SEQUENTIAL BATCH REACTORS AS ALTERNATIVE FOR WASTEWATER TREATMENT IN SMALL COMMUNITIES

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Abstract

BIOAZUL S.L. has performed a study on a sequential batch reactor (SBR) for 45 population equivalent, whose main objectives were: the optimisation of the system for urban wastewater characteristic of southern Europe and for the overall reduction of its energy consumption. The study has been carried out in the frame of the compliance of the Water Quality, Sanitation and Treatment National Plan 2007-2015 (PNCA), which rules sanitation and treatment for villages below 2000 population equivalent (PE).The monitoring has been carried out at CENTA's experimental plant that located in Carrión de los Céspedes (Seville, Spain). The main parameters analysed during the system assessment were: flow, TSS, COD, BOD_5, N_{total}, $N\text{-}NH_4^+$, P_{total}, pH, temperature and conductivity. The results of these tests together with random vales of turbidity and *E. Coli* content are presented in this document. The values obtained of the parameters of SS, COD and BOD5, in absolute numbers and percentages of elimination, fall within the limits specified by the Royal Decree Law 11/95, as well as presenting a good yield removal of nutrients (N and P).

Keywords: SBR, sequential batch reactor, wastewater treatment, small communities.

Introduction

Sequential Batch Reactors (SBR) date from 1898, when the British engineer Sir Thomas Wardle published the first data relating to a system operating under conditions of filling and emptying. Originally, objectives for the SBR were only to remove the organic matter, but today its use goes beyond and in this system can also remove nutrients like phosphorus and nitrogen. This is an activated sludge system in which the degradation of pollutants and the sedimentation occur in a single reactor in separate stages temporarily. The SBR reactor is operated in one or more cycles consisting of four phases:

- Filling: The wastewater that is going to be treated enters into the sequential reactor. The filling could be under static conditions (it does not promote biological reactions) or under agitation and/or aeration (occurring chemical and biological processes that enhance the wastewater treatment).
- Reaction: phase in which the degradation of organic matter and nutrients occurs. The reaction phase begins with a no-aeration period which induces anaerobic-anoxic conditions in order to promote the

biological degradation of phosphorus and the denitrification. During this period, aeration systems or agitators are activated for a few seconds to mix the reactor liquor. Subsequently, the oxidation phase of carbonaceous and nitrogenous matter take place, being interrupted for periods of absence of oxygen for the reduction of nitrates and nitrites generated (denitrification).

- Sedimentation: The aeration and mixing are interrupted inside the reactor to provide favourable conditions for the sedimentation of activated sludge.
- Emptying: once the sludge is removed after the sedimentation phase, the treated wastewater is removed from the reactor.

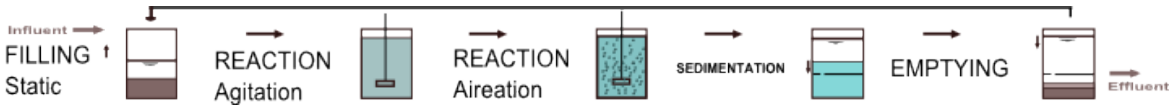

Figure 1. Operating diagram of a SBR

Methods

The system with a treatment capacity of 45 PE was designed by the German company Kordes GmbH and installed in the Experimental Plant of Carrión de los Céspedes managed by CENTA Foundation. The system consists of two independent tanks of 9000 litres each capable of treating 6.8 m^3/d of wastewater. The first one works as pre-treatment, homogenizing tank and for the sludge storage. The second tank is the sequential biological reactor (SBR) where the wastewater is treated biologically. The tanks were half-buried, although these can be totally buried, as required by CENTA due to the demonstration purposes of the plant. The system is controlled by a Siemens PLC TD200 LCD screen and equipped with a modem for SMS alert of faults and alarms, and for remote verification of the operating parameters.

The testing period lasted 18 months, divided in two periods: from January until August 2008 (29 measurements) and from November 2008 until June 2009 (21 measurements). Samples were taken on a weekly basis. Sampling points included pre-treated wastewater and effluent. Turbidity was measured 13 times during the testing period. *E. Coli* have been analyzed every two weeks to determine the reduction capacity of pathogens of the system and the potential reuse routes of the effluent.

The tests were designed to determine the behaviour of the system operating with domestic wastewater in order to:

- Identify the percentage of reduction in BOD_5, COD, TSS, N and P.
- Identify the basic requirements for the correct system operation and maintenance.
- Determine the compliance of effluent parameters in accordance with the Royal Decree Law 11/95 (transposition of European Directive 91/271).

The verification reports performed by Environmental Protection Agency (EPA) have been taken as references.

Results and discussion

The system has been fed with the screened (3cm), sieved (3mm) and desanded-defatted wastewater, with an weekly average flow in the first period of 5,6 m^3/d and 6,9 m^3/d in the second period. The following table shows the average values of TSS (mg/l), COD (mg/l), BOD_5 (mg/l), N_{total} (mg N/l), $N\text{-}NH_4^+$(mg N/l) and P_{total} (mg P/l) determined in the influent and in the effluent of the system in both study periods.

Table 1. Average values of influent, effluent and yield

Parameter	Period	Influent (mg/l)	Effluent (mg/l)	Removal (%)
TSS	1st	245 ± 84	26 ± 32	89
	2nd	243 ± 113	9 ± 12	96
COD	1st	704 ± 272	93 ± 69	87
	2nd	579 ± 199	47 ± 33	92
BOD_5	1st	364 ± 106	21 ± 27	94
	2nd	316 ± 119	11 ± 9	96
N_{total}	1st	61,11 ± 11,2	30,9 ± 22,9	49
	2nd	ND	ND	ND
$N\text{-}NH_4^+$	1st	44,6± 11,1	18,1 ± 23,5	59
	2nd	43,1 ± 16,5	6,2 ± 8,4	86
P_{total}	1st	10,5 ± 2,2	7,8 ± 4,5	25
	2nd	7,1 ± 2,0	3,5 ± 2,6	51

The average values of pH, temperature, conductivity and dissolved oxygen (DO) obtained for the influent are within the usual values for a domestic wastewater with typical seasonal variations. With regard to the effluent, no anomalies are found. The concentration of DO in the output confirms that there is no anoxic condition in the reactor. Different configurations of the SBR were tested in order to reduce the energy consumption ensuring at any time the correct system performance.

The operating time of the aerator was considered as the key factor for reducing the energy consumption of the system. Operation time of each phase was modified with the aim to reduce the aerator running time. Several modifications were tested, being the most important one with regards to energy savings the increase of the denitrification phase duration while the nitrification phase one was decreased. In the first period of the test, the system consumption was 7.3 kWh/d, during the second period of the test it went down to 6.5 kWh/d and in the last two months once the last modification was done the system consumed only 5.7 kWh/d.

Conclusions

During the two test periods carried out in the Experimental Plant of Carrión de los Céspedes, the Clear Water system 45-T has had a stable performance in terms of yield removal for different control parameters used for the evaluation. Taking the discharge limits set by the Royal Decree 11/95 it was observed that:

- The values of TSS, COD and BOD_5 are correct, in absolute values and in elimination percentages, except during the start-up phase.
- The Clear Water system 45-T also shows a good yield of nutrients removal (N and P).

In addition:

- The sludge extracted during the whole period from the first tank was only 5 m^3, with a composition of 63% of volatile matter and 37% of mineral matter.
- The *E. Coli* reduction was between 1 and 6 logarithmic units, where the average is 4 u log.
- A reduction of 11% in the energy consumption per day compare to normal values (initials ones of the test) was achieved. An even higher reduction per day of 20 % was observed with the last modifications applied.
- The system consumed during the last period of the test less than 1 kW/h per $m^3$of wastewater treated.

References

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