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Biological Treatment of Wastewater by Sequencing Batch Reactors

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Abstract. In the present paper the operation of wastewater treatment plant (WWTP) in the town of Hisarya which includes a biological stage with aeration basins of cyclic type (SBR-method) was studied. The values of the standard indicators of input and output water from the wastewater treatment plant were evaluated. Moreover, the reached effects due to the biological treatment of the wastewater in terms of the COD (95.7%), BOD_5 (96.6%), total nitrogen (81.3%), total phosphorus (53.7%) and suspended solids (95.7%) were established. It was concluded that the indexes of the treated water were significantly below the emission limits specified in the discharge permit.

Key words: wastwater, biological, treatment, SBR-technology, performance

Introduction

Nature conservation and improvement of the environment is one of the most considerable problems of the modern world. An important component of the environment is the water whose quality is the basis of the balance of ecosystems. Recent development of urbanization, tourism and industry leads to increasing of worldwide water consumption. On the other hand the volume of wastewater effluents into water intakes containing a variety of pollutants is continuously growing. Wastewater treatment before its discharging into water bodies is an important assignment of any civilized society, central and local government. Domestic and industrial wastewaters incoming into the urban treatment plants are characterized by irregularity in the amount and type of the pollutants. Therefore, the facilities for the treatment of this type of water are combined and typically include a mechanical, biological and in some cases, chemical step. The biotransformation of organic pollutants is carried out in the aeration tanks, where under the action of the existing biocenosis and in the presence of the required amount of dissolved oxygen in the water, the pollutants are converted into environmentally safe substances (TSACEV, 2001; TCHOBANOGLOUS *et al.*, 2002; RAITCHKOV *et al*., 2004; DAVIS, 2010).

For the first time, sequencing batch reactors (SBRs)-technology has been used in 1914. Later in 20th century, it is becoming more and more popular due to the excellent opportunities for adaptation to seasonal changes without limitation of the required optimal treatment capacity at each load. This technology offers great flexibility in terms of the implementation and control of different phases of the biological treatment process, such as biological phosphorus removal, aerobic oxidation of nitrogen (nitrification) and anoxic elimination of nitrate (denitrification). Several studies demonstrated the effectiveness of SBR-technology and its application as an alternative to conventional flow system with respect to the treatment of municipal and industrial wastewater, especially for smaller flow (JANCZUKOWICZ *et al.*, 2001; MACE & MATA-ALVAREZ, 2002).

Bulgarian experience in wastewater treatment with a total biomass for complete removal of BOD_5, nitrogen and phosphorus is relatively new and limited. Recent projects for new wastewater treatment plants (WWTP) are developed by mathematical models and programs. These plants are not susceptible to mathematical verification. For examination of plant's design and efficiency of operation can only be used the results from the wastewater analysis at the inlet and the outlet of the already constructed plant during its exploatation (KUZMANOVA, 2011).

In the town of Hisarya which is one of the famous Bulgarian resorts with its mineral springs and SPA-centers attracting thousands of tourists especially in summer is located one of the newly WWTP.

The purpose of this paper is to evaluate the performance of the WWTP-Hisarya which includes biological stage in aeration basins of cyclic type (SBR-method).

Materials and Methods

The object of this study was WWTP-Hisarya. The results presented are for the period of January to December 2012. The plant was put into operation in 2011. Design values of the performance of the plant are: load 10000-25000 PE, wastewater dry weather flow 7250 m^3/d, wastewater wet weather flow up to 2000 m^3/h, daily treatment volume in wet weather 1080 m^3/h, organic load as BOD_5 up to 1500 kg/d, total nitrogen load 275 kg/d, total phosphorus load 45 kg/d, three aeration basins SBRs, aerobic stabilization of sludge, dewatering machine (centrifuge) and conditioning with lime, installed capacity of about 430 kW, daily consumption of electricity at full load about 2000 kWh/d, specific consumption of electric energy per unit volume of wastewater 0.27 kWh/m^3 and specific electricity consumption equivalent per capita per year 29 kWh/PE.

The WWTP operation was evaluated by the values of the following standard indicators: chemical oxygen demand (COD), five-day biological oxygen demand (BOD_5), total nitrogen, total phosphorus and suspended solids. Determination of all indicators was performed by standard methods with triplicates.

The processes in the plant and the sequence are presented in the schematic flow diagram shown in Fig. 1.

For monitoring of the WWTP operation and to determine the effects of wastewater treatment an appropriate data were taken from the laboratory records which reflect the characteristics of the wastewater influent and effluent. Monthly and average wastewater treatment effects are defined by the following equations:

Required wastewater treatment effect:

$$L = \frac{C_{inlet} - C_{outlet}^{limit}}{C_{inlet}}.100\text{ , \%} \quad (1)$$

Reached wastewater treatment effect:

$$R = \frac{C_{inlet} - C_{outlet}}{C_{inlet}}.100\text{ , \%} \quad (2)$$

where:

C_{inlet} – concentration of the respective pollutant at the inlet of the WWTP, mg/dm^3;

C_{outlet} – concentration of the respective pollutant at the outlet of the WWTP, mg/dm^3;

C_{outlet}^{limit} - individual emission limit for the respective pollutant, mg/dm^3.

Individual emission limits are specified in the permit for the use of water body "Blue River" - Hisarya for discharge of the wastewater.

Results and Discussion

Table 1 shows the characteristic of wastewater influent in the aeration basins.

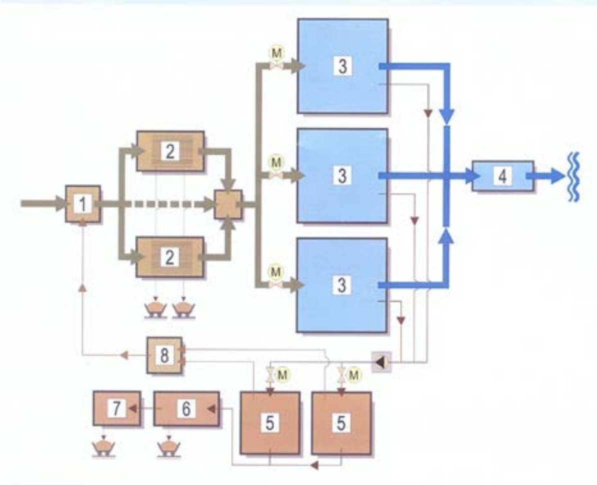

Fig. 1. Schematic flow diagram of the WWTP-Hisarya:

1 - input shaft, 2 - mechanical pre-treatment units, 3 - SBRs, 4 - UV-disinfection, 5 - excess sludge stabilisation tanks, 6 - excess sludge dewatering machine, 7 - conditioning of dewatered excess sludge, 8 - pumping station.

The values of standard indicators of treated water for the investigated period are presented in Tables 2 and 3.

The results in Table 1 show that the actual load of the WWTP is less than the design, which allows for the treatment of additional volumes of wastewater in any expansion of the business in the city and to increase the number of tourists.

Data in Tables 2, 2[a], 3 and 3[a] shows that the average values of indicators COD, BOD_5, total nitrogen, total phosphorus and suspended solids in treated wastewater are significantly below emission limits specified in the discharge permit. For the COD reduction is 9.8 times, for BOD_5 is about 6.1 times, and for total nitrogen, total phosphorus and suspended solids decrease is 2.9, 1.1 and 7.8 times respectively. This indicates that the treated water has a significantly better perfomance compared to the requirements for the category of water intake.

Table 1. Characteristic of wastewater influent in the aeration basins (SBRs)

Month-2012	Influent Q_1, l/s		Wastewater flow Q_2, m^3/d		BOD_5, mg/l		COD, mg/l		N-total, mg/l		P-total, mg/l		SS, mg/l	
	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*
January	25.56	*20.89*	2208	*1805*	132	*37*	261	*60*	25.5	*2.3*	3.5	*0.9*	74	*32*
February	104.90	*93.64*	9067	*8091*	141	*60*	228	*56*	24.5	*2.6*	3.1	*0.9*	68	*18*
March	20.17	*1.99*	1744	*172*	90	-	247	*55*	25.0	*3.4*	3.6	*0.7*	71	*14*
April	26.73	*28.30*	2310	*2445*	106	-	238	*31*	26.3	*2.6*	3.6	*0.3*	69	*18*
May	40.24	*45.21*	3476	*3906*	134	*46*	236	*70*	23.6	*4.3*	3.3	*0.5*	72	*23*
June	21.32	*8.46*	1842	*731*	111	*27*	260	*77*	25.5	*2.4*	3.8	*0.6*	82	*20*
July	18.71	*8.82*	1616	*762*	124	*20*	293	*29*	24.9	*2.6*	4.1	*0.7*	93	*24*
August	21.86	*10.79*	1889	*932*	118	*18*	300	*37*	26.8	*3.2*	4.3	*0.4*	92	*32*
September	20.28	*8.02*	1753	*693*	143	*18*	309	*25*	27.9	*3.0*	4.2	*0.2*	91	*17*
October	19.78	*5.69*	1709	*491*	104	*21*	313	*41*	26.0	*3.0*	4.2	*0.4*	82	*14*
November	18.78	*5.56*	1622	*480*	111	*16*	297	*37*	29.3	*5.1*	4.2	*0.6*	80	*14*
December	23.33	*12.80*	2016	*1106*	113	*22*	303	*43*	23.6	*1.5*	3.6	*0.4*	78	*15*
Average	**30.14**	***24.27***	**2604**	***2098***	**119**	***16***	**274**	***32***	**25.7**	***1.7***	**3.8**	***0.4***	**79**	***9***

Av – average; STD – standard deviation; BOD_5 – five-day biological oxygen demand; COD – chemical oxygen demand; N-total – total nitrogen; P-total – total phosphorus; SS – suspended solids;

Table 2. Characteristic of wastewater effluent from aeration basin SBR_1

Month-2012	pH		N-total, mg/l		NH_4-N, mg/l		NO_3-N, mg/l		DO, mg/l	
	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*
January	7.1	*0.10*	5.40	*1.70*	0.20	*0.10*	3.90	*1.60*	2.68	*0.15*
February	7.2	*0.04*	9.98	*2.10*	1.26	*3.96*	7.85	*1.47*	2.65	*0.08*
March	7.2	*0.03*	5.78	*2.26*	0.20	*0.06*	5.24	*2.89*	2.66	*0.16*
April	7.2	*0.10*	3.34	*0.37*	0.22	*0.03*	2.47	*0.29*	2.70	*0.20*
May	7.2	*0.10*	6.49	*5.34*	0.36	*0.11*	4.73	*5.04*	2.70	*0.21*
June	7.1	*0.10*	4.00	*2.40*	0.44	*0.12*	3.87	*2.40*	2.72	*0.11*
July	7.2	*0.10*	3.15	*0.50*	0.39	*0.21*	2.20	*0.40*	2.73	*0.10*
August	7.1	*0*	3.44	*0.78*	0.42	*0.10*	2.31	*0.62*	2.68	*0.15*
September	7.1	*0.03*	3.13	*0.06*	0.50	*0.10*	2.24	*0.39*	2.72	*0.13*
October	7.2	*0.10*	3.72	*1.23*	0.58	*0.20*	2.60	*0.50*	2.66	*0.15*
November	7.2	*0.04*	5.72	*2.18*	0.44	*0.17*	4.18	*1.78*	2.64	*0.14*
December	7.1	*0.02*	6.48	*1.56*	0.37	*0.08*	5.31	*1.39*	2.60	*0.15*
Average	**7.2**	***0.05***	**5.10**	***2.00***	**0.45**	***0.28***	**3.91**	***1.71***	**2.68**	***0.04***
Limit	**6-9**	**-**	**15**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Av – average; STD – standard deviation; N-total – total nitrogen; NH_4-N – ammonia-nitrogen; NO_3-N – nitrate-nitrogen; DO – dissolved oxygen.

Table 2ª. Characteristic of wastewater effluent from aeration basin SBR_1

Month-2012	COD, mg/l		BOD_5, mg/l		P-total, mg/l		t, ^0C		SS, mg/l	
	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*
January	9.8	*1.6*	3.1	*0.7*	1.49	*0.30*	16.6	*1.5*	3.4	*0.5*
February	12.0	*3.7*	5.0	-	1.48	*0.09*	14.2	*1.0*	3.7	*0.5*
March	10.8	*1.8*	3.4	*0.6*	1.82	*0.21*	18.2	*1.8*	16.6	*28.9*
April	9.9	*1.6*	4.2	*1.6*	1.79	*0.20*	21.5	*1.2*	3.3	*0.6*
May	12.7	*3.1*	4.4	*1.0*	1.74	*0.09*	22.3	*2.1*	3.4	*0.6*
June	9.1	*1.4*	2.3	*0.1*	1.98	-	26.1	*1.5*	3.4	*0.6*
July	14.0	*1.5*	4.4	*0.6*	1.76	*0.20*	28.0	*0.6*	3.6	*0.6*
August	10.8	*0.3*	5.6	*0.6*	1.76	-	27.4	*0.9*	3.0	*1.0*
September	14.1	*2.1*	5.1	*0.2*	1.84	-	26.3	*0.5*	3.9	*0.5*
October	13.4	*2.4*	3.5	*0.7*	1.85	*0.12*	24.9	*1.4*	3.4	*0.5*
November	13.2	*3.8*	3.7	*1.6*	1.84	*0.07*	22.7	*0.8*	3.0	*0.5*
December	11.3	*1.5*	4.1	*0.3*	1.73	*0.23*	17.0	*1.2*	3.4	*0.6*
Average	**11.8**	***1.7***	**4.1**	***0.9***	**1.76**	***0.14***	**22.1**	***4.7***	**4.5**	***3.8***
Limit	**125**	**-**	**25**	**-**	**2**	**-**	**-**	**-**	**35**	**-**

Av – average; STD – standard deviation; COD – chemical oxygen demand; BOD_5 – five-day biological oxygen demand; P-total – total phosphorus; t – water temperature; SS – suspended solids.

Table 3. Characteristic of wastewater effluent from aeration basin SBR_2

Month-2012	pH		N-total, mg/l		NH_4-N, mg/l		NO_3-N, mg/l		DO, mg/l	
	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*
January	7.1	*0.04*	5.20	*1.60*	0.17	*0.03*	4.24	*1.59*	2.70	*0.10*
February	7.1	*0.1*	8.70	*2.00*	0.17	*0.11*	7.34	*2.32*	2.65	*0.23*
March	7.2	*0.04*	6.40	*3.60*	0.20	*0.04*	5.11	*2.87*	2.69	*0.14*
April	7.2	*0.04*	3.14	*0.46*	0.23	*0.05*	2.54	*0.40*	2.70	*0.18*
May	7.2	*0.1*	6.22	*7.40*	0.39	*0.15*	3.98	*4.55*	2.67	*0.16*
June	7.1	*0.04*	4.89	*2.98*	0.42	*0.10*	4.08	*2.46*	2.72	*0.11*
July	7.1	*0*	3.12	*1.03*	0.33	*0.16*	2.11	*0.30*	2.68	*0.13*
August	7.1	*0.04*	2.94	*1.10*	0.42	*0.09*	2.36	*0.54*	2.65	*0.10*
September	7.1	*0.02*	3.10	*0.90*	0.50	*0.10*	2.16	*0.52*	2.69	*0.09*
October	7.2	*0.08*	3.89	*0.81*	0.63	*0.22*	2.60	*0.49*	2.70	*0.13*
November	7.2	*0.05*	5.04	*1.75*	0.43	*0.18*	4.24	*1.68*	2.72	*0.13*
December	7.1	*0.04*	5.00	*1.00*	0.35	*0.06*	5.83	*2.53*	2.66	*0.14*
Average	**7.1**	***0.05***	**4.80**	***1.73***	**0.35**	***0.14***	**3.88**	***1.64***	**2.69**	***0.02***
Limit	**6-9**	**-**	**15**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Av – average; STD – standard deviation; N-total – total nitrogen; NH_4-N – ammonia-nitrogen; NO_3-N – nitrate-nitrogen; DO – dissolved oxygen.

Table 3[a]. Characteristic of wastewater effluent from aeration basin SBR_2

Month-2012	COD, mg/l		BOD_5, mg/l		P-total, mg/l		t, ^0C		SS, mg/l	
	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*	Av	*STD*
January	9.6	*2.1*	3.0	*0.1*	1.50	*0.30*	17.0	*1.1*	3.5	*0.6*
February	12.3	*1.9*	5.1	*1.3*	1.49	*0.19*	14.4	*0.8*	3.2	*0.7*
March	11.0	*5.3*	4.5	*2.0*	1.60	*0.20*	18.2	*1.6*	3.2	*0.4*
April	10.6	*2.1*	3.4	*2.3*	1.68	*0.21*	21.5	*1.2*	3.4	*0.5*
May	13.6	*5.6*	3.3	*1.0*	1.95	*0.04*	22.5	*2.1*	3.3	*0.9*
June	15.8	*8.1*	3.6	*0.8*	1.97	*0.01*	26.1	*1.5*	3.7	*0.6*
July	12.0	*0.7*	3.0	-	1.98	-	27.9	*0.7*	3.9	*0.6*
August	12.0	*1.0*	5.1	*1.4*	1.84	*0.09*	27.3	*0.8*	3.5	*0.5*
September	13.4	*2.0*	4.5	*1.1*	1.90	-	26.4	*0.7*	3.6	*0.5*
October	13.0	*2.9*	3.4	-	1.80	*0.20*	25.1	*1.2*	3.3	*0.4*
November	15.7	*4.0*	5.7	*0.4*	1.82	*0.07*	22.3	*0.8*	3.3	*0.4*
December	13.1	*1.1*	5.0	*1.2*	1.74	*0.20*	17.0	*1.1*	3.3	*0.8*
Average	**12.7**	***1.9***	**4.1**	***1.0***	**1.77**	***0.17***	**22.1**	***4.6***	**3.4**	***0.2***
Limit	**125**	**-**	**25**	**-**	**2**	**-**	**-**	**-**	**35**	**-**

Av – average; STD – standard deviation; COD – chemical oxygen demand; BOD_5 – five-day biological oxygen demand; P-total – total phosphorus; t – water temperature; SS – suspended solids.

Values of the required and reached effects of the biological wastewater treatment are presented in Tables 4 and 5.

Table 4. Effects of biological wastewater treatment in aeration basin SBR_1

Month-2012	Wastewater treatment effect, %									
	by COD		by BOD_5		by N-total		by P-total		by SS	
	L	R	L	R	L	R	L	R	L	R
January	52.1	96.2	81.1	97.7	41.2	78.8	42.9	57.4	52.7	95.4
February	45.2	94.7	82.3	96.5	38.8	59.3	35.5	52.3	48.5	94.6
March	49.4	95.6	72.2	96.2	40.0	76.9	44.4	49.4	50.7	76.6
April	47.5	95.8	76.4	96.0	43.0	87.3	44.4	50.3	49.3	95.2
May	47.0	94.6	81.3	96.7	36.4	72.5	39.4	47.3	51.4	95.3
June	51.9	96.5	77.5	97.9	41.2	84.3	47.4	47.9	57.3	95.9
July	57.3	95.2	79.8	96.5	39.8	87.3	51.2	57.1	62.4	96.1
August	58.3	96.4	78.8	95.3	44.0	87.2	53.5	59.1	62.0	96.7
September	59.5	95.4	82.5	96.4	46.2	88.8	52.4	56.2	61.5	95.7
October	60.1	95.7	76.0	96.6	42.3	85.7	52.4	56.0	57.3	95.9
November	57.9	95.6	77.5	96.7	48.8	80.5	52.4	56.2	56.3	96.3
December	58.7	96.3	77.9	96.4	36.4	72.5	44.4	51.9	55.1	95.6
Average	**54.4**	**95.7**	**79.0**	**96.6**	**41.6**	**80.2**	**47.4**	**53.7**	**55.7**	**94.3**

L – required effect; R – reached effect.

Table 5. Effects of biological wastewater treatment in aeration basin SBR_2

Month-2012	Wastewater treatment effect, %									
	by COD		by BOD_5		by N-total		by P-total		by SS	
	L	R	L	R	L	R	L	R	L	R
January	52.1	96.3	81.1	97.7	41.2	79.6	42.9	57.1	52.7	95.3
February	45.2	94.6	82.3	96.4	38.8	64.5	35.5	51.9	48.5	95.3
March	49.4	95.5	72.2	95.0	40.0	74.4	44.4	55.6	50.7	95.5
April	47.5	95.5	76.4	96.8	43.0	88.1	44.4	53.3	49.3	95.1
May	47.0	94.2	81.3	97.5	36.4	73.6	39.4	40.9	51.4	95.4
June	51.9	93.9	77.5	96.8	41.2	80.8	47.4	48.2	57.3	95.5
July	57.3	95.9	79.8	97.6	39.8	87.5	51.2	51.7	62.4	95.8
August	58.3	96.0	78.8	95.7	44.0	89.0	53.5	57.2	62.0	96.2
September	59.5	95.7	82.5	96.9	46.2	88.9	52.4	54.8	61.5	96.0
October	60.1	95.8	76.0	96.7	42.3	85.0	52.4	57.1	57.3	96.0
November	57.9	94.7	77.5	94.9	48.8	82.8	52.4	56.7	56.3	95.9
December	58.7	95.7	77.9	95.6	36.4	78.8	44.4	51.7	55.1	95.8
Average	**54.4**	**95.4**	**79.0**	**96.6**	**41.6**	**81.3**	**47.4**	**53.4**	**55.7**	**95.7**

L – required effect; R – reached effect.

Reached biological effects of wastewater treatment are significantly above the calculated required effects. For example, difference between the reached and the required effect for COD index is on average 41%, for BOD_5 was 17.6%, and for suspended solids that difference is 38.6%.

Conclusion

The results obtained from this research and statistical analysis of the performance of the wastewater influent and effluent show that the WWTP-Hisarya operates under the regulations. Values of all standard indicators are significantly below established emission limits. Reached biological effects of wastewater treatment significantly exceed the required.

Analysis of the results of WWTP-Hisarya operation shows that it is designed and built a future oriented, modern wastewater treatment plant with all conditions to work reliably for many years, which in terms of equipment, structure and economical effectiveness set new accents.

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