

The matrix $A^{-1}$ is inverse matrix of a square matrix $A$, such that

$$A \times A^{-1} = I \tag{7}$$

where $I$ is identity matrix. The square matrix $A$ has an inverse if the determinant $|A| \neq 0$ and it is the so-called invertible matrix theorem (Lipschutz and Lipson 2008). More about multiplying the matrix can be found in Goumas *et al*. (2008) and Schatz *et al*. (2016).

The "HSG-Sim" method is available for free as MS Excel file on the webpage *www.hsgsim.org*. This Excel workbook implements the method described by Langergraber *et al*. (2007). It is also integrated in the commercial program SIMBA#. The program SIMBA# was developed by Ifak Institute in Magdeburg, Germany *(https://www.ifak.eu/de)*. SIMBA# allows the holistic consideration of sewer system, wastewater treatment plant, sludge treatment and rivers. This commercial simulation software package also implemented ASM models that are most commonly used for simulation of the AS process.

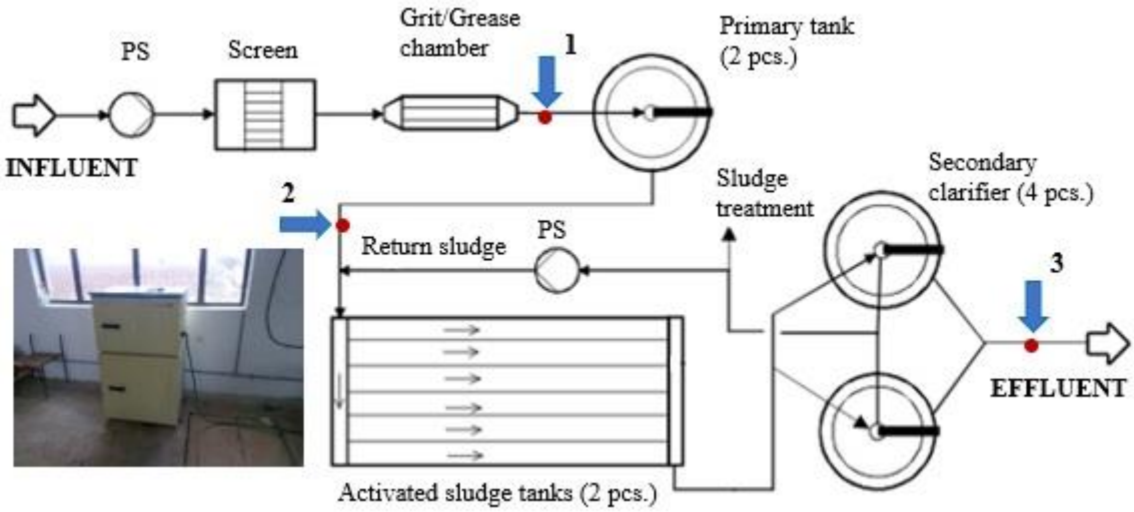


Fig. 3 Scheme of the WWTP Butile/Sarajevo with location of the automatic samplers; 1 - downstream of aerated Grid/Grease Chamber, 2 - inlet to biology and 3 - effluent

## 3. Results and discussion

This paper presents the generation of diurnal flow pattern obtained at the inlet of municipal wastewater treatment plants in Bosnia & Herzegovina (B&H). Examples of plants used in the research are: Butile/Sarajevo, Bihac, Ljubuski and Konjic.

Since the paper deals with defining the variation of the inflow and quality parameters of the plants, it is important to list their basic measuring equipment (measurement of influent flow and quality parameters). The number of sites where continuous monitoring of the influent of wastewater is carried out on plants is different, as well as the locations where appropriate measuring equipment is installed. Nowadays, control, monitoring and maintenance of the WWTP (especially medium and large plants) is done through SCADA (supervisory control and data acquisition) system. Sampling and analyzing the quality of wastewater is usually carried out on the so-called composite samples.

The first location of quality measuring i.e., sampling points at the WWTP Butile/Sarajevo is behind the grit and grease chamber and before the primary tanks - sampler 1. The second and third measuring locations with composite sampling are shown in Fig. 3.

Continuous measurement of wastewater flow is performed after the primary tanks and effluent. There is no continuous measurement of quantities at the inlet (raw wastewater), which presents one of the problems in the control and maintenance of the plant. The WWTP Butile/Sarajevo has been described by Serdarevic and Dzubur (2018, 2019).

Automatic sampling of wastewater and testing at the plant laboratory in Bihac is carried out at two sites. The first sampler was installed after fine screens and the second sampler was installed on the outlet and UV disinfection chamber. The flow measurement at the Bihac plant is regulated with an electromagnetic flow meter after the inlet pumping station and effluent measuring with a flow meter type Khafagi-Venturi.

For WWTP Ljubuski, the measuring data are measured with flow meters - Khafagi-Venturi, with capacity of $Q$=35 l/s and $Q$=100 l/s. The first flow meter is located behind the grit chamber i.e., before the aeration tank and the second flow meter after the disinfection. Two automatic samplers

Table 2 Wastewater characteristics of influent of some WWTPs in B&H (Butile/Sarajevo, Bihac, Ljubuski and Konjic)

| Parameters | Unit | WWTP Butile/Sarajevo | | | WWTP Bihac | | |
|---|---|---|---|---|---|---|---|
| | | Jul-17 | | | Sep-18 | | |
| | | Average | Max | Min | Average | Max | Min |
| Q | $m^3/d$ | 142,031.77 | 209,989.70 | 12,437.60 | 6,395.13 | 7,327.92 | 6,072.00 |
| $BOD_5$ | mg/L | - | - | - | - | - | - |
| COD | mg/L | 186.64 | 455.00 | 104.00 | 243.88 | 272.00 | 216.00 |
| TSS | mg/L | 118.63 | 607.00 | 20.00 | 187.38 | 240.00 | 130.00 |
| VSS | mg/L | - | - | - | - | - | - |
| TN | mg/L | 18.72 | 21.40 | 16.20 | 17.78 | 21.80 | 13.00 |
| TKN | mg/L | 16.74 | 18.17 | 15.32 | 16.95 | 19.59 | 13.83 |
| NH4-N | mg/L | 10.92 | 14.20 | 7.68 | 13.56 | 16.70 | 10.90 |
| TP | mg/L | 2.29 | 2.73 | 1.84 | 4.30 | 5.47 | 2.50 |
| Temp. | °C | 16.63 | 20.00 | 14.00 | 18.40 | 19.00 | 17.30 |
| pH | - | 7.72 | 8.27 | 7.45 | 6.95 | 6.97 | 6.93 |
| Parameters | Unit | WWTP Ljubuski | | | WWTP Konjic | | |
| | | 2017 | | | 2017 | | |
| | | Average | Max | Min | Average | Max | Min |
| Q | $m^3/d$ | 950.00 | - | - | 1,073.50 | 1,377.00 | 495.00 |
| $BOD_5$ | mg/L | 212.35 | 478.00 | 76.00 | 206.42 | 330.00 | 108.00 |
| COD | mg/L | 404.77 | 602.00 | 212.00 | - | - | - |
| TSS | mg/L | 124.23 | 320.00 | 12.00 | 161.00 | 280.00 | 76.00 |
| VSS | mg/L | 267.27 | 546.00 | 126.00 | 123.50 | 223.00 | 58.00 |
| TN | mg/L | 45.74 | 83.00 | 26.60 | - | - | - |
| TKN | mg/L | - | - | - | - | - | - |
| NH4-N | mg/L | 31.77 | 45.40 | 15.60 | - | - | - |
| TP | mg/L | 5.04 | 7.57 | 2.73 | - | - | - |
| Temp. | °C | - | - | - | - | - | - |
| pH | - | 7.97 | 8.60 | 7.66 | - | - | - |

sample wastewater on the inlet and the outlet from the plant.

The first flow measuring for the WWTP Konjic is between the fine screens and following pre-treatment facilities and equipment. The effluent flow meter is located after the equalization tank. Sampling and testing of wastewater quality is carried out at the inlet to biological treatment and effluent.

Table 2 gives a summary of the average, maximum and minimum values of flow (Q) and some of the parameters (Biochemical Oxygen Demand - $BOD_5$, Chemical Oxygen Demand - COD, Total Suspended Solids - TSS, Volatile Suspended Solids - VSS, Total Nitrogen - TN, Total Kjeldahl Nitrogen - TKN, Ammonium - NH4-N, Total Phosphorus - TP, Temperature and pH) for WWTPs that are the subject of research in B&H for the specified period of consideration. Some of these data values (Q, COD, TKN and TP) from the previous table were used for modeling and applying the "HSG-Sim" method, while the fraction of infiltration water and total flow was assumed based on the previously described wastewater analysis (Table 3).

Table 3 Input data for modeling of WWTPs in B&H

| Input data/WWTP | Sarajevo | Bihac | Ljubuski | Konjic |
|---|---|---|---|---|
| PE* | 600.000 | 55.000 | 6.000 | 5.000 |
| Daily influent dry weather flow ($m^3$/day) | 142.031 | 6.790 | 950 | 1073 |
| Fraction of infiltration water/total flow (-) | 0,6 | 0,5 | 0,3 | 0,45 |

*Pollutant equivalent for the first phase of the plant construction

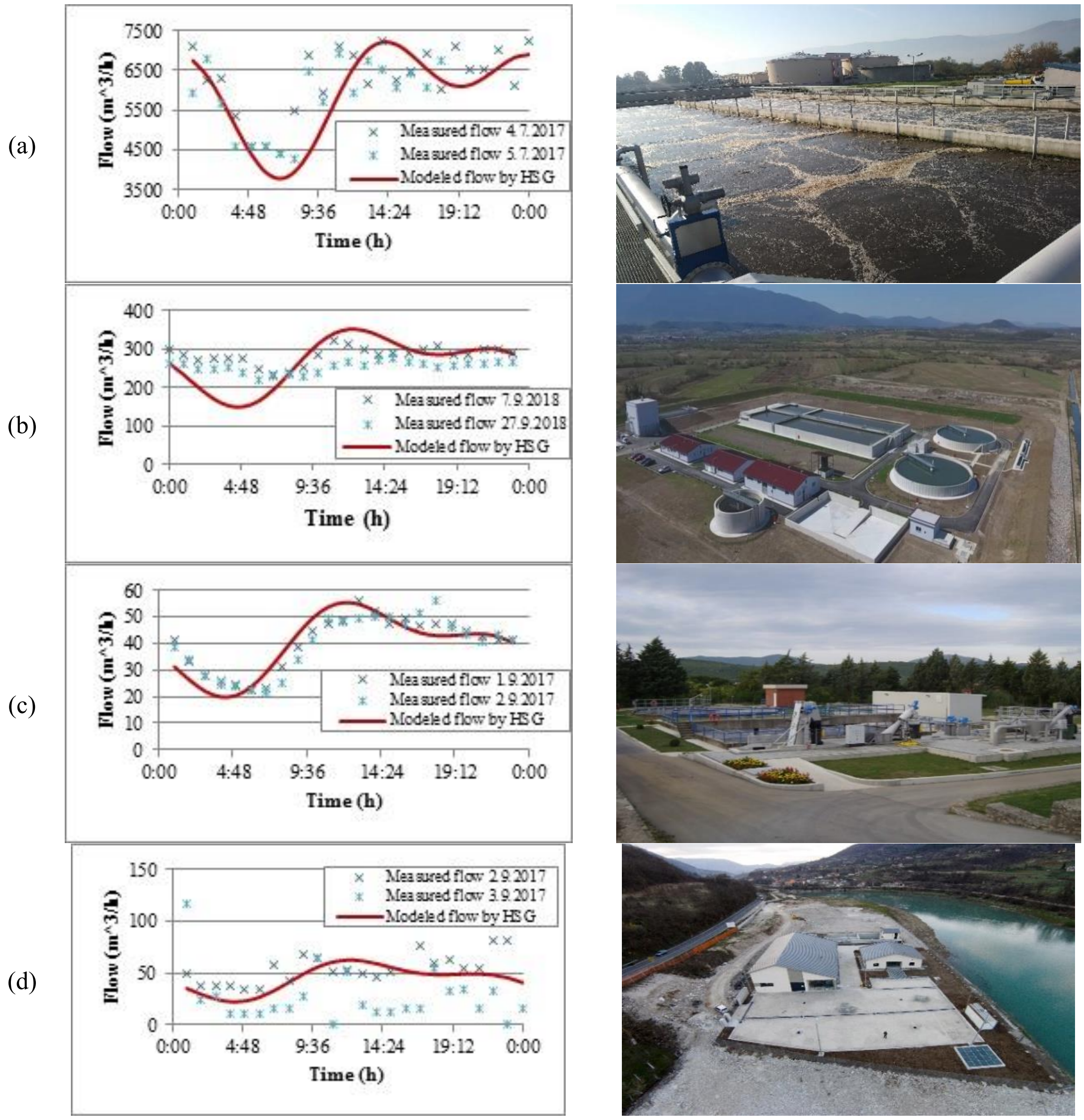


Fig. 4 Charts with comparison of measured and modeled inflow (left side) and view* of WWTPs in B&H (right side): (a) Sarajevo - 600.000 PE, (b) Bihac - 55.000 PE, (c) Ljubuski - 6.000 PE, (d) Konjic - 5.000 PE

*Photos by: Alma Dzubur (October 2018), https://vikici.net (uploaded on May 2019), Lana Bubalo (August 2016), Tarik Muhibic (2017), respectively.

Table 4 Measured flow data for WWTPs in B&H

| Measured flow ($m^3/h$) | WWTP Sarajevo | | WWTP Bihac | | WWTP Ljubuski | | WWTP Konjic | |
|---|---|---|---|---|---|---|---|---|
| | 4.7.2017 | 5.7.2017 | 7.9.2018 | 27.9.2018 | 1.9.2017 | 2.9.2017 | 2.9.2017 | 3.9.2017 |
| Average | 6272.76 | 5804.75 | 282.74 | 253.58 | 40.21 | 39.58 | 61.20 | 26.09 |
| Max | 7241.27 | 6940.23 | 305.21 | 273.51 | 56.17 | 56.14 | 171.00 | 117.00 |
| Min | 4430.42 | 4266.99 | 240.05 | 225.37 | 22.73 | 22.04 | 34.00 | 0.00 |

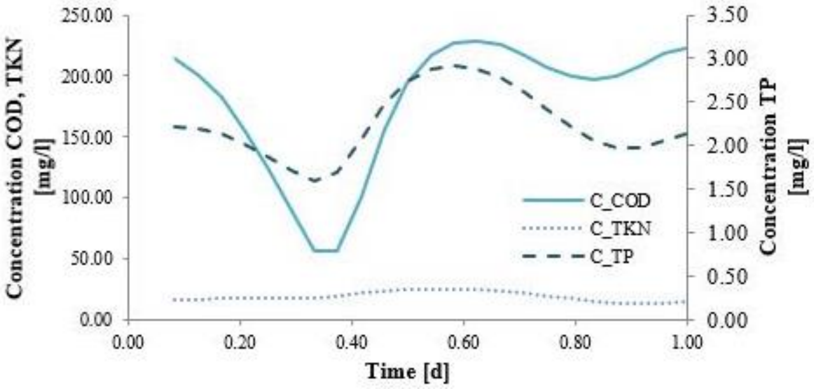


Fig. 5 Modeled influent concentration profiles of COD, TKN and TP for WWTP Butile/Sarajevo

By comparing the values of the quality parameters, it is evident that wastewater from the WWTP Butile/Sarajevo is significantly diluted compared to wastewater from Ljubuski.

In addition to the modeled flow curve (Fig. 4, red curve), for each of the plants, the variations of the actual inflow to the plant during the two selected days were shown. The values of the flows that were analyzed are 1-h values. Specific dry weather flow values (average, max and min) are presented in Table 4 and graphically shown with their individual marks in Fig. 4.

Fig. 4 presents the diurnal flow pattern obtained at the inlet of a municipal wastewater treatment plants in Bosnia & Herzegovina (Butile/Sarajevo, Bihac, Ljubuski and Konjic).

It is recommended exactly for these examples of plants, where available data on the plant, the measured values of quantity and quality of wastewater are not sufficient, etc. to use the “HSG-Sim” method for generating a diurnal flow pattern, where mathematical modeling is required for some of the above cases. The method of generating input data developed in *Excel* is applicable to WWTP, with prior data quality analysis.

Input data used for modeling for the existing plants in B&H are presented in Table 3 and form parameters for this model are default values (Table 1). If we compare the measured and the modeled flow values (see Fig. 4), the smallest deviations are at the plant in Ljubuski (c) because of the good condition of the sewage system (also, it has the lowest infiltration). It is also noted that the measuring points at the above plants are displaced from the input to the biological treatment (described above), which leads to reduction of peak influent and it also influences the variations in the quality of wastewater. In this connection, even greater significance is given to this method, which can eliminate a significant financial cost for the installation of additional equipment for flow measurement and analysis of quality parameters at the inlet to the plant.

The Fig. 5 shows variations of wastewater quality by applying the “HSG-Sim” method, which is described in the flowchart (see Fig. 1). This is an example of wastewater quality variation according the key quality parameters form WWTP Butile/Sarajevo. These three curves represent the modeled daily variations of the concentrations of organics and nutrients in the wastewater. The organic matter in the wastewater is represented by Chemical oxygen demand (COD) and the nutrients by Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP).

## 4. Conclusions

If measurements are not available, dynamic flow rate (influent) can be generated by using the Fourier series which are used in the "HSG-Sim" method (Langergraber *et al*. 2007, 2009, Spering *et al*. 2008).

This paper presents the approach of determining relevant input data and adopting form parameters (based on a large number of data of existing plants), necessary when using the "HSG-Sim" method which could be applied to the existing plants in Bosnia and Herzegovina (Džubur *et al*. 2018). The "HSG-Sim" method is used to generate realistic diurnal variations for input data for dynamic simulations in case that there are not enough measured data. This model was applied to the four existing plants in B&H (WWTPs in Butile/Sarajevo, Bihac, Ljubuski and Konjic). Input data required for the model are available from projects or they are collected during the treatment processes (so-called process parameters).

This method is the appropriate way for the synthetically construction of daily hydrographs where no detailed measured data are available and it has great significance, especially in transition countries such as B&H. The method is especially useful when limited budget is available. In this way it is possible (in the case that detailed measured data are not available) to draw certain conclusion about plant operation, control, maintenance, real plant expansion, etc.

Particular importance for applying this method to WWTPs in B&H is given due to the lack of continuous measurement of the flow and key quality parameters of the influent (raw wastewater), which is presented with experimental results. In order to continue this research, it is recommended to install a flow meter and a sampler at the inlet of least one of the analyzed plants. With continuous flow measuring and analyzing the influent a detailed analysis could be achieved, including the comparison of these values with the modeling results. The following step links the results of the "HSG-Sim" method and the design of WWTP to fine tuning of planning using dynamic simulations.

## Acknowledgments

Measured flow data and wastewater quality parameters were obtained from municipal utilities water supply and sewerage (Sarajevo, Bihac, Konjic and Ljubuski) with the help of plant managers and their associates. Special gratitude for a good mutual cooperation is expressed to the employees of these WWTPs, who perform the tasks of control and maintenance.

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