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Model based control of filter run time on potable water treatment plant

Suvada Jusic*[1] and Zoran Milasinovic[2]

[1]*Department of Water Resources Engineering and Environmental Engineering, Faculty of Civil Engineering, University of Sarajevo, 30 Patriotske lige street Sarajevo, Bosna i Hercegovina*
[2]*Department of Theoretical and Applied Hidromechanics and Hydraulic Structures and Facilities, Faculty of Civil Engineering, University of Sarajevo, 30 Patriotske lige street Sarajevo, Bosna i Hercegovina*

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Abstract. Control of potable water treatment plant (PWTP) is nowadays based on experience. The aim of this article is to show that model based control of treatment process is more efficient than process operation based on experience. Stimela environment is used for modeling of processes of potable water treatment. Application of the model was conducted on PWTP "Crkvice" in Zenica (BiH). This plant has used conventional rapid sand filters. By effective application of the model it is determined the optimal filter run time for different input turbidity of raw water. This results in the possibility of reducing the consumption of backwashing water, lower costs for its pumping and reducing the amount of coagulants. In the existing practice, based on experience, these benefits are not used.

Keywords: mathematical model; potable water treatments; rapid sand filtration; filter run time; model based control

1. Introduction

The challenge is now to shift the operation of Potable Water Treatment Plant PWTP from experience driven to knowledge based. Mathematical process models are a reflection of the knowledge of the treatment processes (Van Schagen 2009). Model becomes a central point in knowledge and input for calibration and validation comes from practice. Mathematical process models that describe typical process behavior are crucial for achieving further improvement in design and operation of water treatment process performance (Bakker *et al*. 2014).

The plant–wide process objectives are water tasteful, clear and healthy to drink. The objective is also related to the minimization of operational cost and environmental impact, while maximizing plant reliability. Using the modeling capabilities, the goal is to ensure water quality in accordance with standards of drinking water quality (safe water supply), and thereby minimize operational costs and negative impact on the environment (e.g., to minimize losses of water to wash the filters, also to minimize the consumption of chemicals, energy, etc). In water treatment the lower level of the parameters means better water quality, but the higher treatment costs. Model

∗Corresponding author, Professor, E-mail: suvada_jusic@gf.unsa.ba

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based control is challenge and way to decrease treatment costs, on the way to decrease consumption of chemicals, energy or backwashing water. This paper discusses the opportunities and applications of modeling the process of rapid filtration in direction of model based control of filter run time / filtration cycle time, as operational parameter. This parameter is defined in more detailed in Chapter 2.2.1.

2. Filtration process modeling by stimela environment

2.1 Set-up of the stimela model

Different models exist for the evaluation of drinking water treatment processes (Dudley et al. 2008). One of them is the Stimela environment. Stimela is an environment, developed at the Delft University, the Netherland. For the use of models to evaluate the data from drinking water treatment plants (and pilot plants) a website is being developed where Stimela environment can be approached and communication about the results can occur (www.stimela.com). Models from Stimela environment are developed in Matlab/Simulink program. Matlab is a commercial modeling environment available from The MathWorks. It comprises a language geared around matrix methods and is extensively used in academia and as a prototyping environment. The most widely used toolbox is the simulation toolbox, Simulink.

The model of a process in the Stimela consists basically of 6 files (Rietveld 2005). In the initialization file, the number of input parameters, output parameters and ordinary differential equations (ODEs) are defined. In addition, the water quality parameters that are of interest in the process are given. In the parameter file the process parameters that are given in the process block are processed. The system file (s-function) is the heart of the model. In this file the ODEs are given in matrix notation. In addition, the output parameters are defined. The graphical output file gives the possibility for visualization of the output from the numerical integration. The remaining two files determine the graphical interface for insertion of process parameters. By Stimela environment different drinking water treatment processes can be modeled, conventional sand filtration process also. The main purpose of rapid filtration is the removal of suspended (and colloidal) solids.

2.2 Parameters of filtration

Table 1 provides an overview of filtration process parameters which have to be defined through Stimela modeling. The process parameters are subdivided into design, disturbance, operational, calibration and control parameters (Jusic 2012). After specifying the design, disturbance and operational characteristics of the process, the plant can be simulated for different set-points of the control parameters.

Features and operation of the filters, i.e. the quality of filtered water (filtrate), or the mode quality of filters are generally defined by control parameters, namely: the concentration of pollution particles (c) (mainly of suspended and colloidal) and pressure losses (I) through the filter filling, as output/control parameters (Table 1).

2.2.1 Filter run time as operational parameter

The time between two backwashing is filter run time / filtration cycle time. It is operational parameter of filtration (Table 1). Manipulative parameters are changed when the disturbance parameters negatively affect the control parameters in order to maintain the control parameters in the plant in the defined limits (prescribed by the drinking water guidelines, for example).

Control of filter operation is usually done by maintaining a constant level, constant speed of filtration or decreasing speed of filtration (Jusic 2012). In practice, washing, or regulating mode of filtration are caused by one or more of the following factors:

- Pressure losses – if losses increase, water level rises automatically above the filter filling, which initiates the need for washing.
- Turbidity – if the filtrate turbidity starts to increase, this indicates that the impurities are retained in the filter filling, again caught by water flow and carried away through the filling into the filtrate. This of course refers to the immediate washing of filters.
- Time – many plants wash filters using fixed schedule, adapted to the characteristics of water, which is treated (for example every 24 hours).
- Flow – some plants determine the water quantity that should be filtered between two washes.

The time to reach the limit values of control parameters of turbidity (t_1) and the pressure drop (t_2) depend on most of the mode of filters (filtration rate, *filtration run time* ...). For optimal operation of the filter, it is necessary to adjust adequately these two periods of time (t_1 and t_2). This optimization means actually finding an optimum *filtration run time*, or time period of operation between two washings (t_{opt}). Fig. 1 presents the dependence of control parameters through two cycles of filtration. For the most economically designed filter there should be that is $t_{opt} = t_1 = t_2$. However, for practical reasons, it is important that the maximum value of pressure drop is reached in a time t_2 shorter than time t_1, corresponding to the breakthrough of filtrates. Precisely, with an appropriate modification of operational parameters, it is possible to satisfy this condition and find the optimal filtration cycle, or an optimal *filter run time* (t_{opt}).

Control of filter operation is subordinated to the required quality of the filtrates. In achieving this quality, affect the level of prior preparation of water (via input disturbance parameters), as well as operating mode i.e., cleaning of filters (Jusic 2011). The control of the filter mode is affected by the operational parameters, especially by the *filter run time* and backwashing time (Table 1). Basic benchmark/indicator for possible changes and corrections of input and operational parameters are the output, i.e., control parameters. If they are not within prescribed limits (drinking water guidelines), it approaches to the appropriate corrections, or changes in operational parameters.

Table 1 Rapid sand filters – Overview of relevant parameters for Stimela modeling (Jusic 2012)

Parameters of Filtration		
Input –	Design:	filter surface area, filtration rate, filter bed height, number of bed layers, water level above the filter bed , filter porosity, grain size
	Disturbance:	water flow, the concentration of pollution (suspended solids, turbidity), temperature
Operational or manipulative:		*filtration cycle time / filter run time*, backwashing time, start time for backwashing
Output – Control:		concentration of filtered water pollution (suspended solids i.e. turbidity), disposition of pressures in the fill (pressure losses)
Calibration:		Lambda – coefficient of filtration, clogging constant, mass density of the flocks, number of completely mixed reactors

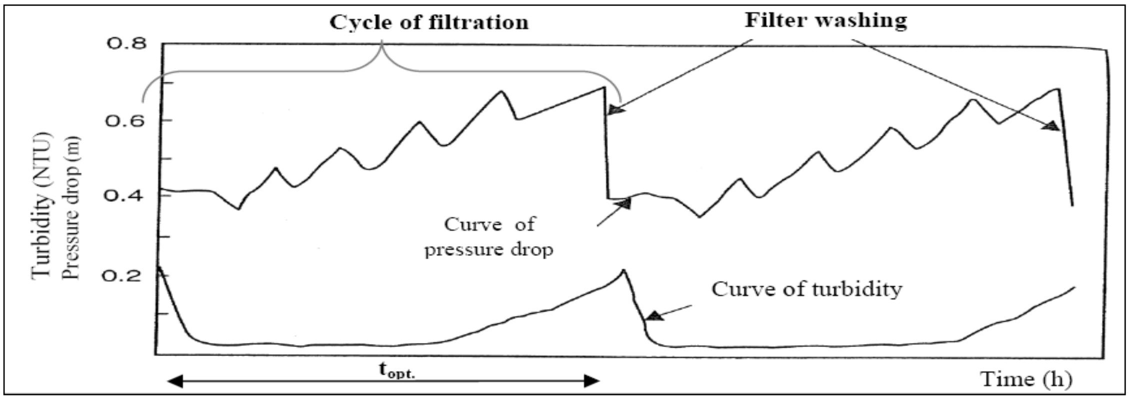

Fig. 1 A typical diagram of the dependence of filtered water turbidity and pressure losses in time – two cycles of filtration (Jusic 2012)

2.3 Mathematical formulation of filtration process

In the aim of mathematical formulation of filtration process the filter bed is subdivided into n unit elements (Fig. 2) and per unit element i per time step the different parameters are calculated (Van Schagen 2009). The suspended solids (c_i) concentration in the i^{th} unit element is the inflow for the subsequent element $i+1$. The suspended solids concentration (c_n) of the n^{th} element is the concentration leaving the filter bed and can be compared with measured effluent concentrations. The head loss over a unit element is the head loss gradient (I_i) times the height of the element (Δx). The sum of the head losses of the unit elements is the total head loss over the filter bed (I_n).

Water flows through a (sand) bed while the grains capture the particles and floc. Fig. 3 presents accumulation of suspended solids on filter grain (Rietveld 2005). The filtration rate (k_2) is dependent on the clean bad filtration coefficient λ_0 and the concentration of removed solids (c) (Milasinovic 2004). The concentration of the compound in the solid phase (c) is given as mass per volume reactor, whereas flows with pore velocity u/ε (m/s).

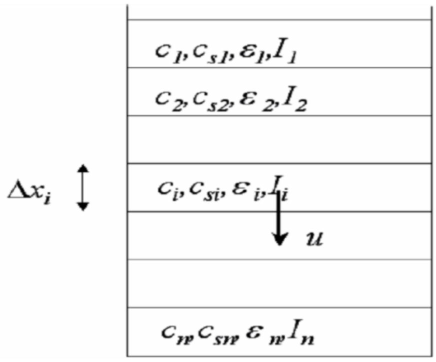

Fig. 2 Schematic representation of filter bed (Van Schagen 2009)

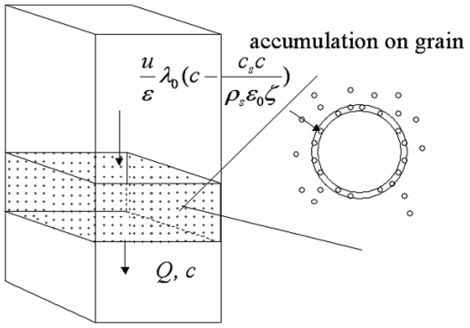

Fig. 3 Schematic impression of rapid filtration (Rietveld 2005)

Several authors (Ives, Amirharajah…) have tried to determine the clean bed filtration rate (k_2) in an empiric way for different circumstances (Ives 1973, Amirtharajah 1988). Elaborations of Ives equation is given by Moraudas. Mathematical formulation of filtration process in Stimela environment, as advection – dispersion type of model, is based on Maroudas' equation (for suspended solids concentration) and Carman Kozeny's equation (for head loss calculation in the filter bed) (Eqs. (1) and (2)) (Rietveld 2005).

$$\frac{dc_i}{dt} = -\frac{u}{\varepsilon_i}\frac{c_i - c_{i-1}}{\Delta x} - k_{2i}c_i\left(1 - \frac{c_{si}}{\rho_d \varepsilon_0 \zeta}\right)$$
$$\frac{dc_{si}}{dt} = -u\frac{c_i - c_{i-1}}{\Delta x} \tag{1}$$

$$I_i = I_0\left(\frac{\varepsilon_0}{\varepsilon_0 - \frac{c_{si}}{\rho_s}}\right)^2$$
$$I_0 = 180\frac{\nu}{g}\frac{(1-\varepsilon_0)^2}{\varepsilon_0{}^3}\frac{\nu}{d_0{}^2} \tag{2}$$

Where:
Δx - height of unit element (m),
k_2 - transfer coefficient / filtration rate (s^{-1}),
λ_0 - filtration coefficient (m^{-1}),
ζ - maximum pores filling (-),
ρ_s - density of solids (kg/m^3),
c - suspended solids concentration (kg/m^3),
c_{si} - concentration of accumulated solids in filter (g/m^3),
I_i - head loss gradient over unit element (-),
I_0 - initial head loss (-),

ε - porosity (-),
d_0 - particle diameter (m),
ν - cinematic viscosity (m^2/s).

These partial differential equations are converted into ordinary differential equations (ODE), usually by using either finite differences or a series of mixed tanks (Fig. 1) (Rietveld 2005). For a combination of three unit elements in series the system of ODEs becomes

$$\begin{pmatrix} \frac{dc_1}{dt} \\ \frac{dc_2}{dt} \\ \frac{dc_3}{dt} \end{pmatrix} = \frac{u}{\Delta x}\begin{pmatrix} 1 & -1 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 0 & 1 & -1 \end{pmatrix}\begin{pmatrix} c_0 \\ c_1 \\ c_2 \\ c_3 \end{pmatrix} - k_2\begin{pmatrix} c_{e1}-c_1 \\ c_{e2}-c_2 \\ c_{e3}-c_3 \end{pmatrix}$$
$$\begin{pmatrix} \frac{dc_{s1}}{dt} \\ \frac{dc_{s2}}{dt} \\ \frac{dc_{s3}}{dt} \end{pmatrix} = \frac{u}{\Delta x}\begin{pmatrix} 1 & -1 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 0 & 1 & -1 \end{pmatrix}\begin{pmatrix} c_0 \\ c_1 \\ c_2 \\ c_3 \end{pmatrix} \tag{3}$$

Matlab/Simulink provides a number of solvers for the simulation of such equations. The resulting ordinary differential equations are numerically integrated so that variations in time and space can be followed.

2.4 Algorithm – flowchart of rapid sand filtration modeling

After mathematical formulation of filtration process (its control parameters (Eqs. (1) and (2)) it is developed algorithm / flowchart for rapid sand filtration process through Stimela model. Program Matlab/Simulink through Stimela model has used algorithm for solving the conventional rapid sand filtration process. That algorithm is given in Fig. 4.

The flowchart indicates the sequence of operations used in the simulation procedure (Campos *et al*. 2006). The data required for implementation of the simulation model consist of disturbance (influent water quality concentrations) and design parameters as input data and operational and calibration parameters defined in Table 1. The next step is testing of model using result of simulation and measurement data from pilot, laboratory or full plant. Actually the model calculated values can be compared with measured data. After setting of calibration parameters and model testing, the next step is effective use of modeling (what could mean finding optimum filter run time, for example). Effective use could be obtained by changing operational parameters to the process block/file of Stimela model. By repeating this process for the various alternative operational scenarios of the system, most promising scenarios can be identified. The best alternative is implemented for operation of the filtration process. Of course, boundary conditions have to be satisfied.

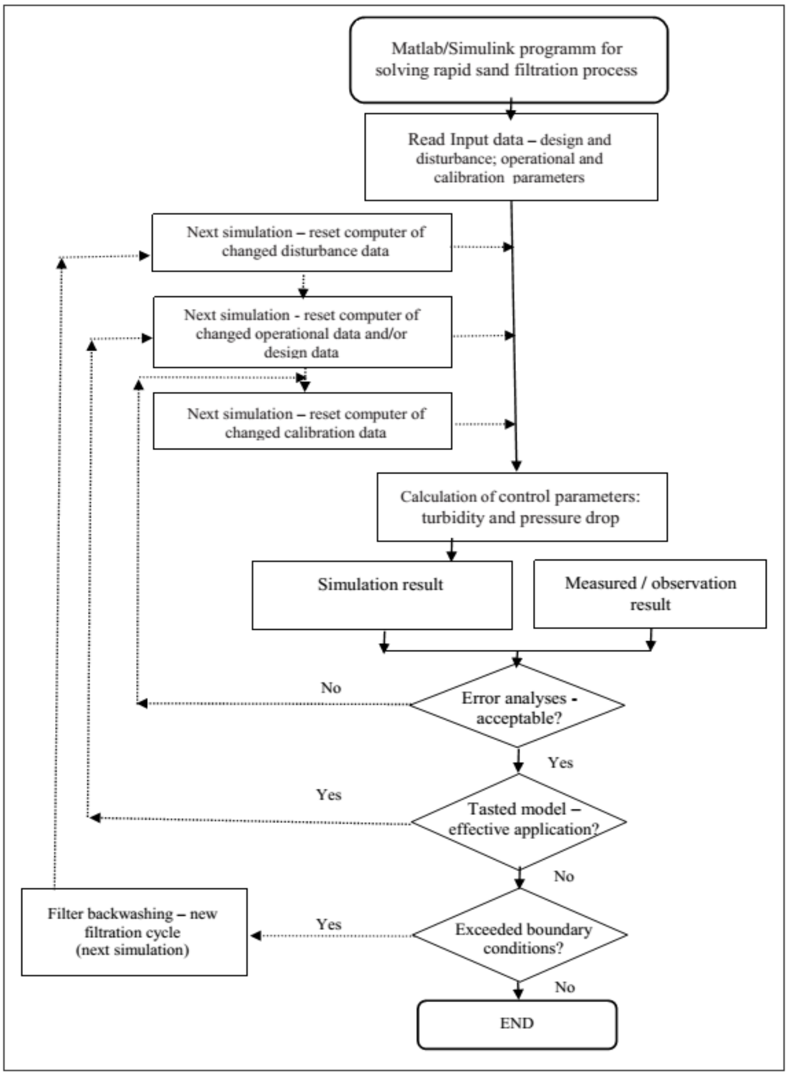

Fig. 4 Algorithm for rapid sand filtration process through Stimela model (Jusic 2011)

2.5 Graphical output – Numerical Integration

The issue of filtration process, which is defined by modeling, is primarily focused on detailed consideration of output/control parameters. When modeling or simulating the process of filtration, the output/control parameters are shown mainly graphically, i.e., in diagrams (graphical output). The graphical output gives the possibility for visualization of the output parameters from the numerical integration of ODEs. So, the results of simulations in the model, double layer filter of the Stimela environment provides graphical representation of output parameters (Fig. 5), and the graphical representation of changes in concentration of particulate pollutants (suspended solids or turbidity) of filtrates and pressure drop in time (Fig. 5, left) and graphical representation of changes in pressures at a depth of filter filling: Lindquist's diagram (Fig. 5, right) (Rietveld 2005).

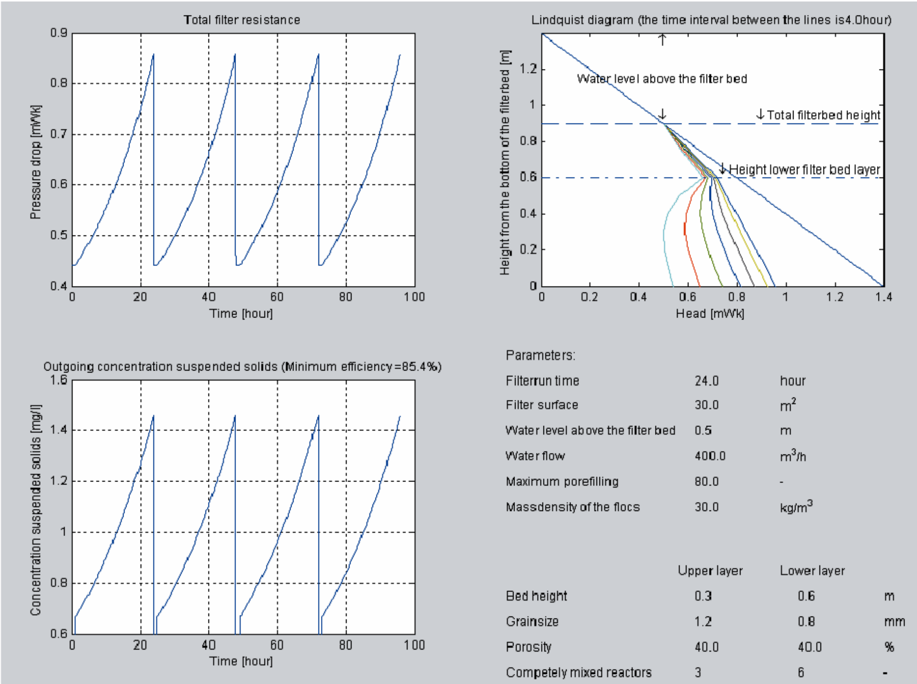

Fig. 5 Graphical output of simulation of (dual media) filtration (Rietveld 2005)

3. Model based control of filter run time on PWTP "Crkvice" Zenica

3.1 Effective application of model

The application of a model assumes the knowledge of the model, then the characteristics of the process and disposal with the appropriate database, i.e. parameters of the process from that PWTP (Jusic 2012). Disposal with the appropriate database means definition of input and operational parameters, and the understanding and evaluation of calibration parameters defined according to Table 1. Certainly, database includes also defining, collecting and analyzing the output control parameters for testing the model (measured data) (Fig. 4). Only after the steps performed of calibration and validation (testing) we can approach to more effective application of the model. To sum up, in order to efficiently use of modeling, for example to find the optimal filter run time, it is necessary previously to:

- define the basic characteristics of the plant, or the process,
- define database for modeling,
- test the model (perform calibration and verification),
- discuss the results of modeling for the purpose of effective use of the model.

3.2 Basic characteristic of PWTP "Crkvice"

Application of the model (from the Stimela environment) was conducted in the PWTP which use the conventional rapid sand filters - "Crkvice" in Zenica, BiH (capacity of the plant: 720 m^3/d =

200 l/s) (Jusic 2011). Problems, related to the filtration at PWTP "Crkvice", are the lack of adequate control/regulation of the filter and insufficient quantity of water for backwashing. This directs the course of modeling application on the analysis of changes in operational parameters related to washing of filters and, in this regard, the ability to efficiently control the filter (by extension of filter run time, for example).

Optimizing the filter run time means actually finding the optimal time period of operation between two washing (t_{opt}) (Capture 2.2.1). So, for example, in order that the filter performs optimally, it is important that the pressure drop (I_{max}) reached in time t_2 equal to or slightly shorter than the time t_1, which corresponds to the breakthrough of the filtrates (Fig. 1). This rule is used when applying modeling of filtration at the plant "Crkvice". Of course, limitations have been used, for example, regarding the time of simulation of model (www.stimela.com), and limits of control parameters etc. According of water quality guidelines maximum concentration of turbidity (MDK) is 1,2 NTU and maximum pressure drop - calculated ($I_{max} \equiv H_{max}$) is 1,7 m. These limits are presented on Fig. 6.

3.3 Define database for modeling

According to Table 1, it is presented overview of PWTP "Crkvice" data, which are required by Stimela model (for different blocks of the model). These data are collected in situ, from laboratory (measured data for one year) and by review of project documents.

- Input – disturbance parameters (block: Water Quality)
  - ✓ water flow ……………................ max 709,2; aver. 219,6; min 54 (m^3/h),
  - ✓ water temperature .... max 20; aver. 11; min 1,8 (°C),
  - ✓ suspended solids concentration .... max 350; aver. 22; min 1 (mg/l),
  - ✓ turbidity .... max 1270; aver. 22,4; min 0,6 (NTU),
  - ✓ color... max 1300; aver. 58; min 0 (°Co-Pt scale).
- Input – design parameters (block: Filter)
  - ✓ filter surface ....168 (m^2),
  - ✓ water level above the filter bed .....1,3 (m),
  - ✓ filter bed height (upper)..................0,2 (m),
  - ✓ filter bed height (lower)..................0,5 (m),
  - ✓ grain size (upper)..............................0,6 (mm),
  - ✓ grain size (lower).............................0,7 (mm),
  - ✓ filter porosity (upper).......................40 (%),
  - ✓ filter porosity (lower).......................40 (%).
- operational / manipulative parameters (block: Backwash)
  - ✓ *filter run time*……..............................24 (h),
  - ✓ backwash time …………...................5-6 (min),
  - ✓ start time for backwashing .... 0,3 (h) (=20 min).

Calibration parameters (block: Filter) are defined by testing of the model (next Chapter 3.4).

3.4 Testing of the model - perform calibration and verification

Using before mentioned design and disturbance data, some assumptions (regarding missing of some data) and certain boundary conditions (regarding output data and condition $t_2 < t_1$) the model is tested. Various alternatives were inflicted in order to assess, or set the value of calibration parameters that will give an acceptable error and calibrated model (Fig. 4). Fig. 6 presents the graphical visualization of the output/control parameters of calibrated model of PWTP "Crkvice".

In order to carry out verification of the reliability and validate the calibrated model, model validation is conducted also. For the validation, model has used measured data that were not used in calibrating - and were taken under different conditions of flow, temperature and load filter. Fig. 7 gives a diagram as overview of changes in turbidity during the month of January (input turbidity - green line, output turbidity: measured – pink line, simulated results – blue line). By the analysis of this diagram (Fig. 7), it can be seen that previously calibrated model provides satisfactory results and in the changed conditions of filtering that are not used in the calibration (acceptable errors – Fig. 4).

Only after step of testing model (calibration and validation), next step is effective application of the model in order to increase the control of filtration process (Bakker *et al.* 2014). Next chapter provides a summary of the results of effective application of the model in the direction of efficient control of filtration through optimizing of the filter run time as operational parameter.

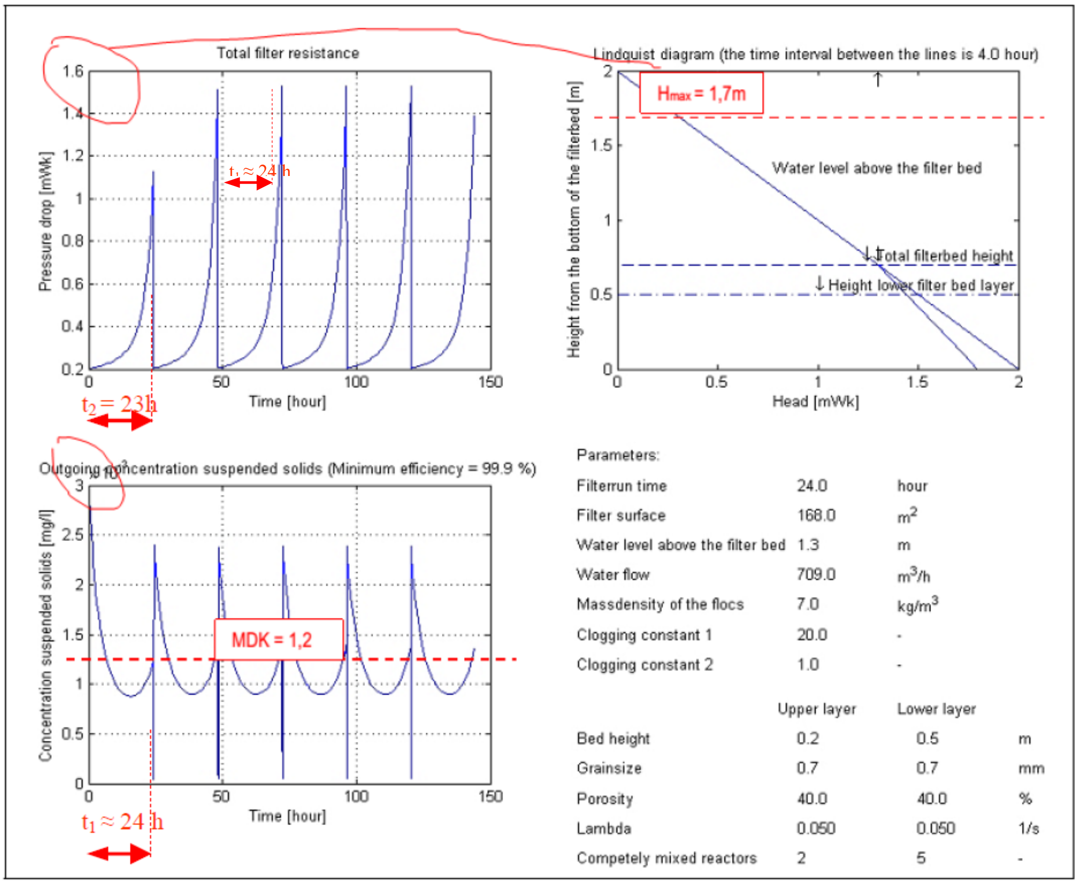

Fig. 6 Satisfactory assessment of calibration parameters - limit values set (PWTP Zenica) (Jusic 2011)

Table 2 Impact of changes in operational parameters on the behavior of the model output results (Jusic 2012)

Operational parameters		Output / control parameters		Comment:
		Pressure drop	Concentration of water pollution	
Filtration run time (h)	↗	↗	↗	significant increase of pressure drop
	↘	↘	↘	-
Backwashing time (min)	↗	↘	-	concentration without changing
	↘	↗	↗	significant increase of pressure drop

3.5 Discuss the results of modeling for the purpose of effective use of the model

Effective use of the model assumed the implementation of steps listed at the beginning of Chapter 3 and defined according to Fig. 4, i.e., pre-defining characteristic of the plant, database, testing model and after that effective use of the model. One of the results of effective application of the modeling is better understanding the influence between different parameters. By changing of operational parameters it could be defined the way of its influence on output / control parameters. Table 2 presents overview of that influence.

Table 2 shows the way of impact of the change (increase ↗ or decrease↘) in the value of operational parameters on the behavior of output results and efficiency of the model. The analysis of Table 2 shows that increasing the filter run time, with the invariance of all other parameters of calibrated model, managed to achieve a significant increase in pressure loss in the fill (vacuum phenomenon), and the turbidity of filtered water also increases. On the other hand, backwashing time reduction causes an increase in pressure drop in the fill, and the filtrate turbidity increase, i.e. pollution concentrations.

In the next phase of model application, starting from these interactions, the model is used for control of filter run time for different input turbidity, with satisfying the limit values of the output control parameters. As analyzed in Chapter 2.2.1, optimizing the filter run time means actually finding the optimal time period of operation between two washing (t_{opt}). So, for example, in order that the filter performs optimally, it is important that the pressure drop H_{max} reached in time t_2 equal to or slightly shorter than the time t_1, which corresponds to the breakthrough of the filtrates (Figure 1). This limit is used when applying modeling of filtration at the PWTP "Crkvice". Of course, the other, previously mentioned limitations have been used (for example, regarding the time of simulation of models, water quality guidelines, etc.)

Application of the model is effective for turbidity less of 3 NTU (Rietveld 2005). In applying the model at PWTP "Crkvice" it is defined the optimal values of filter run time, for different values of input turbidity. By effective application of modeling, on way of model based control of filter run time, it is shown that the existing filter run time, 24 hours, may be extended (common practice, fixed schedule (Chapter 2.2.1)). Results are presented on Fis. 8-11.

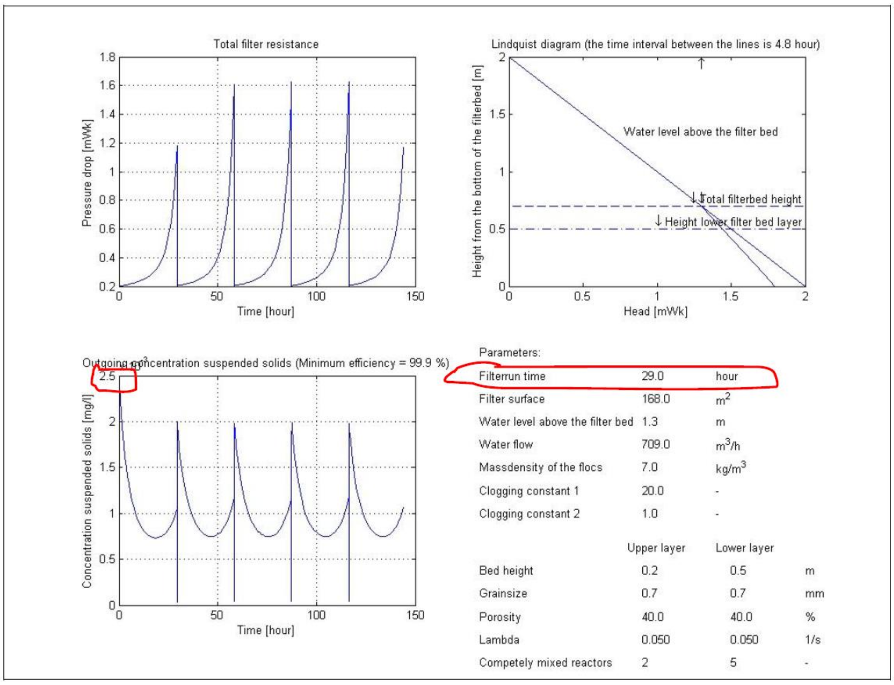

Fig. 8 Output results of simulation for input turbidity 2,5NTU – filter run time 29h (Jusic 2011)

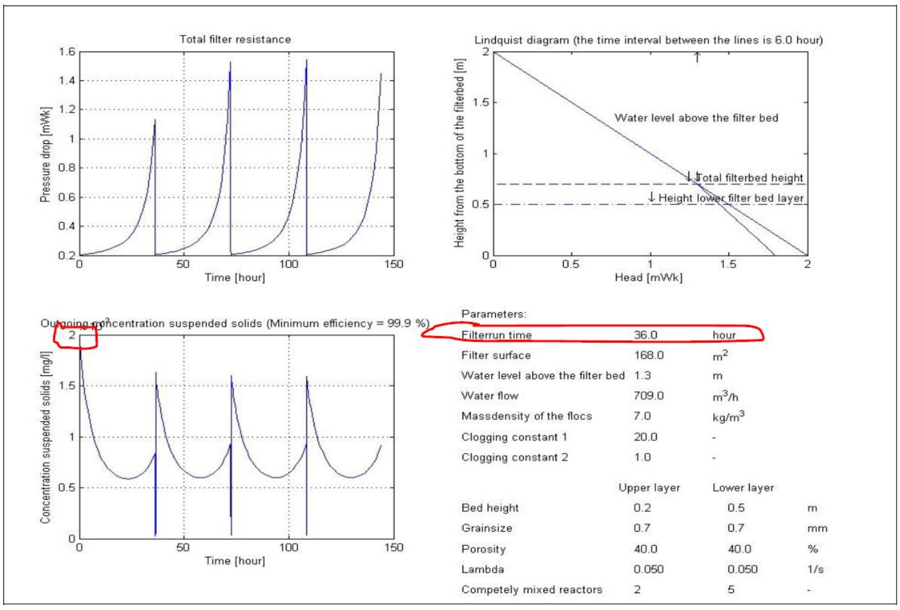

Fig. 9 Output results of simulation for input turbidity 2,0NTU – filter run time 36h (Jusic 2011)

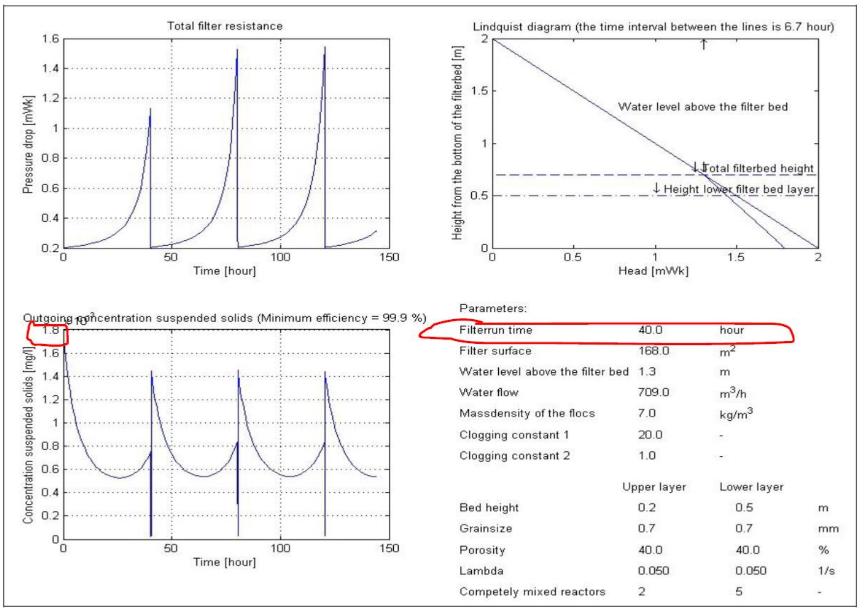

Fig. 10 Output result of simulation for input turbidity 1,8 NTU – filter run time 40h (Jusic 2011)

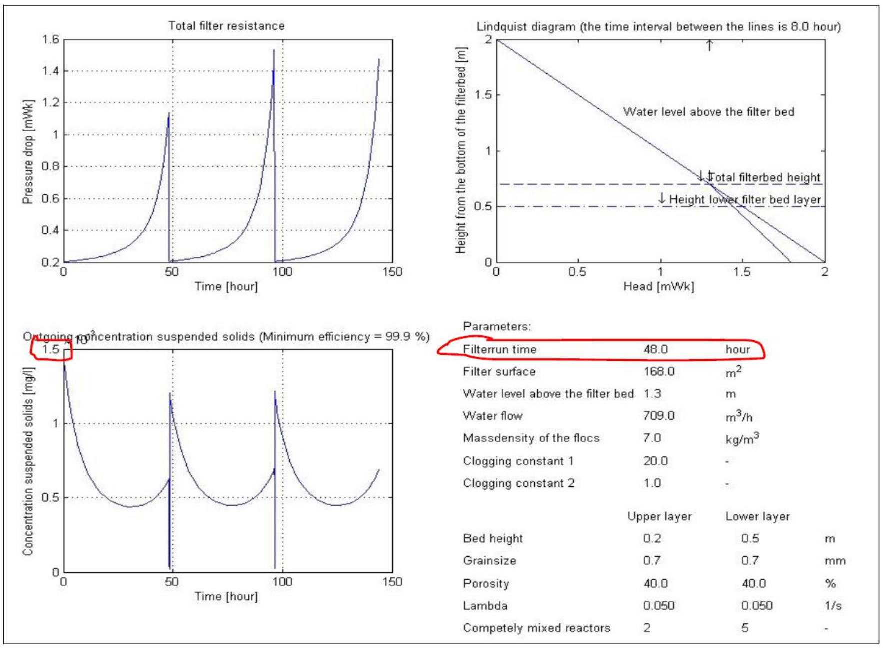

Fig. 11 Output result of simulation for input turbidity 1,5 NTU – filter run time 48h (Jusic 2011)

Table 3 Review of values of model block parameters for different values of input turbidity PWTP "Crkvice"

MODEL BLOCK	WATER QUALITY			F I L T E R									BACKWASH			MEASUREMENTS			
																Output / control			
PARAMETERS	Input - disturbance			Input – design					Calibration				Operational /manipulative			Simulation results		Boundary conditions	
Number of Figure	Water flow (m^3/h)	Temperature (°C)	Turbidity (NTU)	Filter surface area (m^2)	Water level above the filter bed (m)	Bed height (upper +lower) (m)	Grain size (mm)	Filter porosity (%)	Lambda (1/s)	Clogging constant 1 and 2 (-)	Mass density of the flocs (kg/m^3)	Number of complet. mixed reactors upper and lower (-)	Filter run time (h)	Backwsh time (min)	Start time for backwashing (h)	Pressure drop (m)	Turbidity (NTU) input – output	Pressure drop (m)	Turbidity (NTU)
6	709	14	**3.0**	168	1.3	0,2+ 0,5	0.7	40	0.05	201	7	2 - 5	**24**	5	0.3	1.6	3.0 – 1.2	1.7	1.2
8	709	14	**2.5**	168	1.3	0,2+ 0,5	0.7	40	0.05	161	7	2 - 5	**29**	5	0.3	1.6	2.5 - 1.0	1.7	1.2
9	709	14	**2.0**	168	1.3	0,2+ 0,5	0.7	40	0.05	101	7	2 - 5	**36**	5	0.3	1,5	2.0 - 0.9	1.7	1.2
10	709	14	**1.8**	168	1.3	0,2+ 0,5	0.7	40	0.05	161	7	2 - 5	**40**	5	0.3	1.5	2.5 - 0.8	1.7	1.2
11	709	14	**1.5**	168	1.3	0,2 + 0,5	0.7	40	0.05	161	7	2 - 5	**48**	5	0.3	1.5	2.5 - 0.7	1.7	1.2

According on these results, Table 3 presents overview of all model database for calibrated model for turbidity 3,0 NTU. Also, it is presented increased values of filter run timed for turbidity less than 3,0 NTU. It is clear that filter run time could be increased by model based control what confirmed the contribution of effective application of model.

More optimum filtration means, among other things, longer duration of filtration cycle – longer filter run time. That means less water consumption for washing; less consumption of chemicals, less consumption of electricity for water pumping (for example, reduced production of waste backwashing water). It is possible for turbidity less of 3,0NTU (turbidity on which the model is calibrated). For the turbidity greater than 3.0 NTU model simulated values of filter run time are shorter (than 24 h), because it is not taken into account the effect of chemistry (coagulation). For the turbidity greater than 3.0 NTU it is recommended to keep the existing filter run time (24 h), and use the prescribed amount of coagulant and effects of chemistry, which is the current practice on this PWTP.

Basic problems, related to the filtration at PWTP "Crkvice", as it was before mentioned, are the lack of adequate control/regulation of the filtration and insufficient quantity of water for backwashing. By model based control, these problems could be solved. After successful testing of the model, effective application of the model was carried out and came to satisfactory results. Results, presented on diagrams (Figs. 8-11) and Tables 2 and 3, confirmed the contribution of the application of the model in a way to better understand the influence of the interactions between different parameters of filtration.

4. Conclusions

During the application of modeling it is proved educational effect, given the possibility to provide a better understanding of the process, increasing insight into how different parameters affect the process. The aim is, by varying values of operational parameters to understand how these parameters influence the output e.g. the turbidity and pressure drop in case of filtration process.

By effective application of the model, on PWTP "Crkvice", it is determined the optimal filter run time for different input turbidity of raw water. It is confirmed possibility of reducing the consumption of backwashing water, lower costs for its pumping and reducing the amount of coagulants. In the existing practice based on experience, these benefits are not used. Appropriate changes in filter run time as operational parameter allow more efficient use of existing capacity - facilities, equipment (pumps, for example), the wash water, electricity, chemicals (coagulants), etc. The filtration operation costs and environmental impact are determined, among other things, by the frequency of washing. Modeling provides an opportunity for appropriate changes to operational parameters with the aim of more adequate control of the process. Operational parameters allow an active control and thereby optimization of filtration, because they can be changed. In practice, in the plant operation, the possibilities of positive effects of operational parameters are insufficiently utilized and largely depend on experience, training and diligence of operators. Precisely the modeling provides the possibility of more efficient use, or changes of these parameters.

Using modeling it is possible rapid and inexpensive analysis of large number of alternatives in a way that by changing of operational data of the water treatment process follows the impact on output/control parameters. In this way, it is possible by modeling select appropriate values of parameters (filtration cycle time, for example). Also, modeling i.e. simulation of the impact of such changes, for example in this case the operational parameter on the output parameters can support the operator in making decisions in the control of plant operations.

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