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MONITORING OF WATER AND ACTIVATED SLUDGE ASSESSMENT IN WWTP WITH SEQUENCING BATCH REACTORS

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Abstract: In the present study the operations of the relatively new wastewater treatment plant (WWTP) located near Hisarya – a traditional tourist city in Bulgaria was evaluated. The plant uses aerobic activated sludge to treat wastewater in the aeration basins of cyclic type (SBR-method). These activated sludges thrive and best perform their function in sufficiently oxygen-rich environments. Therefore, the bacterial diversity of activated sludge from the aeration basins during the seasons was investigated, as an important indicator of WWTP`s effectiveness. However, the Cyclic Activated Sludge System is one of the most popular sequencing batch reactor (SBR) processes. The hydrobiological characterization of the activated sludge was performed with regular observations by using light microscopic examinations, but also by evaluation of the flocculation ability and settleability. The presence of positive bioindicators – *Aspidisca* and *Epistyllis* species as well as the prevalence of *Vorticella convallaria* and *Arcella vulgaris* during the investigated period of time (2013 Year) was established, which confirmed the good carrying out of the nitrification process and thus the purification of the wastewater. The results obtained demonstrated that the performance of the SBR maintained high level, and the SBR system remained stable during the studied period of time.

INTRODUCTION

The increase in the population nowadays resulted in production of more wastewater and the subsequent deterioration of the environment. Biological wastewater treatment, in its simplest form, is the conversion of biodegradable waste products from municipal or industrial sources by biological means. The practice of using a controlled biological system like activated sludge, to degrade waste has been used for centuries, but while early wastewater treatment processes were quite simple, they have become more and more complex over time.

Cyclic Activated Sludge System as the name suggests, is one of the most popular sequencing batch reactor (SBR) processes employed to treat municipal wastewater and wastewater from a variety of industries including refineries and petrochemical plants. In 1914 for the first time sequencing batch reactors-technology has been used. Later in the 20th century, this method 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. The technology provide many advantages compared to common flow-through aeration tanks - reduced construction effort, small footprint and minimal operating costs, high purification efficiency, sedimentation and withdrawal take place on ideal influent-free conditions, the fully automated operation strongly facilitates management of the activated sludge plant, SBRs are odorless and can be operated in settlement areas and last but not least minimal place requirement compared to common aeration tanks. Several studies demonstrated the effectiveness of SBR-technology and its application as an alternative to the conventional flow system with respect to the treatment of municipal and industrial wastewater, especially for smaller flow (Janczukowicz et al., 2001; Mace and Mata-Alvarez, 2002; Prokopov et al., 2014).

If untreated, the wastewater, discharged directly to the environment, will cause pollution of the receiving waters and waterborne diseases will be widely distributed. In the early years of the twentieth century the method of biological treatment was invented, and nowadays forms the basis of wastewater treatment worldwide. It simply involves confining naturally occurring bacteria at higher concentrations in tanks. These bacteria, together with some protozoa and other representatives are collectively referred to as activated sludge. The bacteria remove small organic carbon molecules by their growth. The treated wastewater or effluent can then be discharged to receiving waters – normally a river or the sea (Davis, 2005).

However, the key to any biological treatment system is ensuring that the existing microbial community has the right conditions to grow. In biological wastewater treatment, microorganisms are utilized to treat wastewater as they can uptake organic matter and nutrients (such as nitrogen and phosphorus) that are present in wastewater for their growth. Thus the organic and inorganic contaminants are removed from biologically treated wastewater to a great extent. The microorganisms that treat wastewater require carbon sources for their cell synthesis (growth) and energy sources for both cell synthesis and maintenance.

Communities of prokaryotic microorganisms present in activated-sludge or biofilm reactors are responsible for most of the carbon and nutrient removal from sewage and thus represent the core component of every biological wastewater treatment plant (WWTP). By contrast, the mass occurrence of certain bacterial species can also be detrimental for sewage treatment by negatively influencing the settling properties of activated sludge in the secondary clarifiers, by contributing to the formation of foam or by outcompeting microorganisms required for nutrient removal. Consequently, a thorough knowledge on the ecology of the microbial communities and the representatives of micro and meta-fauna is required to reveal factors influencing the efficiency and stability of biological WWTPs and to develop promising strategies for improved process performance.

The Bulgarian experience in wastewater treatment plants with a total biomass for complete removal of BOD_5, nitrogen and phosphorus is relatively new and limited. However, Kozuharov et al. (2009) investigated the structure and function of the activated sludge from WWTP in addition to the bioindicative potential of the micro- and metafauna (Kozuharov et al., 2001) and recent projects for new wastewater treatment plants are designed by mathematical models and programs (Kuzmanova, 2011). One of the recently build WWTP is located in Hisarya, which is one of the famous resorts in Bulgaria with its famous mineral springs and spa, attracting thousands of tourists especially in summer. The installation was developed with the financial help of the EU Project in collaboration with Germany.

The aim of the present study was to evaluate the performance of the WWTP – Hisarya in 2013. For this purpose the biological stage in aeration basins of cyclic type (SBR-method) in terms of presence of bioindicators was investigated, which represent the effectiveness of purification process itself.

MATERIALS AND METHODS

Wastewater treatment plant (WWTP)

The object of the present study was WWTP – Hisarya, Bulgaria. The represented results were reordered for the period of twelve months (January to December, 2013). The station is relatively new (put into operation in 2011). The design values of the performance of the plant are as follow: 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 – in the investigated period only two were put into operation (Fig.1), 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.

Figure 1. SBR aeration basins of WWTP-Hisarya.

Analytical methods

Wastewater sampling was conducted according to BDS ISO 5667-10 standard by using of automatic samplers. Samples were collected in 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: acidity (pH), temperature (t, ºC), ammonia-nitrogen (NH_4-N, ISO 11732), nitrate-nitrogen (NO_3-N, ISO 13395) and dissolved oxygen (DO_2, ISO 5814) of the water. For the characterization of the activated sludge the parameters settled sludge volume (SSV), sludge volume index (SVI) and the dry matter (DM, BDS EN 872) were determined in addition to the bioindicators evaluation. The bioindicators, representatives of micro and meta-fauna were analyzed by light microscopic observations (Jenkins et al., 1993) and calculated after that.

Statistical analysis

All experiments were performed regularly in triplicate. The data were analyzed and presented as mean values with standard deviation (SD).

RESULTS AND DISCUSSION

One of the critical elements in designing an aeration system is the estimation of oxygen demand requirements by the fauna-indicators and the observation of the waste activated sludge production. Therefore, in the present study the values of those parameters were evaluated.

The functioning of nitrifying bacteria is affected by a number of environmental factors (U.S. EPA, 1993). Dissolved oxygen and pH are among the most significant. The activity of the nitrifying bacteria is reduced when the dissolved concentration is reduced below 2 to 3 mg/l, and it is totally inhibited when dissolved oxygen is not being supplied. Based on the results it can be concluded that during the investigated period of time in the WWTP-Hisarya the oxygen concentrations are in the appropriate range. The average of dissolved oxygen content in aeration basins SBR_1 and SBR_2 were 2.62±0.18 and 2.67±0.12 mg/l, respectively, which indicates sufficient aeration (Tables 1 and 2).

The nitrification process is also affected by pH. The optimum pH is generally about 7.5. The process is reduced as the pH is below 7.0, and it is inhibited significantly when the pH drops below 6.5. In the present investigation the established temperatures were in the range 22.5±3.9 and 22.4±3.9 ºC, respectively, and the pH values were also relevant 7.2±0.1 in both aeration basins.

Table 1. Characteristic of wastewater effluent from aeration basin SBR_1.

Months, 2013	**pH**	**t, ^{0}C**	**NH_4-N, mg/l**	**NO_3-N, mg/l**	**DO, mg/l**
January	7.2±0.0	17.2±0.9	0.42±0.20	5.5±1.5	2.61±0.14
February	7.2±0.0	16.7±0.5	0.49±0.11	7.6±1.7	2.65±0.18
March	7.2±0.0	17.7±1.0	0.50±0.10	5.6±2.3	2.65±0.15
April	7.2±0.1	18.9±2.0	0.60±0.20	5.8±2.9	2.54±0.15
May	7.3±0.0	24.7±1.6	0.45±0.19	3.3±1.2	2.48±0.10
June	7.3±0.1	25.5±1.1	0.52±0.12	3.1±0.7	2.70±0.12
July	7.3±0.1	26.0±0.6	0.57±0.07	3.4±0.7	2.10±0.10
August	7.2±0.1	27.3±0.2	0.50±0.10	2.9±0.4	2.74±0.07
September	7.2±0.1	25.0±1.2	0.51±0.09	2.4±0.7	2.70±0.06
October	7.3±0.1	25.1±0.6	0.47±0.05	3.7±1.1	2.74±0.08
November	7.2±0.1	24.0±1.1	0.49±0.17	2.7±0.8	2.74±0.07
December	7.2±0.1	21.4±1.2	0.34±0.07	3.8±0.7	2.75±0.11
Average	**7.2±0.1**	**22.5±3.9**	**0.48±0.07**	**4.2±1.6**	**2.62±0.18**
Limit	**6-9**		**-**	**-**	**-**

For an ideal activated sludge, the flock is dense, big, has a spherical shape and contains only a few filamentous bacteria. An activated sludge with ideal flocks is easy to settle, filters the wastewater during the clarifying process, and produces a transparent effluent with little suspended solids content. The values of the activated sludge in the aeration basins in terms of settled sludge volume, dry matter, and sludge volume index are represented in table 3. Sludge Volume Index (SVI) is an indication of the sludge settleability in the final clarifier. It is a useful test that indicates changes in the sludge settling characteristics and quality. The settled sludge volume (SSV) of a biological suspension is useful in routine monitoring of biological processes.

Table 2. Characteristic of wastewater effluent from aeration basin SBR_2.

Months, 2013	pH	t, ^0C	NH_4-N, mg/l	NO_3-N, mg/l	DO, mg/l
January	7.2 ± 0.0	17.1 ± 1.4	0.40 ± 0.17	5.4 ± 1.5	2.55 ± 0.10
February	7.2 ± 0.0	16.7 ± 0.6	0.54 ± 0.17	7.0 ± 2.7	2.69 ± 0.16
March	7.2 ± 0.1	17.7 ± 1.1	0.50 ± 0.10	3.7 ± 1.9	2.69 ± 0.13
April	7.2 ± 0.0	18.8 ± 2.2	0.60 ± 0.10	5.6 ± 3.6	2.50 ± 0.16
May	7.3 ± 0.1	24.9 ± 1.4	0.50 ± 0.20	2.8 ± 0.9	2.47 ± 0.14
June	7.3 ± 0.0	25.7 ± 1.1	0.50 ± 0.20	3.4 ± 1.0	2.62 ± 0.10
July	7.2 ± 0.1	26.0 ± 0.7	0.59 ± 0.14	2.9 ± 0.8	2.68 ± 0.08
August	7.3 ± 0.1	27.3 ± 0.3	0.53 ± 0.03	2.7 ± 0.4	2.74 ± 0.06
September	7.3 ± 0.0	24.7 ± 1.2	0.48 ± 0.11	1.7 ± 1.1	2.70 ± 0.06
October	7.3 ± 0.1	24.8 ± 0.6	0.47 ± 0.07	3.6 ± 0.8	2.79 ± 0.06
November	7.2 ± 0.1	24.4 ± 0.9	0.48 ± 0.10	2.8 ± 0.9	2.72 ± 0.09
December	7.2 ± 0.1	21.0 ± 0.2	0.38 ± 0.08	3.7 ± 0.6	2.88 ± 0.05
Average	**7.2 ± 0.1**	**22.4 ± 3.9**	**0.50 ± 0.07**	**3.8 ± 1.5**	**2.67 ± 0.12**
Limit	**6-9**		**-**	**-**	**-**

The results represented in table 3 confirmed the high quality of the technological process of water purification and the very good sedimentation properties of the sediment. It has to be noted that all values of sludge index are in the recommended range.

Every wastewater treatment plant has a specific bioindicators community, which is not directly determined by the characteristics of the wastewater or the treatment technology. These indicators have for many years been a useful tool to assess operation conditions by microscopic sludge investigation (Eikelboom and Buijsen, 1981; Jenkins et al., 1993). The long term microscopic tracking of activated sludge flock structure and microorganisms is needed for information about the treatment performance (Pásztor and Szentgyörgyi, 2004).

The purity level of water, the current relevant properties of water quality can be determined in a fast, efficient, and cost effective way using bioindicators. Bioindicators indicate the presence and condition of the different stages of sewage treatment, also indicating the absence or excessive level of an entity. Light microscopic observation of the bioindicators and thus the quality of water, the condition and operations of the treatment equipment can be continuously checked and controlled in a cost effective way. Thus the monitoring of bioindicators in the water is absolutely justifiable.

Table 3. Characteristics of the activated sludge in the aeration basins SBR_1 and SBR_2.

Months, 2013	**Aeration basin SBR_1**			**Aeration basin SBR_2**		
	SSV, cm^3/l	**DM, g/l**	**SVI, cm^3/g**	**SSV, cm^3/l**	**DM, g/l**	**SVI, cm^3/g**
January	357 ± 63	4.0 ± 0.4	90 ± 11	553 ± 47	5.4 ± 0.4	102 ± 3
February	493 ± 88	4.9 ± 0.6	98 ± 7	551 ± 71	5.3 ± 0.4	103 ± 7
March	421 ± 83	4.3 ± 0.7	97 ± 5	498 ± 57	4.9 ± 0.5	101 ± 6
April	516 ± 69	5.0 ± 0.5	103 ± 6	445 ± 93	4.7 ± 0.7	94 ± 7
May	383 ± 59	4.2 ± 0.3	91 ± 12	459 ± 54	4.6 ± 0.4	99 ± 9
June	444 ± 81	4.5 ± 0.4	98 ± 11	450 ± 87	4.6 ± 0.6	97 ± 9
July	422 ± 78	4.3 ± 0.7	98 ± 7	409 ± 40	4.2 ± 0.3	98 ± 6
August	388 ± 55	4.1 ± 0.5	95 ± 8	413 ± 100	4.1 ± 0.5	99 ± 14
September	368 ± 56	4.1 ± 0.4	89 ± 10	395 ± 86	4.1 ± 0.6	93 ± 10
October	472 ± 78	4.8 ± 0.7	99 ± 6	412 ± 69	4.4 ± 0.6	94 ± 6
November	534 ± 38	5.5 ± 0.8	99 ± 9	519 ± 56	5.4 ± 0.9	97 ± 11
December	495 ± 38	5.6 ± 0.2	89 ± 4	450 ± 100	5.3 ± 1.1	84 ± 3
Average	**441 ± 60**	**4.6 ± 0.5**	**96 ± 5**	**463 ± 55**	**4.8 ± 0.5**	**97 ± 5**

The optimal conditions in the aeration basins are indicated not only by the sufficient aeration but also by the presence of certain ciliate protozoan: *Aspidisca* species. They signal the process of nitrification, decreased ammonia level, and favorable aerobic (i.e. pertaining to the amount of oxygen) conditions. *Epistylis* ciliate protozoa are present in large numbers when the efficiency of sewage treatment is above 65 %.

During the monitored period of time various microorganisms were detected in the examined activated sludge. In table 4 are represented the established indicator microorganism species found.

Table 4. Presence of bioindicators in the activated sludge.

Bioindicators	Months, 2013											
	01	02	03	04	05	06	07	08	09	10	11	12
Flagellatae sp.	2	2	2	4	3	2	3	2	4	1	2	2
Euglypha laevis	1	1	1	1	1	1	1	1	4	1	1	1
Arcella vulgaris	1	1	1	1	1	2	1	1	4	1	2	1
Epistyllis plicatilis	4	2	2	4	2	3	3	4	2	4	2	4
Turricolla similis	1	2	3	2	2	1	2	4	4	4	2	2
Arcella discoides	2	2	2	2	3	1	1	2	4	1	2	2
Vorticella microstoma	4	2	2	4	4	4	2	2	2	3	2	4
Rotatoria	3	4	4	4	4	4	4	4	4	4	3	3
Hyalodiscus linax	4	4	4	4	4	4	4	4	4	4	4	4
Aspidisca sp.	2/3	4	4	2	3	3/2	3	3	2	2	4	2
Vorticella convallaria	2	4	3	1	2	1	4	4	1	3	2	2
Opercularia coarctata	4	4	4	4	4	4	4	3	4	2	4	4
Hydracarina sp.	4	4	4	4	4	4	3	4	4	3	3	4
Aspidisca costata	4	4	3	4	4	4	4	4	4	4	4	4
Nematoda	4	4	4	4	4	4	4	4	4	4	4	3
Philodina roseola	4	4	4	4	4	4	3	4	4	4	4	4

1- commonly represented
2- mid represented
3- poorly represented
4- not represented

Many different living beings live in sewage water. Bacteria represent the most populous group. The protozoan communities of the activated sludge were considerably different. In the sludge of WWTP-Hisarya several genera of protozoa were found. The most abundant genera in sludge were the stalked ciliates *Vorticella*. The dominant group of protozoa was ciliates.

The most important bioindicative processes could be observed e.g.: abundance of *Aspidisca* species indicated good nitrification and dominancy of *Ciliates* showed excellent treatment performance. The presence of *Vorticella convallaria* and *Arcella vulgaris* (Fig. 2) was a positive indicator of the wastewater treatment process, whereas the presence of *Vorticella microstoma* was undesirable and indicates bad effluent quality. The numerous flagellates in the activated sludge were unexpected, because they generally indicate low oxygen concentration or overloading. However, the appearance of activated sludge is good, is fast settling of dense flocks supernatant is clear.

*Vorticella convallaria***

*Arcella vulgaris**

Figure 2. Bioindicators presented in the activated sludge
*protest image; **wikipedia.

CONCLUSIONS

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.

The massive presence of positive bioindicators and the rare presence or absence of undesirable bioindicators indicates that the aeration basins work well and microorganisms are able to purify to a sufficient degree the incoming wastewater.

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