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PHYSICOCHEMICAL MONITORING AND PERFORMANCE EVALUATION OF SBR MUNICIPAL WASTEWATER TREATMENT

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Abstract: *Hisarya town is one of the famous Bulgarian resort with mineral springs and SPA-centers attracting thousands of tourists where is installed one of the newly wastewater treatment plants (WWTP) designed on the base of sequencing batch reactor (SBR) technology. In recent years, SBR has been applied as an efficient technology for wastewater treatment. Monitoring and control of SBR is a very attractive field of research nowadays. Present study are dealt with monitoring of physicochemical characteristics viz.* BOD_5*, COD, suspended solids (SS), total nitrogen (TN) and total phosphorus (TP) and performance evaluation of SBR municipal wastewater treatment at WWTP-Hisarya. Significant reduction (*$p<0.05$*) in the physicochemical characteristics of the SBR treated wastewater was established. The average removal of* BOD_5 *(95.1±0.6 %), SS (95.1±0.6 %), COD (93.2±0.7 %), TN (80.3±8.0 %) and TP (53.4±7.2 %) were recorded. The values obtained of physicochemical parameters in treated wastewater were considerably below permitted emission limits which indicate that WWTP-Hisarya is working perfectly. Thus it is helpful in the control of the pollution of "Blue River" as a discharging water body.*

Keywords: *characteristics, effluent, influent, pollutants, purification*

1. Introduction

Water environment pollution has become a major environmental problem recently. Continuous 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. It is an urgent task for mankind to improve the wastewater treatment efficiency. Domestic and industrial wastewater 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 steps [1].

The Sequencing batch reactor (SBR) represents a modern approach to wastewater treatment. Unlike the traditional continuous flow activated sludge process, where different reactions are carried out in separated tanks, SBR allows using a single tank for the whole process. SBR is a modified activated sludge process used to treat a variety of wastewaters. In recent years, SBR has been employed as an efficient technology for wastewater treatment, especially for domestic wastewaters, because of its simple configuration and high efficiency in

BOD_5 and suspended solids removal, nitrification, denitrification and phosphorus removal [2]. There are several literatures supporting the applicability of this promising reactor in different wastewater treatment [3-15].

Monitoring and control of SBR is a very active field of research nowadays. The quality and quantity of influent wastewater are floating with season, temperature and weather. Meanwhile wastewater treatment systems have characteristics of high dimensional data and strong nonlinearity. Therefore precise monitoring and control for SBR is still complex for research and practice [16].

The efficiency of wastewater treatment plant (WWTP) can be illustrated by a study on the evaluation of pollution levels of the influent and the effluent at the treatment plant discharging into the environment [17]. On the other hand, process monitoring of wastewater treatment systems can be used successfully for the WWTP optimization [18].

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 installed one of the newly wastewater treatment plants designed on the base of SBR-technology. Bulgarian experience in wastewater treatment for complete removal of BOD_5, nitrogen and phosphorus is relatively new and limited. Recent projects for new 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 exploitation. Monitoring and performance evaluation will also help for the better understanding of design and operating difficulties in WWTP and also to assess reuse potential of treated water.

This work aimed the monitoring of physicochemical characteristics of municipal wastewater before and after treatment at SBR plant installed in Hisarya town, Bulgaria and the performance evaluation of SBR treatment.

2. Materials and methods

Wastewater treatment plant (WWTP) general description

The object of this study was WWTP designed on the base of SBR-technology installed in Hisarya town, Bulgaria (Fig. 1). 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 and total phosphorus load 45 kg/d. WWTP includes three aeration basins (SBRs), aerobic stabilization of sludge, dewatering machine (centrifuge) and lime conditioning, with 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.

Analytical methods

Wastewater sampling was conducted according to BDS ISO 5667-10 standard. Samples were collected automatically into the plastic bags and were brought to the laboratory for analysis.

Physicochemical monitoring of the wastewater treatment was carried out by the values of the following standard parameters: five-day biological oxygen demand (BOD_5), chemical oxygen demand

(COD), total nitrogen (TN), total phosphorus (TP) and suspended solids (SS). Values of COD, TN and TP were determined, spectrophotometrically by using of standard cuvette tests (HACH LANGE), according ISO 6060, EN ISO 11905-1 and ISO 6878-1, respectively and DR3900 spectrophotometer acomplished with Termostat LT200. Values of BOD_5 were determined by using of BODTrak^{TM} II Respirometric BOD apparatus (HACH LANGE). Quantity of suspended solids was measured by filtration through glass filter, according to BDS EN 872 standard.

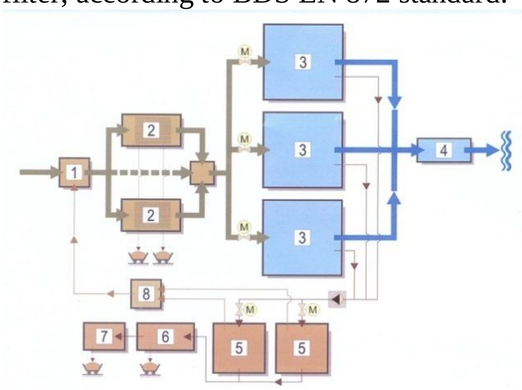

Fig. 1. Schematic flow diagram of the WWTP-Hisarya: 1 - input shaft, 2 - mechanical pre-treatment units, 3 - SBRs, 4 - UV-disinfection, 5 - excess sludge stabilization tanks, 6 - excess sludge dewatering machine, 7 - conditioning of dewatered excess sludge, 8 - pumping station

Performance evaluation

Performance evaluation of the SBR wastewater treatment was carried out by assessment of percentage degree of purification (DP, %) calculated by the following equation:

$$DP = \frac{C_{inlet} \quad C_{outlet}}{C_{inlet}}.100 \qquad (1)$$

where: C_{inlet} – concentration of the respective pollutant at the inlet of the SBR, mg/L; C_{outlet} – concentration of the respective pollutant at the outlet of the SBR, mg/L.

Individual emission limits for controlled pollutants which are specified in the permit for the use of water body "Blue River" – Hisarya for discharge of the wastewater were used for the WWTP performance evaluation.

Statistical analysis

All experiments were performed in triplicate. The data were analyzed and presented as mean values with standard deviation. Statistical analysis was conducted by using of Statgraphics Centurion XVI Version 16.2.04 software. Values are considered at a significance level of 95 %.

3. Results and discussion

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

Results for average wastewater influent in the WWTP for 2013 year are presented in Fig. 2. The established average wastewater daily influent for 2013 year was 2995.3±614.2 m^3/d. For monitoring of the SBR operation and to calculate pollutants degree of purification, physicochemical characteristics of the wastewater influent and effluent were determined. Table 1 presents physicochemical characteristic of the SBR wastewater influent. Average BOD_5 of the inlet was 100.1±11.7 mg/L with maximum 121 mg/L and minimum 90 mg/L. Average values of the inlet for COD, TN, TP and SS were 272±26 mg/L, 25.3±2.0 mg/L, 3.65±0.27 mg/L and 74.1±8.2 mg/L respectively. The results in Fig. 2 and 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 if any expansions of the business in the town and to increase the number of tourists.

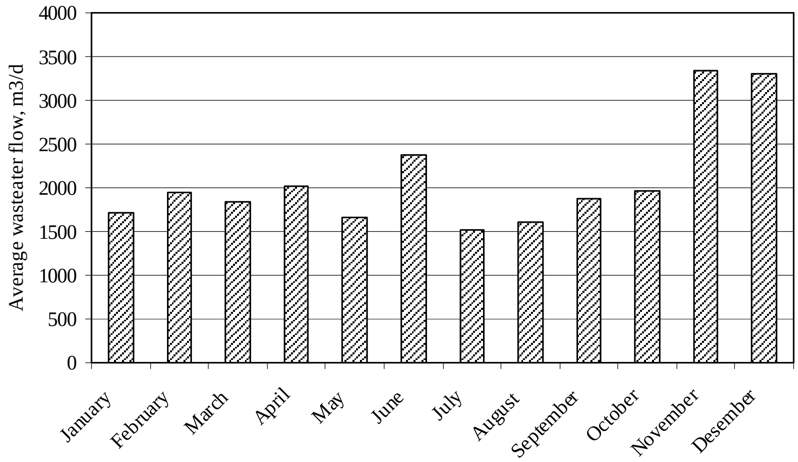

Fig. 2. Average wastewater influent in the WWTP-Hisarya for 2013 year

Table 1

Physicochemical characteristic of the SBR wastewater influent

Month/ Year 2013	BOD_5 (mg/L)	COD (mg/L)	TN (mg/L)	TP (mg/L)	SS (mg/L)
January	119±23	302±34	24.5±2.4	3.3±0.5	82.6±13.3
February	121±14	310±35	23.5±2.9	3.4±0.4	76.0±17.0
March	98±7	299±40	25.0±1.4	3.4±0.3	77.8±12.6
April	117±29	282±27	23.8±1.8	3.4±0.2	75.0±13.0
May	90±3	258±26	24.4±2.7	3.7±0.2	71.0±18.0
June	92±6	261±24	23.7±2.0	3.4±0.3	64.0±12.0
July	92±9	236±28	22.0±1.9	3.7±0.3	63.0±12.0
August	93±9	285±51	28.7±3.0	3.8±0.1	80.0±30.0
September	98±9	291±23	27.2±1.2	3.7±0.1	89.0±38.0
October	95±6	257±43	26.2±2.8	3.9±0.2	75.1±13.8
November	93±6	244±37	27.0±1.9	4.0±0.2	73.8±14.8
December	93±6	239±35	27.5±1.3	4.1±0.1	61.8±16.3

Values of standard parameters of the SBR treated wastewater for the investigated period of time are presented in Tables 2 and 3. Statistical analysis indicated that there are not significant differences ($p>0.05$) between the average values of physicochemical parameters determined for the effluents from SBR 1 and SBR 2, respectively. Contrary, values of BOD_5, COD, TN, TP and SS were decreased to be significantly ($p<0.05$) in finally treated (outlet) wastewater (Tables 2 and 3) in comparison to inlet (Table 1). For example, the average BOD_5 decreasing was from 100.1±11.7 mg/L to 4.7±0.7 mg/L. For COD, TN, TP and SS it was from 272±26 mg/L to 18.2±1.4 mg/L, from 25.3±2.0 mg/L to 4.4±1.6 mg/L, from 3.65±0.27 mg/L to 1.67±0.15 mg/L and from 74.1±8.2 mg/L to 3.5±0.2 mg/L, respectively. The obtained results are in accordance to [4, 7, 9, 14, 17] which described such significantly decreasing of pollutants after SBR treatment of different wastewaters.

Table 4 presents percentage degree of purification of SBR municipal wastewater treatment. Reached degree of purification for BOD_5 was in the range from 93.2 % to 95.9 %, average 95.1±0.6 %. For COD this degree was in the range from 92.1 % to 95.0 % (93.2±0.7 %). For TN it was from 60.0 % to 94.5 % (80.3±8.0 %). Such intervals for TP and SS were from 44.5 % to 66.8 % (53.4±7.2 %) and from 93.7 % to 96.2 % (95.1±0.6 %), respectively.

Similar degree of purification of municipal wastewater treatment plant as follow: BOD_5 (91.31 %), COD (91.84 %), TN (71.40 %) and SS (88.37 %) was reported by [7]. Recently, degree of purification of SBR municipal wastewater treatment of BOD_5 (89-98 %), COD (80 %), total SS (85 - 97 %), TN (>75 %) and Bio-P (57-69 %) was reported by [8] also.

Fig. 3 represents the results for performance evaluation of SBR municipal wastewater treatment based on the average pollutant's concentration in the wastewater and emission limit. The average values of standard parameters BOD_5, COD, TN and SS of treated wastewater were considerably below emission limits (25 mg/L, 125 mg/L, 15 mg/L and 35 mg/L, respectively) specified in the discharge limit. Average values of TP of the effluents from SBR 1 (1.69±0.17 mg/L) and SBR 2 (1.67±0.15 mg/L) were closed to the permitted emission limit (2 mg/L).

Table 2

Physicochemical characteristic of wastewater effluent from SBR 1

Month/Year 2013	**BOD_5 (mg/L)**	**COD (mg/L)**	**TN (mg/L)**	**TP (mg/L)**	**SS (mg/L)**
January	5.3±0.7	17.9±8.5	7.43±0.97	1.83±0.05	4.2±1.1
February	5.4±0.8	17.5±1.5	9.40±2.20	1.85±0.07	3.6±0.5
March	4.9±0.1	18.1±1.3	5.80±2.70	1.78±0.09	3.5±0.5
April	5.5±1.3	20.1±3.2	7.95±4.98	1.87±0.13	3.7±0.3
May	4.1±0.4	19.6±1.2	3.75±1.37	1.70±0.42	3.7±0.6
June	3.8±0.3	16.9±0.1	4.72±0.48	1.81±0.12	3.4±0.4
July	4.8±0.6	18.7±1.6	4.37±1.11	1.75±0.15	3.3±0.4
August	4.1±0.7	20.8±3.8	4.11±0.76	1.72±0.14	3.6±0.4
September	4.0±0.3	18.6±3.1	3.17±0.96	1.76±0.11	3.6±0.6
October	5.1±0.5	18.2±1.5	5.07±1.79	1.51±0.03	3.6±0.5
November	4.7±0.1	17.7±1.3	3.72±0.97	1.40±0.16	3.8±0.6
December	4.7±0.1	18.8±1.2	4.85±0.48	1.36±0.16	3.9±0.6

Table 3

Physicochemical characteristic of wastewater effluent from SBR 2

Month/Year 2013	**BOD_5 (mg/L)**	**COD (mg/L)**	**TN (mg/L)**	**TP (mg/L)**	**SS (mg/L)**
January	5.9±0.6	15.2±3.0	5.8±2.0	1.82±0.13	3.8±0.6
February	5.4±2.1	18.2±1.9	7.2±3.3	1.86±0.04	3.3±0.5
March	5.5±0.4	18.3±1.2	3.8±2.4	1.78±0.12	3.5±0.6
April	5.4±0.9	19.2±2.2	6.9±4.0	1.59±0.08	3.6±0.4
May	6.1±0.1	19.5±1.9	3.2±0.3	1.61±0.43	3.7±0.6
June	4.1±0.4	19.3±2.0	4.4±1.3	1.79±0.11	3.2±0.4
July	4.6±0.4	17.1±2.9	3.8±1.3	1.72±0.18	3.3±0.5
August	4.2±0.3	20.0±2.6	4.0±0.7	1.79±0.14	3.4±0.4
September	4.2±0.1	18.6±1.0	1.5±0.1	1.72±0.07	3.4±0.4
October	4.6±0.4	18.2±1.8	4.2±0.9	1.49±0.05	3.5±0.5
November	5.2±0.1	16.4±1.8	3.9±1.2	1.44±0.19	3.8±0.4
December	5.2±0.1	17.8±0.9	4.6±0.4	1.46±0.09	3.7±0.1

Table 4

Degree of purification of SBR municipal wastewater treatment

Month/Year 2013	DP_{BOD5} (%)		DP_{COD} (%)		DP_{TN} (%))		DP_{TP} (%)		DP_{SS} (%)	
	SBR 1	*SBR 2*	*SBR 1*	*SBR 2*	*SBR 1*	*SBR 2*	*SBR 1*	*SBR 2*	*SBR 1*	*SBR 2*
January	95.5	95.0	94.1	95.0	69.7	76.3	44.5	44.8	94.9	95.4
February	95.5	95.5	94.4	94.1	60.0	69.4	45.6	45.3	95.3	95.7
March	95.0	94.4	93.9	93.9	76.8	84.8	47.6	47.6	95.5	95.5
April	95.3	95.4	92.9	93.2	66.6	71.0	45.0	53.2	95.1	95.2
May	95.4	93.2	92.4	92.4	84.6	86.9	54.1	56.5	94.8	94.8
June	95.9	95.5	93.5	92.6	80.1	81.4	46.8	47.4	94.7	95.0
July	94.8	95.0	92.1	92.8	80.1	82.7	52.7	53.5	94.8	94.8
August	95.6	95.5	92.7	93.0	85.7	86.1	54.7	52.9	95.5	95.8
September	95.9	95.7	93.6	93.6	88.3	94.5	52.4	53.5	96.0	96.2
October	94.6	95.2	92.9	92.9	80.6	84.0	61.3	61.8	95.2	95.3
November	94.9	94.4	92.7	93.3	86.2	85.6	65.0	64.0	94.9	94.9
December	94.9	94.4	92.1	92.6	82.4	83.3	66.8	64.4	93.7	94.0

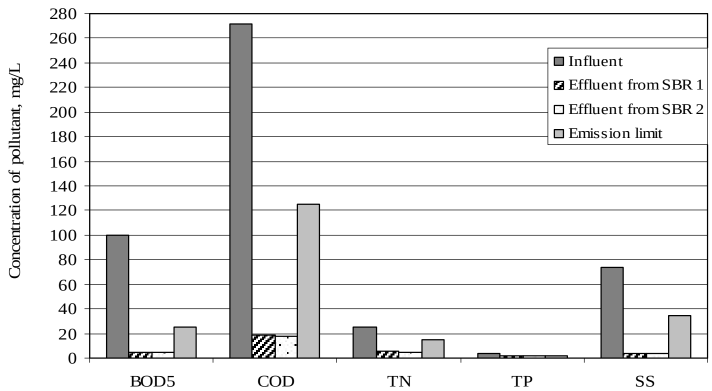

Fig. 3. Performance evaluation of SBR municipal wastewater treatment

Recorded maximum values of the standard parameters for discharged wastewater (Tables 2 and 3) during the investigated period of time were below emission limits also. These results indicates a significantly better performance of SBR wastewater treatment compared the requirements for the discharge into the water body and also potential of treated water for non-potable reuses, like gardening, cooling water and etc.

4. Conclusion

The results obtained in present research and performance evaluation of the SBR municipal wastewater treatment indicated that WWTP installed in Hisarya town, Bulgaria is working perfectly. The significant reduction ($p<0.05$) was observed in the physicochemical characteristics viz. BOD_5, COD, TN, TP and SS. The average removal of BOD_5 (95.1±0.6 %), SS (95.1±0.6 %), COD (93.2±0.7 %), TN (80.3±8.0 %) and TP (53.4±7.2 %) of municipal wastewater were recorded after SBR treatment. The values obtained of standard parameters for treated wastewater were considerably below emission limits which indicate a significantly better performance of SBR wastewater treatment compared the requirements for the discharge into the water body and also reuse potential of treated water. Thus it is helphul in the control of the pollution of “Blu River” – Hisarya.

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