Mathematical Correlations of the Variable Parameters Specific for an SBR Experimental Laboratory Plant

NARCIS BARSAN[1], DANA CHITIMUS[1]*, FLORIN MARIAN NEDEFF[1]*, ION SANDU[2,3], EMILIAN MOSNEGUTU[1], ANDREI VICTOR SANDU[3,4], CLAUDIA TOMOZEI[1]

[1]Vasile Alecsandri University of Bacau, 157, Calea Marasesti Str., 600115, Bacau, Romania

[2]Alexandru Ioan Cuza University of Iasi, Arheoinvest Interdisciplinary Platform, Scientific Investigation Laboratory, 11 Carol I Blvd., 700506 Iasi, Romania

[3]Romanian Inventors Forum, 3 Sf. Petru Movila Str., Bloc L11, III/3, 700089, Iasi, Romania

[4]Gheorghe Asachi Technical University of Iasi, Materials Science and Engineering Faculty, 53A D. Mangeron Blvd., 700050, Iasi, Romania

The presents paper a research regarding the possibility to establish some mathematical correlation between variable parameters specific for a small SBR plant. The data were collected for 180 days and as inflow was used real domestic wastewater. Some wastewater key parameters were used, and the obtained data was corelated by using Table Curve 3D program. The obtained data reveal some direct influences of the SBR cycle times and the analyzed parameters.

Keywords: SBR, wastewater, mathematical model

Water and wastewater management are current issue in all the countries. The developed countries must maintain an evolve high level of performance in water and wastewater domain (researches, infrastructures) to create new trends and areas of works. Less developed countries, and here we can refer to the east European countries, must adopt plans to reconsider their water and wastewater management strategies in the context of global warming (and its effect to water resources) and regulation dynamics (new restrictions implemented on the water and wastewater quality).

Wastewater treatment (even we refer to smaller of bigger localities) involve a high cost. This aspect is a real problem in special in less developed countries were the population were limited resources. For these situations must adopt lower cost solutions and developed plans to sustain adaptive methods for wastewater treatment [1-9].

The municipal wastewater treatment is based on physical, chemical and biological processes. If we refer to lower and variable inflow, the Sequencing Batch Reactor (SBR) treatment process is one of the most adaptive and performed method to resolve the wastewater issues [10-13].

The SBR process, as a part of a wastewater treatment plant, can be easier controlled in the cases of inflows variation, even if at the beginning of the plant implementation cost are, sometime, higher in comparation with continuous systems. For an SBR plant, the biological tank is the main element of the system. The treatment process is divided into five phases: filling, reaction, settling, discharge of treated water and sludge [10-22].

In the cases of lower variable inflows, the mechanical-biological treatment process is directly by several factors (wastewater temperatures, chemical composition). Also, it is known that, SBR process efficiency depend by operation time cycle and who the working parameters can counterbalance the problems introduced in the system by qualitative and quantitative inflow variation [10-22].

In some researches SBR modeling process were performed by taken into consideration some important parameters and how these interact [10-22].

Considering these, the mathematical SBR process modeling can be extremely useful to evidence the interaction between operating conditions and the system performance.

In this study was performed a mathematical model which evidence the influence between some key SBR parameters in some specific working conditions. So, for mathematical model we used the dependency from operating time cycle and sludge volumetric index (SVI).

Experimental part

Materials and methods

The experimental data used in the mathematical model were performed by using a small Sequencing Batch Reactor (SBR) treatment system utilized for domestic wastewater treatment in real operating condition The experimental plant configuration use as pretreatment a septic tank which is also a buffer basin for inflow (fig. 1).

**email: dana.chitimus@ub.ro; florin_nedeff@ub.ro*

Fig. 1. SBR experimental plant

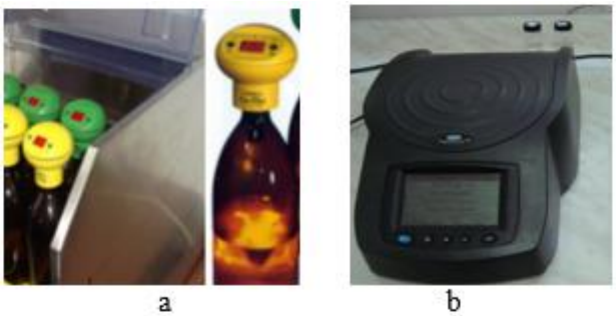

Fig. 2. Laboratory used equipment's [13]: a OxiTop, b Odyssey DR/2500

The operational inflow rate was 0.905 m^3/day for 180 days of experimental period. For inflow were used real domestic wastewater from Marasesti Campus of Vasile Alecsandri University of Bacau. The wastewater was pumped in the septic compartment by using an automatic pump [13].

Considering the five operation phases of an SBR system, the operating experimental installation cycle were: SBR compartment filling; The reaction phase, with aerobic and anaerobic conditions; The settling; wastewater evacuation after treatment.

The wastewater monitored parameters were temperature: total solid suspension TSS, BOD_5, COD, ammonium nitrogen and total phosphorus. To perform measurements for the water quality parameters were used: OxiTop (for BOD_5) (fig. 2 a) and Odyssey DR/2500 (COD, ammonium nitrogen and total phosphorus (TP) determination) (fig. 2 b) [13]. The sludge volumetric index was also performed.

The operating times variable are presented in the Table 1.

Table 1
OPERATING CYCLE TIMES

Type of process	**Time values (s)**		
$t_{denitrification}$	360	300	240
$t_{nitrification}$	240	300	360
$t_{sludge\ recirculation}$	5	10	15

The recorded data, regarding SVI and water quality parameters reduction, were introduced in the Table Curve 3D program so, was obtain a mathematical model that describe the correlation for analyzed factors.

Results and discussions

By using TableCurve 3D program were obtained some models that describe correlations between:

- Reduction degree performed by SBR plant correlated with operating times cycle and SVI (fig. 2).
- Reduction degree performed by SBR plant correlated with wastewater temperature and SVI (fig. 3).

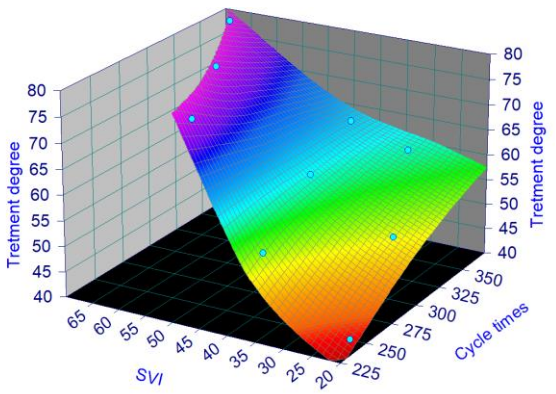

Fig. 2. The model regarding reduction degree performed by SBR plant correlated with operating times cycle and SVI

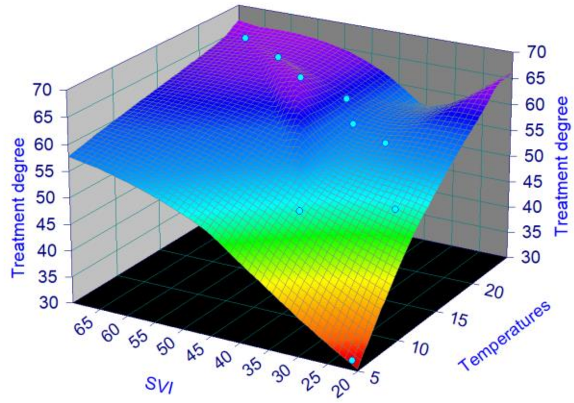

Fig. 3. The model regarding reduction degree performed by SBR plant correlated with wastewater temperature and SVI

The general equation for above models is [13]:

$$z = a + b \cdot x + c \cdot \ln y + d \cdot x^2 + e \cdot (\ln y)^2 + f \cdot x \cdot \ln y$$

Where: z is reduction degree (%) performed by plant; x represent operation times (s), and y is SVI.
The equation constants are a, b, c, d and f. The values of these constant are presented in the Table 2, 3, 4 and 5.

Table 2
EQUATION CONSTANTS VALUES FOR THE MODEL THAT DESCRIBE CORRELATION BETWEEN REDUCTION DEGREE FOR TSS, BOD_5 AND COD, CORRELATED WITH OPERATING TIMES CYCLE AND SVI

Equation constants	TSS			BOD_5			COD		
	t_d	t_n	t_{sr}	t_d	t_n	t_{sr}	t_d	t_n	t_{sr}
a	830.7579738	295.1078472	410.9993425	420.8680998	-264.039359	-37.9769552	966.5715539	121.2914419	353.9183969
b	-1.24833388	0.537166539	9.006200903	-0.97809841	1.304926451	14.48253648	-1.57512621	1.242474166	16.10723734
c	-341.037445	-192.80524	-237.274901	-137.350662	42.13571741	-11.7101963	-400.431758	-170.967106	-239.806502
d	0.000592639	0.000592639	0.085340081	-0.00027236	-0.00027236	-0.03921936	0.00027721	0.00027721	0.039918245
e	39.7642609	39.7642609	39.7642609	9.615943775	9.615943775	9.615943775	43.78005668	43.78005668	43.78005668
f	0.247053676	-0.24705368	-2.96464411	0.299143965	-0.29914397	-3.58972758	0.382441087	-0.38244109	-4.58929304

Where: t_d is denitrification time; t_n nitrification time and t_{sr} time for sludge recirculation.

Table 3
EQUATION CONSTANTS VALUES FOR THE MODEL THAT DESCRIBE CORRELATION BETWEEN REDUCTION DEGREE FOR NH_4^+ AND PHOSPHORUS, CORRELATED WITH OPERATING TIMES CYCLE AND SVI

Equation constants	NH_4^+			Phosphorus		
	t_d	t_n	t_{sr}	t_d	t_n	t_{sr}
a	420.8680998	-264.039359	-37.9769552	-1372.24661	-493.265107	-677.882498
b	-0.97809841	1.304926451	14.48253648	2.092564876	-0.83737346	-14.5671706
c	-137.350662	42.13571741	-11.7101963	576.8915126	348.7080085	417.1630597
d	-0.00027236	-0.00027236	-0.03921936	-0.00104599	-0.00104599	-0.15062297
e	9.615943775	9.615943775	9.615943775	-60.1484148	-60.1484148	-60.1484148
f	0.299143965	-0.29914397	-3.58972758	-0.38030584	0.38030584	4.563670084

Table 4
EQUATION CONSTANTS VALUES FOR THE MODEL THAT DESCRIBE CORRELATION BETWEEN REDUCTION DEGREE FOR TSS, BOD_5 AND COD, CORRELATED WITH WASTEWATER TEMPERATURE AND SVI

Equation constants	TSS			BOD_5			COD		
	T_{inf}	T_{septic}	T_{SBR}	T_{inf}	T_{septic}	T_{SBR}	T_{inf}	T_{septic}	T_{SBR}
a	385.9072836	386.2404738	-126.083079	-719.231919	-721.242189	-179.979563	-2256.41359	-2133.46731	-119.368367
b	39.06332863	41.24608609	-17.8495339	-6.97763342	-5.18376572	-15.1372445	-47.3577686	-39.7350207	-15.5258252
c	-288.914104	-293.72269	162.7157496	452.870387	452.1823264	168.7538351	1458.790947	1374.111205	136.9605848
d	0.67874744	0.686878509	-0.37933448	0.191241738	0.203643807	-0.27431655	-0.02531705	0.035679886	-0.45922647
e	61.00546692	62.39399834	-35.9016526	-65.3137768	-64.9380195	-33.3337477	-228.65681	-214.274159	-31.3344233
f	-14.7155043	-15.3712902	7.981623818	1.111799837	0.565349152	6.524682079	13.95793229	11.53749886	8.063046719

Were T_{inf} is wastewater temperature at inlet; T_{septic} is wastewater temperature from septic tank; T_{SBR} is the wastewater temperature from SBR tank.

Table 5
EQUATION CONSTANTS VALUES FOR THE MODEL THAT DESCRIBE CORRELATION BETWEEN REDUCTION DEGREE FOR NH_4^+ AND PHOSPHORUS, CORRELATED WITH WASTEWATER TEMPERATURE AND SVI

Equation constants	NH_4^+			Phosphorus		
	T_{inf}	T_{septic}	T_{SBR}	T_{inf}	T_{septic}	T_{SBR}
a	-5589.14915	-5404.71825	53.18458638	3598.919124	3555.172722	-1123.5638
b	-187.30533	-179.452693	4.105826747	109.544221	104.6550016	-28.104166
c	3748.889787	3632.794278	-33.503948	-2374.48282	-2348.12096	736.129128
d	-1.55614011	-1.48053913	-0.16779345	0.40331911	0.35357231	-0.3261128
e	-622.40391	-604.165078	6.164327875	388.9406364	384.895785	-118.16484
f	62.32458486	59.83193146	0.410192399	-32.8654808	-31.3305974	10.1645128

The mathematical model was verified, respectively for all quality indicators analyzed corelated with operation times cycle and SVI. Figure 4 present the relative deviations specific for the mathematical model and the obtained experimental data.

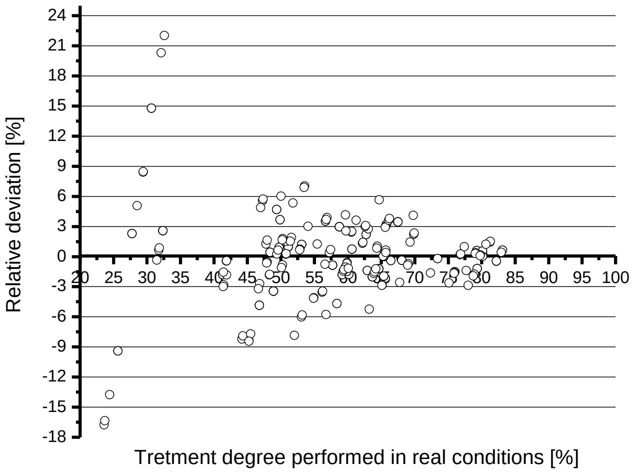

Fig. 4. Representation of the relative deviation of the mathematical and the obtained experimental data.

From the figure 4 it can be observed that most of the deviations is around 0 value. This means that the performed mathematical model is applicable to created experimental conditions by considering all the variables. Also, the high relative deviation of the mathematical model was -16.77225 and respectively 20.2917 %.

Conclusions

Experimental techniques particularities were revealed the correlations between the factors that influence an SBR plant process. These correlations were also evidenced by mathematical model performed.

Monitoring of the SBR operation variables factors for 180 days (temperature, cycle times) provide data and creates the possibility of methods identifying to reduce operational times and to increase wastewater parameter reduction.

The model predictability was confirmed by the values of the relative deviation an also comparing the experimental data and the mathematical model data.

The present research confirms the appliance of the TableCurve 3D software in the wastewater treatment process data interpretations and provide some direction to other cases of SBR plant with similar application.

References

1.FABIAN, F., NEDEFF, V., BIRSAN, N., MOSNEGUTU, E., Energy and Chemicals Consumption Evaluation in Water Treatment Plant A comparative study between Bacau and Turin, Rev.Chim. (Bucharest), **70**, no. 3, 2019, p. 881.

2.IRIMIA, O., TOMOZEI, C., PANAINTE, M., MOSNEGUTU, E.F., BARSAN, N., Efficiency of filters with different filtering materials: comparative study in water treatment, Environmental Engineering and Management Journal, **12**, no. 1, 2013, p. 35.

3.TIRTOACA IRIMIA, O., NEDEFF, V., PANAINTE-LEHADUS, M., TOMOZEI, C. Efficiency of water filtering process depending on the filter layer porosity and flow-a mathematical model, Journal of Engineering Studies and Research, **22**, no. 4, p. 54.

4.TATARU, L., NEDEFF, V., BARSAN, N., MOSNEGUTU, E., PANAINTE-LEHADUS, M., SANDU, I., CHITIMUS, D., Studies of Humic Acid Removal from Aqueous Systems by Using Polymeric Membrane Ultrafiltration Process, Mat. Plast., **55**, no. 4, 2018, p. 660.

5.TATARU, L., NEDEFF, V., BARSAN, N., SANDU, A.V., MOSNEGUTU, E., PANAINTE-LEHADUS, M., SANDU, I., Applications of Polymeric Membranes Ultrafiltration Process on the Retention of Bentonite Suspension, Mat. Plast., **56**, no. 1, 2019, p. 97.

6.MISAILA, L., NEDEFF, F.M., BARSAN, N., SANDU, I.G., GROSU, L., PATRICIU, O.I., GAVRILA, L., FINARU, A. L., WATERSHED - android application for the mineral waters, classification, Rev.Chim. (Bucharest), **70**, no. 6, 2019, p. 2212.
7.EBLIN, S. G., KONAN, K. S., MANGOUA, OI M. J., NEDEFF, V., SANDU, A. V., BARSAN, N., SANDU, I., Nitrate Pollution of Groundwater Based on GIS in the City of Daloa, West-central Cote d'Ivoire, Rev.Chim. (Bucharest), **70**, no. 7, 2019, p. 2579.
8.COCHIORCA, A., NEDEFF, V., BARSAN, N., MOSNEGUȚU, E.F, PANAINTE-LEHADUȘ M., Aspects related to water quality assessment in a mining activity area. Case study, mining area Targu Ogna, Romania. International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & Mining Ecology Management, **18**, 2018, p. 87.
9.COCHIORCA, A., NEDEFF, V., BARSAN, N., PANAINTE-LEHADUS, M., MOSNEGUTU, E. F., Aspects related to water quality assessment in a mining activity area. Case study, mining area Tg. Ogna, Romania, Proceeding of the International Multidisciplinary Scientific Geo Conference Surveying Geology and Mining Ecology Management, SGEM, **18**, no. 3.1., 2018, p. 87.
10.BARSAN, N., JOITA, I., STANILA, M., RADU, C., DASCALU M., Modelling wastewater treatment process in a small plant using a Sequencing Batch Reactor (SBR), Environmental Engineering and Management Journal, **13**, no. 7, 2014, p. 1561.
11.BARSAN, N., NEDEFF, V., TEMEA, A., MOSNEGUTU, E., CHITIMUS A.D., TOMOZEI, C., A perspective for poor wastewater infrastructure regions: a small-scale Sequencing Batch Reactor treatment system, Chemistry Journal of Moldova, **12**, no. 1, 2017. p. 61.
12.BARSAN, N., NEDEFF, V., MOSNEGUTU, E.F., PANAINTE, M., Heat balance components of a small sequencing batch reactor applied for municipal wastewater treatment, Environmental Engineering and Management Journal, **11**, no.12, 2012, p. 2131.
13.BARSAN, N., Studies and research for increase treatment capacity of municipal wastewater in small plants, PhD Thesis, Vasile Alecsandri University of Bacau, 2011.
14.BUNGAY, S., HUMPHRIES, M., STEPHENSON, T., Operating strategies for variable flow sequencing batch reactors, Journal of Water and Environment, **21**, 2007, p. 1.
15.MAHVI, A.H., Sequencing batch reactor, a promising technology in wastewater treatment, Journal of Environmental Health Science and Engineering, **5**, 2008, p. 79.
16.MESDAGHINIA, A.R., MAHVI, A.H., KARAKANI, F., Feasibility of continuous flow sequencing batch reactor in domestic wastewater treatment, American Journal of Applied Sciences, **1**, 2004, p. 348.
17.FREITAS, F., TEMUDO, M.F., CARVALHO, G., OEHMEN, A., REIS, M., Robustness of sludge enriched with short SBR cycles for biological nutrient removal, Journal of Bioresource Technology, **100**, 2009, p. 1969.
18.LARREA, L., ALBIZURI, J., IRIZAR, I., HERNÁNDEZ, J.M., Design and operation of SBR processes for small plants based on simulations, Water Science and Technology, **55**, 2007, p. 163.
19.LISHMAN, L.A., LEGGE, R.L., FARQUHAR, G.J., Temperature effects on wastewater treatment under aerobic and anoxic conditions, Water Research, **34**, 2000, p. 2263.
20.ANDRES, H., HU, Z., SNOWLING, S., SCHRAA O., Model-Based Optimum Design of Sequencing Batch Reactors for COD and Nitrogen Removal from a Slaughterhouse Wastewater, Proceedings of the Water Environment Federation, WEFTEC, Session 61 through Session **70**, 8, 2006, p. 5100.
21.ARTAN, N., TASLI, R., ORHON, D., Rational basis for optimal design of sequencing batch reactors with multiple anoxic filling for nitrogen removal, Journal of Process Biochemistry, **41**, 2006, p. 901.
22.VAIGAN, A.A., MOGHADDAM, M.R.A., HASHEMI, H., Aerobic sequencing batch reactor system with granular activated carbon for the treatment of wastewater containing a reactive dye, Environmental Engineering and Management Journal, **9**, 2010, p. 407.

Manuscript received: 11.12.2019