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Biological treatment of grey water using sequencing batch reactor

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Abstract

The aim of this study was to investigate the application of sequencing batch reactor (SBR) technology for treating grey water collected at outlet of showers room of students. The performance of SBR was satisfactory as the effluent had respectively 20 and 5 mg/L of COD and BOD. Applied two hydraulic retention times (HRTs) showed that the nitrogen and phosphorus removal could be improved while adapting to load variations.

Keywords: Grey water; SBR; HRT; Performance

1. Introduction

Grey water is defined as wastewater without any input from toilets, which means that it corresponds to wastewater produced in bathtubs, showers, hand basins and laundry machines in households, office buildings, schools, etc. [1–2]. The total grey water fraction has been estimated to account for about 75% of all wastewater of the combined residential sewage [3].

The characteristics of grey water vary regionally and over time. Three factors significantly affect grey water compositions: water supply quality, the composition of the system that transports both grey and drinking water and the activities in the house [4].

Possibilities of reuse for this fraction of wastewater have come into special focus. Treated grey water can be used for many activities such as toilet flushing, garden watering and recreational irrigation. Usually simple treatment system for the purpose of landscape irrigation, like sand/gravel filtration or settlement and flotation are operated to prevent clogging of the distributing system. A more sophisticated design is needed, if the treated water is used “in-house”, e.g. for toilet flushing. A disinfection step is added to remove microbial contaminants since the potential for human

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contact is greatly increased in these applications [5]. Treating grey water with SBR goes one step further. On a very small footprint hygienically acceptable water is produced.

Tunisia characterised by arid and semi-arid climate and water resources rare. A research project was approved to reduce fresh water consumption in El Manzeh students house at Tunis City. Ecological sanitation corresponding to separate collection of different stream of wastewater such grey and blacks water was applied in this house occupied by 200 students (Fig. 1). Investigations are in hand to determine the process treatment of each type of wastewater and its possible re-use.

The purpose of the present study was to investigate the application of sequencing batch reactor (SBR) technology for treating grey water collected at outlet of showers room. This study aimed to establish an approach to removing nutrients from grey water in an SBR and to explore the feasibility of this more-cost efficient removal system.

2. Materials and methods

2.1. Wastewater characteristics

The grey water was collected from students house at outlet of showers room. The characteristics of the grey wastewater are given in Table 1. A statistical analysis is made at a rather simple standard by common calculation software EXCEL.

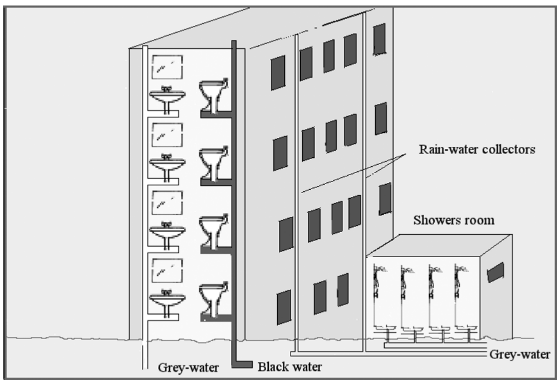

Fig. 1. Schema of streams of wastewaters in students house.

Table 1
Characteristics of wastewater used as feed to SBR

Parameters	*N*	Min	Max	Average	SD
pH	11	7.5	7.9	7.6	0.4
TSS (mg/L)	16	23	50	33	16
COD (mg/L)	23	25	300	102	86
BOD_5 (mg/L)	11	15	140	97	56
TOC (mg/L)	13	12	67	32.6	32
NH_4-N (mg/L)	14	1.2	15.2	6.7	5.6
NO_2-N (mg/L)	14	ND	0.2	0.0	0.2
NO_3-N (mg/L)	14	ND	1.2	0.2	0.1
PO_4-P (mg/L)	14	2.8	11.3	3.5	4.8
TKN (mg/L)	10	4.2	20	8.1	3.7

N: number of samples.

2.2. System configuration

The SBR reactor was fabricated from a transparent Plexiglas cylinder (19.0 cm in diameter), with a total volume of 11 L and a working volume of 5 L. The reactor was equipped with two peristaltic pumps in charge of influent feeding and effluent discharging, respectively. A mechanical agitation (30 rpm) was operated for complete mixing. Air (5 L/min) was provided by an aerator through an air stone placed at the bottom of the reactor. Fig. 2 gives the schematic diagram of SBR reactor.

Typically, SBR operations are divided into five phases: filling, reaction, settling and effluent discharge. The sequences time was controlled automatically by computer.

2.3. Start up of SBR

The activated sludge, obtained from a local municipal wastewater treatment plant, was inoculated in the reactor for start-up. The mixed

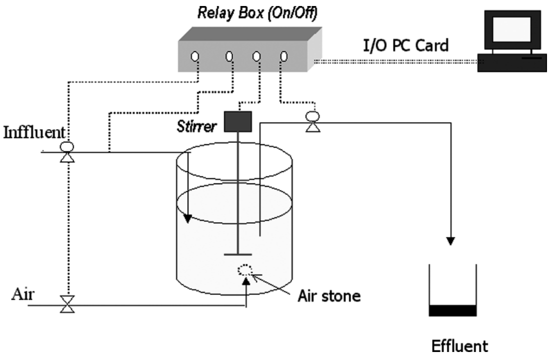

Fig. 2. Schematic diagram of a SBR with real-time control strategy.

liquor suspended solids (MLSS) concentrations were maintained at 2.5 ± 0.3 g/L.

The SBR had been operated under alternating anoxic–aerobic conditions over 20 days to reach steady state before the start of experiments. The reactor was operated at room temperature without control.

The SBR system worked at two cycles per day. The one cycle (12 h) consists of 30 min influent feeding, 5 h anoxic, 5 h aerobic, 1 h sludge settling and 30 min effluent discharging.

A sludge retention time (SRT) of 10 days was fixed to limit sludge production. Two different hydraulic retention times (HRTs) were applied, 0.6 and 2.5 days. At the start up of SBR operation the HRT was fixed at 0.6 days.

2.4. Analytical procedures

MLSS, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammonium and sludge volume index (SVI) parameters were analysed according to standard methods [6]. Nitrogen compounds, nitrates, nitrites were analysed with an ionic chromatograph (Waters 432). The *ortho*-phosphate was measured according to the vanado-molybdo-phosphoric method. TOC was detected with TOC Analyser (TOC-550A, Shimadzu).

Samples were filtrated through 0.45 µm to remove suspended solids prior to being fed to chromatographic columns.

To gain more detailed information of the performance of reactor to nutrient removal, a detailed cycle analysis has been carried out, by measuring COD, $N\text{-}NO_3$, $N\text{-}NO_2$, $N\text{-}NH_4$ and $P\text{-}PO_4$ concentrations.

3. Results and discussion

3.1. SBR performance

The SBR performance was initially evaluated by measuring COD, TSS, BOD_5, PO_4-P and nitrogen compounds in effluent. The whole period of investigations are presented in Table 2.

During the total operational period, high COD removal was achieved in the reactor and the effluent COD was nearly 20 mg/L at two HRTs.

Table 2
Effluent characteristics

Parameters	HRT = 0.6 days			HRT = 2.5 days		
	Max	Average	SD	Max	Average	SD
TSS (mg/L)	38	23	16	40	23	16
COD (mg/L)	25	12	10	38	20	16
BOD_5 (mg/L)	15	7	6	16	7	6
NH_4-N (mg/L)	10.3	6.2	4.8	0.9	0.3	0.6
NO_2-N (mg/L)	0.2	0.1	0.1	0.1	0.05	0.1
NO_3-N (mg/L)	6.2	5.4	6.5	16	10	5.6
PO_4-P (mg/L)	17.6	8.7	7.8	5.9	4.9	2.3

Hydraulic retention time (HRT) variations affected the nitrification rate. At HRT of 0.6 days, the NH_4-N concentration in effluent was relativity high; it can be exceeded 10 mg/L. At HRT of 2.5 days the performance of the system to reduce NH_4^+ concentration became higher and the effluent is exempted of ammonium and NO_3-N concentrations in the effluent varied between 6 and 16 mg/L.

HRT variations affected also PO_4-P removal. At HRT of 0.6 days, the effluent concentration of the PO_4-P varied between 0.6 and 17.5 mg/L, but at HRT of 2.5 days it is lower than 6 mg/L.

The settling properties were also evaluated using the sludge volume index (SVI). SVI is an important parameter affecting the performance of the system. Low SVI values (SVI < 100 mL/g) indicate good sedimentation characteristics of the sludge yielding high biomass concentration in the aeration tank; whereas high SVI values (SVI >> 100 mL/g) reflect bulking sludge and low biomass concentration in the aeration tank [7]. SVI was monitored during the end of each cycle before withdrawal. During the experiments, settling properties of the SBR sludge were excellent. The SVI of SBR reactors did not exceed 100 mL/g.

3.2. *Profiles of nutrient concentration and organic matter*

3.2.1. *N-removal profiles*

Fig. 3 shows variations of nutrient (N-NH_4, N-NO_3) concentrations with time when the system was operated at 0.6 and 2.5 d of HRT. As shown in this figure, the nitrification occurred during the aeration stage, where NO_3 increased and NH_4 decreased constantly.

During anoxic phase, nitrate decreased but it never reached zero, denitrification seems incomplete and the nitrates accumulated in the system. The nitrogen removal had the same profile at the two levels of HRT. But there is a difference in the removal rate.

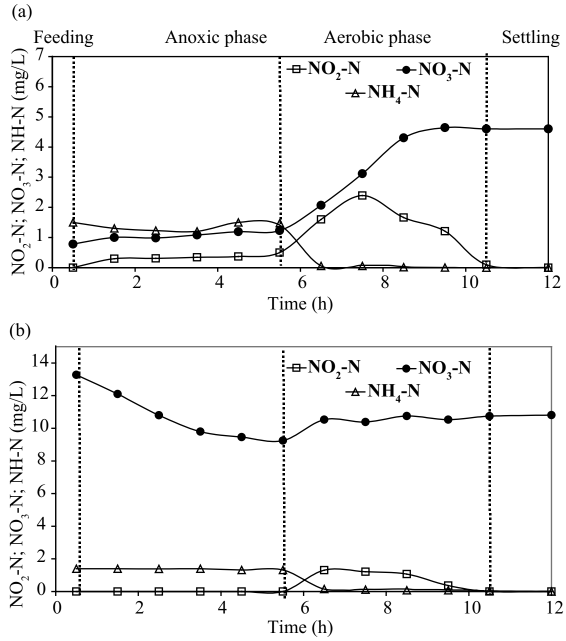

Fig. 3. Nitrate, nitrite and ammonium profiles for one cycle with HRT of 0.6 days (a) and 2.5 days (b).

3.2.2. *PO_4 removal profiles*

The variation of PO_4 concentration during a complete cycle after the system reached steady-state conditions is illustrated in Fig. 4. At HRT of 0.6 days, the first stage of PO_4 removal, during the anoxic stage, saw an increase in phosphate concentration from 3.5 to 15.5 mg P-PO_4/L. During the 5 h of the aerobic stage, this concentration decreased to 3 mg/L.

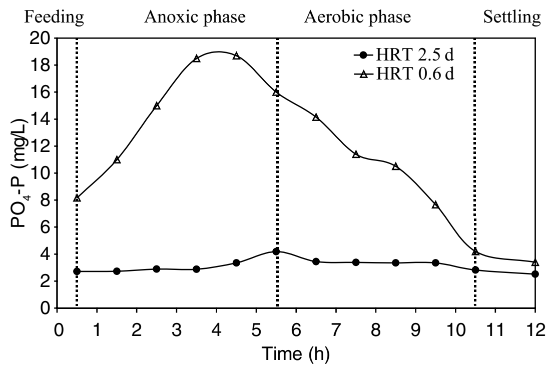

Fig. 4. PO_4 profiles for one cycle.

At HRT of 2.5 days, $P\text{-}PO_4$ concentration was nearly constant during the anoxic phase and decreased slightly during the aerobic step. The final concentration of $P\text{-}PO_4$ was nearly 3 mg/L at the end of 12 h operation.

In order to stimulate the growth of phosphate accumulating organisms (PAOs) in an activated sludge system, an anaerobic–aerobic sequence and the presence of short chain fatty acids in the anaerobic phase are required [8]. Under anaerobic conditions PAOs use the energy released from the hydrolysis of intercellular polyphosphate to transport VFA (mainly acetic acid) across their cell membranes and, hence produce polyhydroxybutyrate (PHB). The phosphate is released in connection with the storage of organic matter under anaerobic conditions. Under aerobic conditions PHB serves as an energy source for cell growth as storage of polyphosphate. The accumulation of phosphorus beyond that needed for normal cell growth for disposal biological phosphorus removal (EBPR) or bio-P removal [9].

So, at HRT of 0.6 days, the apparent increase in phosphate concentration must be attributed to the phosphorus release, which may have occurred in the anoxic phase. Certainly phosphorus accumulating organisms (PAOs) were present and active in the biofilm despite the lack of positively anaerobic conditions.

The high nitrate concentration complicates the EBPR. The denitrification consumes a portion of substrate before which can be used by the biological phosphorus (bio-P) removing organisms. This limits the phosphorus removal in such systems [9,10]. Therefore at HRT of 2.5 days, the transfer of nitrate into the anoxic phase inhibits phosphate release. So, at this condition, the performance system to remove phosphorus is decreased.

3.2.3. COD removal characteristics

Large quantities of COD were adsorbed and/or up taken on activated sludge in the anoxic phase (Fig. 5). It was used for denitrification when

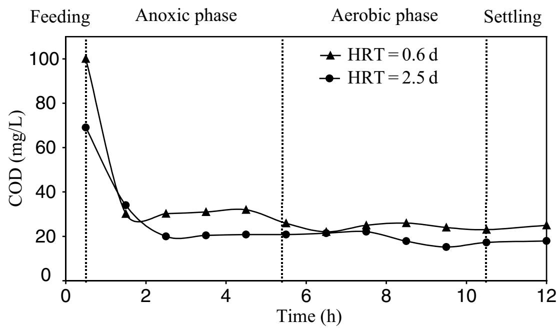

Fig. 5. COD profiles for one cycle.

the system was operated with 2.5-d HRT and for release phosphorus with 0.6-d HRT. The residual COD was therefore limited to aerobic stage.

4. Conclusion

The SBR system can effectively remove nutrients and promote biodegradation of organic matter for domestic grey water. The SBR reactor achieved 90% COD removal and good sludge settling properties (SVI < 100 mL/g).

When the reactor operated with 2.5 d HRT the nitrification rate increased and the effluent is exempted of ammonium but the performance of system to remove phosphorus is decreased. The application of two HRTs showed that the nitrogen and phosphorus removal could be improved while adapting to load variations.

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