STUDIA UBB CHEMIA, LX, 2, 2015 (p. 399-408)
(RECOMMENDED CITATION)

MODELLING AND SIMULATION OF BOD AND COD FOR EFFLUENT LEVELS OF AN AERATION TANK FROM GHERLA WASTE WATER TREATMENT PLANT

MARIUS-DANIEL ROMAN[a*], RALUCA-ANDREEA FELSEGHI[a], MIRCEA-VLAD MUREŞAN[b]

ABSTRACT. The modelling results of BOD and COD for an aeration tank from Gherla's WWTP 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. 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.

Keywords: *simulation, modelling, Matlab, flow; BOD, COD.*

INTRODUCTION

Simulation of activated sludge, is based on phenomena such as carbon oxidation, nitrification and denitrification, must necessarily account for a large number of reactions between of components. Mathematically is needed while to providing realistic predictions, the reactions must be representative of the most important fundamental processes occurring within the system. In this case the term process is used to mean a distinct event acting upon one or more system components. Furthermore, the model should quantify both the rate, concentration dependence and the relationship that one component has to another in a reaction, of each process [7].

[a] *Technical University of Cluj-Napoca, Building Services Engineering Department, 128-130 Boulevard December 21 Str., RO-400604, Cluj-Napoca, Romania*
[b] *Technical University of Cluj-Napoca, Engineering Materials and the Environment Department, 28 Memorandumului, 400114 Cluj-Napoca, Romania*
** Corresponding author: Marius.ROMAN@insta.utcluj.ro*

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 [7]. The first step is to identify the components of relevance in the model. In this case these are BOD, COD, TN and others. 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 were used Matlab/Simulink software. Although a number of environmental factors can influence the parameter values, these are specific factors in the wastewater, pH and temperature.

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 ^{o}C. 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 from 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 [1], [2].

When a wastewater treatment system can be modelled, a certain number of simplifications and assumptions must be added in order to take the model tractable. Often this simplifications and assumptions are implicit, which may cause the user to overlook them. The system operates at constant temperature, because many of the coefficients are functions of temperature, their functionality would have to be explicitly expressed in the rate expressions, in order for time-variant temperature fluctuations to be considered.

It is known that the pH influences many of the coefficients. The inclusion of the alkalinity in the model allows the user to detect potential problems with pH control. The effects of limitations of nitrogen, phosphorus and other inorganic nutrients on the removal of organic substrate and on cell growth have not been considered. The coefficients for nitrification are assumed to be constant and to incorporate any inhibitory effects that other waste constituents are likely to have on them [3].

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. For existing wastewater treatment plants the BOD/COD correlation should be developed, to compromise the use of these parameters. In order to establish the BOD/COD correlation for a particular existing wastewater, one should have both COD and BOD5 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 [2].

RESULTS AND DISSCUSIONS

Were performed 22 simulations for BOD to increasing values of inflow starting from 155.79 m^3/h up to 400.54 $m^3/$ h. Influent flow values and the influent concentrations were taken from experimentally determined data from treatment plant using the analysis method according to STAS 6560-82 [5].

Table 1. Experimental values for BOD

Probes	Influent flow	Influent BOD	Effluent BOD	Probes	Influent flow	Influent BOD	Effluent BOD
	m^3/h	mg/l	mg/l		m^3/h	mg/l	mg/l
1	155.79	179.00	9.00	12	220.46	261.50	12.35
2	156.92	264.00	12.00	13	221.04	275.60	12.82
3	165.67	219.00	11.00	14	236.51	82.00	3.00
4	179.67	114.00	4.80	15	255.92	132.00	9.00
5	184.71	155.00	8.10	16	258.10	88.00	3.50
6	190.58	121.20	5.26	17	276.45	127.00	5.33
7	193.33	195.50	9.84	18	282.21	123.00	5.10
8	195.08	203.00	10.78	19	297.42	93.00	3.78
9	199.42	308.00	6.00	20	302.60	118.00	4.90
10	201.08	269.50	12.55	21	394.80	106.00	4.00
11	215.07	83.00	3.10	22	400.54	158.00	8.20

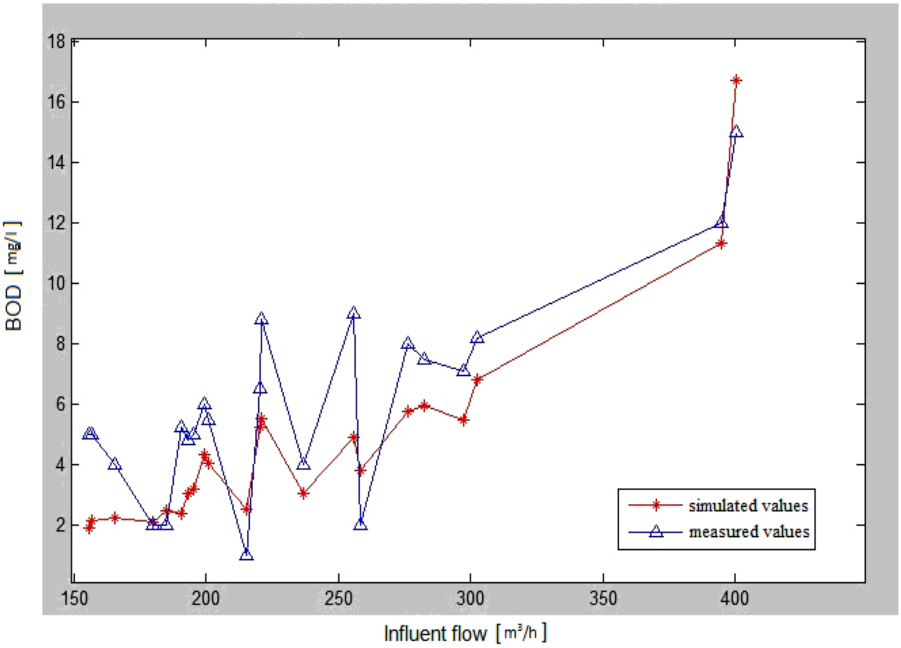

Figure 1. Simulated and measured values of BOD from Gherla's WWTP

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.

As was shown in the graphic all data were simulated in according to standard NTPA-001/2005, below 25 mgO_2/l, although influent concentrations values were between 82 and 308 mgO_2/l. The dissolved oxygen concentration can be measured by an electrochemical sensor for continuous determination of oxygen [6]. For COD, were performed 19 simulations for the increasing values of flow starting from 110.00 m^3/h up to 257.00 m^3/h. Concentration values from the influent and effluent have been determined experimentally by potassium dichromate method according to SR ISO 6060/1996 [5].

Table 2. Experimental values for COD

Probes	Influent flow	Influent COD	Effluent COD	Probes	Influent flow	Influent COD	Effluent COD
	m^3/h	mg/l	mg/l		m^3/h	mg/l	mg/l
1	110.00	346.56	63.84	11	142.63	470.08	54.24
2	114.38	470.08	54.24	12	171.25	264.00	46.80
3	121.71	519.20	61.60	13	171.38	331.00	55.90
4	122.33	546.56	68.32	14	201.42	293.00	92.20
5	125.04	342.72	28.56	15	202.25	252.72	94.88
6	125.25	428.40	66.64	16	212.08	288.00	76.80
7	129.58	508.80	57.60	17	212.63	205.20	84.14
8	132.25	431.20	70.40	18	255.96	212.00	54.40
9	130.00	380.64	58.56	19	257.00	280.80	93.60
10	141.79	518.40	57.60				

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 absence of linearity is present as well in simulation of this parameter, but the trend keeps disorganized 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.

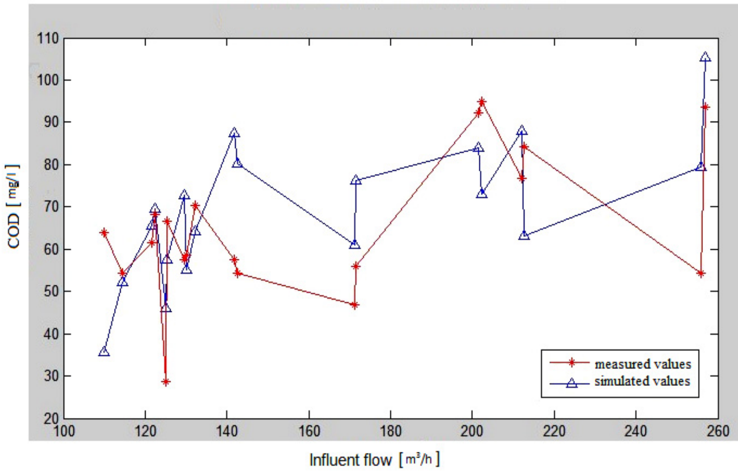

Figure 2. Simulated and measured values of COD from Gherla's WWTP

All simulation data are below to the maximum allowed by the standard 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 two input quantities of inflow in m^3/h and biochemical oxygen demand after 5 days from the entry into the tank. The two 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.

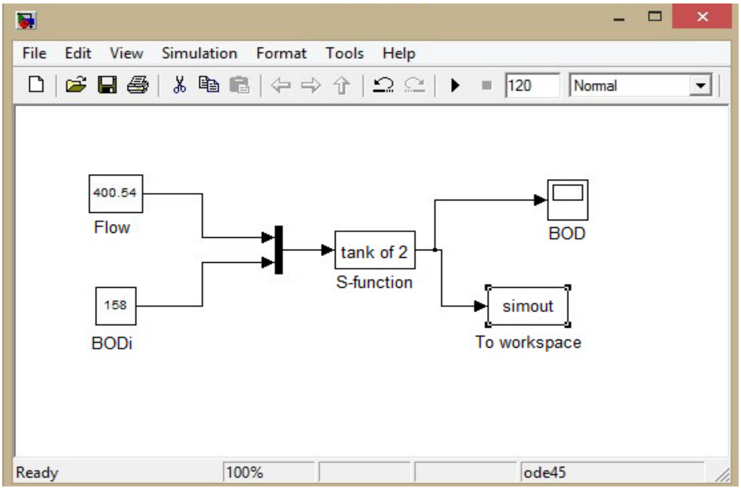

Figure 3. Block diagram of the model in Simulink

Data collected from the wastewater treatment plant keeps approximately a uniform trend, this was underlined by the results of simulations. In simulation we can't see a very good overlap of simulated results over determined experimentally, because the tank is circular and in case of rectangular tanks which is enough close to ideal form.

In some instances the tank geometry is very important for modelling, because in circular tanks the flow rate is smaller than in case of rectangular tanks, but it is not a rule.

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.

In the model should be included only those processes which are essential to a realistic solution and must select rate expressions for them that allow the use of simplified solution techniques without detracting from the applicability of the results.

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 [7].

Models may be linear with respect to variables or parameters; furthermore, a model can be nonlinear to parameters and linear to variable [8]. Linear models are used frequently, because the analytical solution can be found. For nonlinear models numerical solutions are predominant. Term mechanistic, physiological and white-box are used to describe that models structure is based on physical, chemical and biological laws.

Simulation is a reasonable way to extrapolate performance and scaling up process; additionally, it helps in understanding behavior and mechanisms of processes. Also the effects of system parameters and disturbances can be investigated using process simulation [9].

EXPERIMENTAL SECTION

We considered a tank which has: width 8.15 m and height of 5.7 m, with the volume of 4050 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 - wetted area [m^2]
H - height of the tank [m]
l - width of the tank [m]

Wetted perimeter is then calculated:

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

Pu - wetted perimeter [m].

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

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

Dech - equivalent diameter [m]

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

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

A - 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:

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

W - water flow rate [m / h]; F - 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:

$\frac{dBOD_5}{dt}$ - represents the changes in biochemical oxygen demand after 5 days

Y_1 - theoretical stoichiometric ration

Y_2 - theoretical stoichiometric ration

C_i - 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 [4].

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.

Acknowledgments

This paper is supported by the Sectoral Operational Programme Human Resources Development POSDRU/159/1.5/S/137516 financed from the European Social Fund and by the Romanian Government.

REFERENCES

1. J. Hur, B.-M. Lee, T.-H. Lee, D.-H. Park, *Sensors*, **2010**, *10(4)*: 2460-2471.
2. K.Z. Abdalla, G. Hammam, *International Journal of Sciences: Basic and Applied Research*, **2014**, *13*, *1*, 42.
3. M. Henze, W. Gujer, T. Mino, M. van Loosdrecht, *Scientific and Technical Report*, **2000**, 6–8-16-26.
4. M.D. Roman, M.V. Muresan*, International Journal of Latest Research in Science and Technology*, **2014**, *3, 2*, 30.
5. NTPA-001/2005, *Normative act regarding the determination of limits of loading with pollutants of industrial and town wastewaters at evacuation in natural receptors*, **2005**.
6. E.M. Pică, *Development and study of an electrochemical sensor for continous determination of oxygen*, PhD Thesis, University Babes-Bolyai, Cluj-Napoca, **1990**.
7. H. Haimi, M. Mulas, K. Sahlstedt R. Vahala, *Helsinki University of Technology Water and Wastewater*, **2009**, *9*, 7.
8. S.A. Dellana, D. West, *Environmental Modelling & Software*, **2008**, *24*, *1*, 96.
9. S. Marsili-Libelli, *Advances in Biochemical Engineering/Biotechnology,* **1989**, *38*, 90-148.
10. http://www.water.me.vccs.edu/courses
11. http://www.eea.europa.eu
12. http://www.environmental-expert.com
13. http://www.iasj.net
14. https://fortress.wa.gov