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CONSIDERATIONS REGARDING THE CONTROL OF BIOCHEMICAL OXYGEN DEMAND AND CHEMICAL OXYGEN DEMAND FROM DEJ WASTEWATER TREATMENT PLANT

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Abstract

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are the most commonly used parameters for the characterization of the organic pollution of wastewaters. Both of these parameters have advantages and disadvantages and the choice usually depends on many factors such as the time period required to determine each one of them. It is essential to obtain a control between BOD and COD for various wastewater treatment plants, to help in the design and operation of these plants. In this paper the modelling results of BOD and COD for an aeration tank from Dej wastewater treatment plant by Matlab/Simulink software program has no significant difference, because the results are close enough to the real ones that allow the user to make a good prediction regarding this parameters. A true validation of these results, including experimental validation of simulations of the entire collecting data was realistic.

Keywords: *biochemical oxygen demand, chemical oxygen demand, wastewater, simulation, parameters*

Introduction

Wastewater is characterized in terms of physical, chemical and biological composition (Hur et al 2010). Depending on the level of pollutants and local regulations; physical, chemical and biological treatment may be used (Tchobanoglous et al 2003, Cossu et al 2017). Before any wastewater can be treated, it must first be characterized, because knowing the composition of the influent wastewater is essential for successful design and operation of wastewater treatment plants (Sincero & Sincero 2003). The impact of an effluent or wastewater discharge on the receiving water is predicted by its oxygen demand (Sawyer et al 2003, Ahmed et al 2013). The two most common parameters used to recognize the composition of wastewater are the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD). BOD_5 is a measure of how much dissolved oxygen is consumed by aerobic bacteria in 5 days at 20℃. It is the broad measure of the strength of the organic matter in a waste stream. The typical range of BOD_5 in domestic wastewater ranges is between 100 to 300 mg/L. COD is chemical oxygen demand and is measured chemically by digestion with acid. There exists a definite correlation between the COD and BOD under certain conditions and by determining the COD, the information about the BOD of the wastewater can be derived, but it is highly waste dependent (Sawyer et al 2003, Khaled & Gina 2014, Henze et al 2000). These two parameters have advantages and disadvantages and the choice usually depends on many factors such as, the reproducibility of the determinations, time period required location of the test (Evangelou et al 2017). COD analysis estimates the amount of organic matter in wastewater in only three to four hours, rather than the five days required by the BOD_5 test and can be used as an alternative. COD results are typically higher than BOD_5 values and the ratio between them will vary depending on the characteristics of the wastewater.

In this case for a model is important to have something representative in the design and operation of wastewater treatment systems, it must be possible to evaluate parameter values which are wastewater specific and to estimate concentrations of important components in the influent (West & Dellana 2008). The first step is to identify the components of relevance in the model. In this case these are BOD and COD. The second step is to identify the biological processes occurring in the system, for example the transformations or the conversions that happen and write mathematical relations that describe the process. The third step is to use a simulation program. In this study was used Matlab/Simulink. Although a number of environmental factors can influence the parameter values, these are specific factors in the wastewater, pH and temperature.

The purpose of this model is to find a mathematical model able to determine certain effluent levels, for BOD and COD concentrations depending on influent and effluent. Khaled & Gina (2014) obtained in the case studies, for parameters COD and BOD in different plants of variable types and treatment capacities, that the correlation between BOD_5 and COD is generally linear, except in some rare cases where the relation was polynomial and sometimes doesn't have a definite pattern. However, this rare indefinite pattern might be due to inaccuracy in determination of the BOD_5 and COD parameters in such cases. Since the BOD and COD are correlated, the estimation of BOD_5 values using the quick COD test, and plant specific biodegradability index (which is the slope of the plotted correlation) became possible and relatively reliable. Thus, it can be used as a check parameter to evaluate performance for quick action. In order to establish the BOD and COD correlation for a particular existing wastewater, one should have both COD and BOD_5 values for several representative wastewater samples. From graphics the BOD_5 values versus the COD values then use the regression analysis to develop the correlation. The plotted BOD_5 and COD figures indicated that there is a clear linear positive correlation for most case studies, which differs from plant to another (Khaled & Gina 2014).

Materials and Methods

We consider a tank which has: width 35.1 m and height of 4.95 m, with the volume of 8947 m^3. It was considered as a static system with a piston-type flow with changing parameters as the water moves into the tank.

Were taken into account the following simplifying assumptions:

- All parameters are constant in radial section of the reactor (flow piston type).
- The flow rate is considered constant.
- Flow regime is considered ideal (flow regime shift (type D).
- Density and water temperature are considered constant and have not been taken into account.
- The influence of pH was not taken into account, which is assumed constant.
- Ammonification was considered constant.
- Biomass concentration in the tank was considered constant (specific death rates, the increase is much smaller than reaction rates).
- The vapour pressure of the water surface was not been considered.

To achieve simulation method was used Matlab/Simulink software. The mathematical model of the aeration tank consists of a system by a differential equation for each parameter to be determined. For numerical solutions of differential equations using the method of integration ODE45 (Dormánd-Prince) with variable step and relative tolerance of 10^{-3}. For calculation was used Matlab program version 7.14.0.739.

Knowing the size of the tank could calculate the cross section area as follows:

Wetted area is calculated first using the formula:

$$A_u = H \cdot l \tag{1}$$

where: A_u is the wetted area [m^2], H is the height of the tank [m] and l is the width of the tank [m].

Wetted perimeter is then calculated:

$$P_u = 2 \cdot (H + l) \tag{2}$$

where: P_u is the wetted perimeter [m].

This is necessary to determine equivalent diameter, which has the following formula:

$$D_{ech} = 4 \cdot \frac{A_u}{P_u} \tag{3}$$

where: D_{ech} is the equivalent diameter [m].

Having calculated the equivalent diameter of the cross-sectional area can be calculated:

$$A = \frac{\pi \cdot (D_{ech})^2}{4} \tag{4}$$

where: A is the cross-sectional area of the tank considered [m^2].

Input flow is known from experimental data and calculated using the above area can cause water flow rate:

$$w = \frac{F}{A} \tag{5}$$

where: W is the water flow rate [m^3/h] and F is the experimentally measured water flow [m^3/h].

All these equations are part of the mathematical model, namely the algebraic equations of the model.

Differential equations of the model are:

For BOD_5:

$$\frac{dBOD_5}{dt} = -Y_1 \cdot \frac{(BOD_5 - C_i)}{w} \tag{6}$$

For COD:

$$\frac{dCOD}{dt} = -Y_2 \cdot \frac{(COD - C_i)}{w} \tag{7}$$

where: $dBOD_5/dt$ is the the changes in biochemical oxygen demand after 5 days, Y_1 is the theoretical stoichiometric ration, Y_2 is the theoretical stoichiometric ration, C_i is the standard oxygen concentration (1.5 mg/ml).

In the last decade, stringent quality standards are being applied to effluent plants, whether by regulatory authorities or environmentally concerned plant management. More often than not now, limits on nitrates, ammonia, phosphates, suspended solids, etc. are applied to outfalls (Turak & Fsar 2004).

To realise an optimum biological process, it is necessary to assure the best environment for the bacteria. A few important parameters are oxygen, pH and temperature, as well as suspended solids which indicate the bacteria concentration in the tank. Advanced monitoring of the bacteriological processes based on oxygen, ammonia and nitrate makes it possible to satisfy strict legal regulations and to optimize energy consumption at the same time.

Results and Discussion

For BOD were obtained 20 simulations with increasing values of inflow starting from 188.88 m^3/h up to 314.67 m^3/h. Influent flow values and the influent concentrations were taken from experimentally determined data from treatment plant using the analysis method according to SR EN 1899-2/2002 (NTPA-001/2005).

Simulation results from data obtained were compared with those determined experimentally. In the case of biochemical oxygen demand after 5 days was obtained the graph from Figure 1. It may be noted that the data obtained from simulation and the data obtained experimentally keeps tendency, which otherwise have no trend. The data measured at the plant can vary widely from day to day even for the same rate, this being also very difficult to simulate. But with this mathematical model results are close enough to the real ones that allow the user to make a good prediction of biochemical oxygen demand after 5 days, knowing the inflow of water and oxygen concentration standard.

Table 1. Experimental values for BOD

Sample	Influent flow	Influent BOD	EffluentBOD	Sample	Influent flow	InfluentBOD	Effluent BOD
	m^3/h	mg/l	mg/l		m^3/h	mg/l	mg/l
1	188.88	190	4	11	256.71	100	14
2	197.42	195	6	12	261.33	200	10
3	201.79	140	4	13	262.54	125	8
4	214.00	125	6	14	267.04	110	8
5	224.17	105	10	15	272.63	105	6
6	226.08	150	10	16	281.71	70	10
7	229.13	205	10	17	289.54	100	10
8	236.29	155	8	18	301.17	150	8
9	244.46	160	10	19	302.00	125	12
10	247.67	100	6	20	314.67	160	10

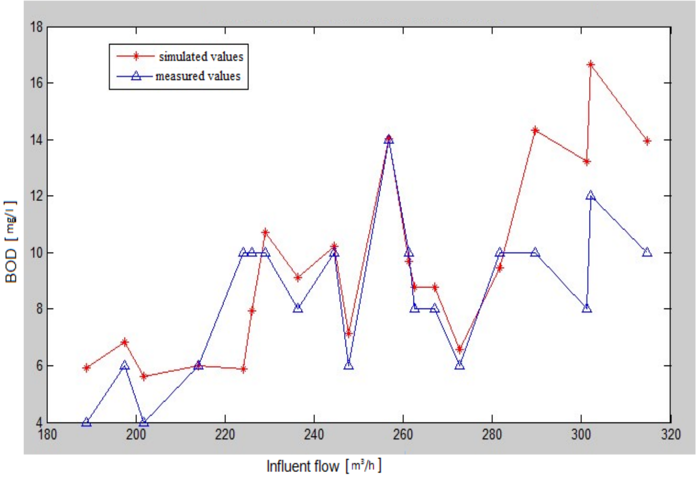

Figure 1. Simulated and measured values of BOD from Dej WWTP

As was shown in the graphic all data were simulated in according to normative NTPA-001/2005, below 25 mg/l, although influent concentrations values were between 70 and 205 mg/l. The dissolved oxygen concentration can be measured by an optical sensor for continuous determination of oxygen (Haimi et al 2009). For COD, were performed 20 simulations for the increasing values of flow starting from 188.88 m^3/h up to 314.67 $m^3/$ h. Concentration values from the influent and effluent have been determined experimentally by potassium dichromate method according to SR ISO 6060/1996 (NTPA-001/2005).

Table 2. Experimental values for COD

Sample	Influent flow	Influent COD	Effluent COD	Sample	Influent flow	Influent COD	Effluent COD
	m^3/h	mg/l	mg/l		m^3/h	mg/l	mg/l
1	188.88	674	47	11	256.71	422	58
2	197.42	505	37	12	261.33	307	38
3	201.79	269	29	13	262.54	238	48
4	214.00	307	58	14	267.04	269	29
5	224.17	317	38	15	272.63	189	28
6	226.08	217	19	16	281.71	269	48
7	229.13	490	28	17	289.54	378	57
8	236.29	422	58	18	301.17	400	38
9	244.46	384	38	19	302.00	422	38
10	247.67	211	67	20	314.67	355	29

The results obtained of the simulation are compared to the experimental ones as was shown in Figure 2. If in the case of biochemical oxygen demand after 5 days the results can vary widely from one day to another day, from a flow or even at the same flow, in case of oxygen concentration determined by the COD also from the influent and effluent varies more than in the previous simulation.

This linearity is present as well in simulation of this parameter, but the trend keeps organized pattern of actual data. However data from simulation is close to the real values and the mathematical model can be used to predict the effluent of the oxygen concentration normally determined experimentally with COD method.

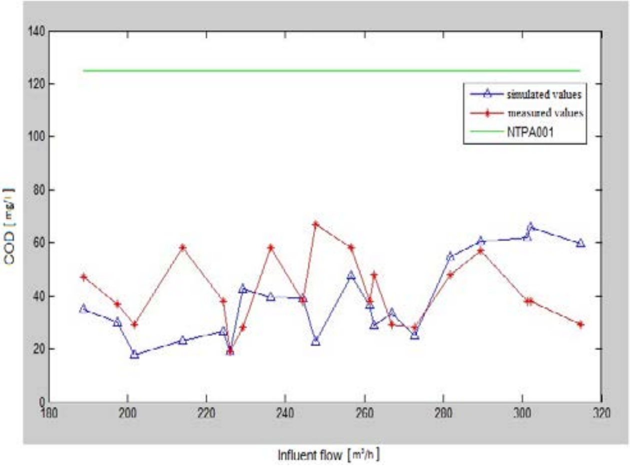

Figure 2. Simulated and measured values of COD from Dej WWTP

All simulation data are below to the maximum allowed by the normative NTPA-001/2005, below 125 mg/l. Block diagram of the model in Simulink can be seen in Figure 3. In the left diagram can be seen the three input quantities of inflow in m^3/h and BOD after 5 days from the entry into the tank and COD from the entry into the tank. The three enter in a multiplier which forwards them to the position S.

After completing the steps in the S output as is represented in figure 3, but also are sent to the workspace in the form of a matrix. Simulation time is set to 120 minutes.

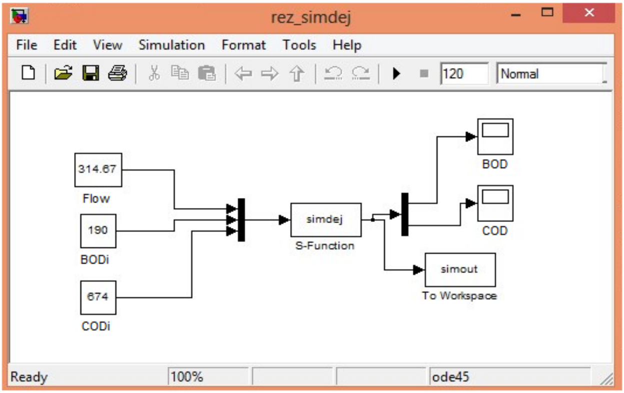

Figure 3. Block diagram of the model in Simulink

Data collected from the wastewater treatment plant keeps a uniform trend, this was underlined by the results of simulations. In simulation we can see a very good overlap of simulated results over determined experimentally, because the tank is rectangular, which is enough close to ideal form.

Conclusions

In this paper, a procedure for getting a set of solutions for development of a mathematical model must incorporate the major events occurring within a system in a manner which is consistent with established knowledge about that system.

Validated process models can be used for dynamic simulations, for example, with different kinds of input data. In simulations the mathematical equations of process model are solved and the results given. Models and software for simulation have the possibility to control and evaluate the parameters. The presented control strategies use mainly ideal conditions, given the circumstances, for controllers and plant operations.

The formal modelling of systems has been done with a mathematical model, which attempts to find analytical solutions enabling the prediction of the behavior of the system from a set of parameters and initial conditions. Modelling techniques include statistical methods, computer simulation, system identification, and sensitivity analysis; however, one of these is as important as the ability to understand the underlying dynamics of a complex system. Models applied for prediction aim at providing an accurate and fast image of a real systems behavior under different conditions.

Models may be linear with respect to variables or parameters; furthermore, a model can be nonlinear to parameters and linear to variable. Linear models are used frequently, because the analytical solution can be found. For nonlinear models numerical solutions are predominant. Term mechanistic, physiological and whitebox are used to describe that models structure is based on physical, chemical and biological laws.

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