Effect of HRT on SBR Performance for Treatability of Combined Domestic and Textile Wastewaters

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(Received on 27th July 2012, accepted in revised form 2nd October 2012)

Summary: Textile wastewater contains organics and color dyes which need to be treated before discharging into receiving water bodies. Sequencing batch reactor (SBR) is proved promising against textile wastewater due to its high organic and nutrient removal efficiencies. In this study the influence of variable hydraulic retention time (HRT) on the performance of SBR in treating combined textile and domestic wastewater was evaluated. Six SBRs were operated in parallel at 12 and 8 hrs HRTs respectively, three for synthetic and three for real textile plus domestic wastewater. SBRs were operated at constant temperature 25 ± 1 ^{0}C and pH 7 ± 1 to avoid seasonal effects. The biological oxygen demand (BOD) removal efficiency was consistent at 73% while, total suspended solids (TSS) removal efficiency increased from 52 to 63% in SBRs with decrease in HRT from 12 to 8 hrs. The organic loading rate (OLR) increased from 0.45 to 0.68 Kg/m^3/d, SVI decreased from 94 to 84 mL/g and chemical oxygen demand (COD) removal efficiency increased in real waste water (RWW) SBRs from 59 to 63% with decrease in HRT from 12 to 8 hrs. Low COD removal at 12 hr HRT can be attributed to poor settling characteristics of sludge due to possible filamentous growth at low F/M (0.03) and greater SRT (28 days) as compared to 8 hr HRT condition, where F/M was 0.05 and SRT of 20 days.

Key words: Sequencing batch reactor (SBR); textile wastewater; hydraulic retention time (HRT); treatability; combined wastewater.

Introduction

The cumulative effects of wastewater discharge from industries and urban sewage have striking negative impact on the streams and rivers flowing through the cities of Pakistan [1]. In Faisalabad more than 270 full scale textile units are working at present. A large percent of these industries discharge their untreated wastewater in the Paharang Drain [2]. According to the present study the Paharang Drain has total flow of 100 MGD and the cumulative flow of 80 textile units is around 10 MGD, which is 10% of the total flow. So the water of Paharang Drain may be attributed as combined domestic and textile wastewater. From the environmental point of view, the textile industry is characterized not only by its enormous water consumption but also by the variety and complexity of chemicals employed [3, 4]. Variation in fabric quality, color and treatment process results into large fluctuation in daily flow rates and pollutant concentrations in textile wastewater [5]. Textile wastewater containing synthetic dyes causes significant environmental pollution and must be treated before discharge into water bodies [6].

Chemical and physical treatment processes for textile wastewater like coagulation-flocculation, advanced oxidation and electrochemical techniques can be effective but economically unviable due to high chemical and operating costs as well as complex solid waste generation [7- 9].

The biological treatment is considered effective for combined textile and domestic wastewater. The aerobic treatment is effective in organic removal but inefficient against color removal. The anaerobic treatment is effective in biodegradation of dyes but it is difficult to keep bacteria in functional form because of their special nutritional requirements and environmental conditions [10, 11]. The other problem associated with anaerobic decolorization is low COD removal and formation of toxic aromatic amines as a result of azodye biodegradation, which becomes an additional issue for treated wastewater reuse [8]. Research findings have shown that aerobic unit after anaerobic decolorization is necessary in order to increase the effluent water quality to remove the possible aromatic amines [12, 13].

SBR combines both anaerobic-aerobic phases in one reactor. It is widely used in organic and nutrient removal from wastewater by providing alternated anaerobic-aerobic-anoxic phases [14]. The advantages of SBR process are to eliminate the need

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for primary and secondary clarifiers, the biomass remains inside reactor and is not washed out, no pumping required for returning the activated sludge and the temperature variations can be adjusted by varying the HRT [15]. SBR are especially flexible in operation for the treatment of textile wastewater. The treatment cycle time plays an important role in SBR performance [16].

There are very few studies available in literature about the effect of HRT variation on treatability of combined textile and domestic wastewater using SBR. Therefore, this particular study was carried out where Paharang Drain Faisalabad wastewater was treated using SBR technology.

Results and Discussion

Effect of HRT on MLSS and MLVSS

Under the sludge growth conditions, the desired mixed liquor suspended solids (MLSS) of 6000 mg/L was achieved which was followed by the real and synthetic wastewater feeding of the SBRs operated under the 12 and 8 hr HRT conditions. Fig. 1 shows the average MLSS concentrations in real and synthetic wastewater SBRs at 12 hr HRT. Initially the MLSS showed a decreasing trend for first 10 days in both real and synthetic wastewater reactors due to the biomass acclimatization with real wastewater and with decreased synthetic COD (from 6000 mg/L during growth condition to 1000 mg/L under 12 hr HRT). In the next 15 days, MLSS was stabilized at almost 5000 mg/L in RWW SBRs while In SWW SBRs, the MLSS increased consistently to touch 7000 mg/L at the end of 12 hrs HRT condition. The mixed liquor volatile suspended solids (MLVSS) also followed a similar trend like MLSS for both real and synthetic wastewater SBRs and showed an initial decline up to first 12 days followed by subsequent increase in values till the end of the condition (figure not shown). At the end of 12 hrs HRT the MLVSS/MLSS ratio was almost 60% in real wastewater SBRs and 78% in synthetic wastewater SBRs. Similar kind of MLSS and MLVSS trends were reported in study by Zuriaga- Agusti and co-workers. [17]. No sludge removal was done under this 12 hr HRT condition.

At HRT of 8 hrs both MLSS and MLVSS showed an increasing trend in both real and synthetic wastewater SBRs. The MLSS trends are shown in Fig. 2 and the figure for MLVSS trends is not shown. When the MLSS value touched 7000 mg/L then sludge removal was started and 20 days sludge retention time (SRT) was maintained in real as well as synthetic wastewater SBRs. 130 ml sludge was wasted from each of the six SBRs on every alternate day during aeration phase to maintain the desired 20 days SRT. At the end of 8 hrs HRT the MLVSS/MLSS ratio was at 75 and 80% for real and synthetic wastewater SBRs, respectively. Similar increasing MLSS trend was reported by Kawasaki and co-workers, where synthetic domestic wastewater was treated with starting MLSS of 4900 mg/L and after 15 days it was around 6200 mg/L [18]. It shows that the MLSS growth depends basically on the amount of COD available in the reactor and COD removed.

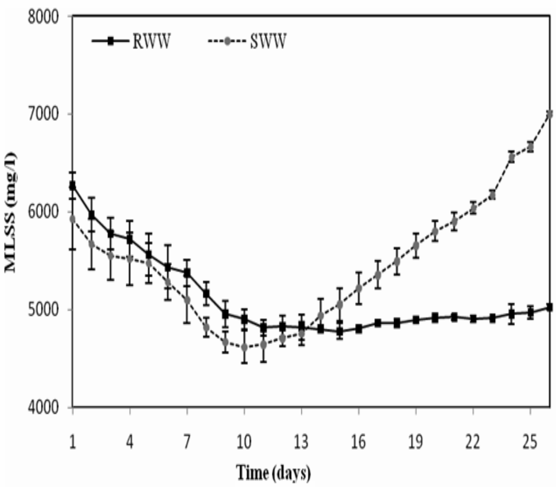

Fig. 1: Average MLSS trends in real and synthetic wastewater SBRs at 12 hr HRT.

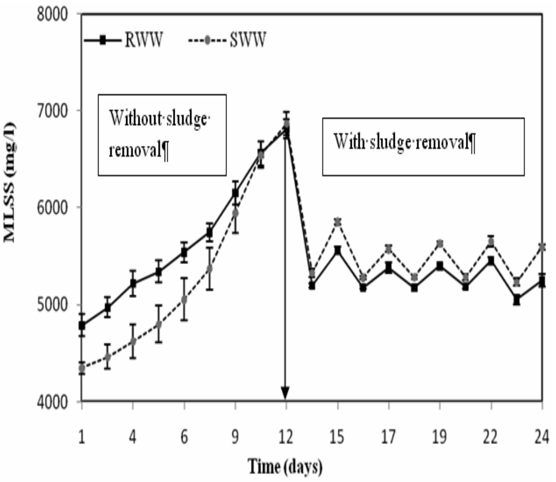

Fig. 2: Average MLSS trends in real and synthetic wastewater SBRs at 8 hr HRT.

Effect of HRT on COD Removal Efficiency

Fig. 3 and 4 describes average COD removal efficiency and average effluent COD values for both real and synthetic wastewater SBRs at 12 and 8 hrs HRT respectively. According to these figures, the COD removal efficiency remained between 70-80% in synthetic wastewater SBRs under both HRTs. However in real wastewater SBRs the efficiency increased from 59 to 63% when HRT varied from 12 to 8 hr, due to the increase in MLSS concentration at 8 hrs HRT. The effluent COD remained between 170-200 mg/L in synthetic and 150-190 mg/L in real wastewater SBRs. The national environmental quality standards (NEQS) of Pakistan allow up to 150 mg/L COD to be discharged after effluent treatment. Hence, through SBR treatment at 8 hrs HRT we can come close to the desired effluent standards. In another study by Kapdan and Oztekin the average COD removal efficiency with synthetic wastewater was almost 80% which are in accordance with synthetic COD removal in this study [19]. Sirianuntapiboon and Sansak reported COD removal efficiency of 93% with synthetic wastewater and 84% with real wastewater, but they used glucose as supplement for COD removal in their real wastewater SBRs [20]. Tufekci and co-workers reported COD removal efficiency of 56, 55, 31 and 42% for four different textile wastewaters using aerobic treatment [21]. Our achieved COD removal efficiency of 59 and 63% at 12 and 8 hrs HRTs is better than their results. This difference can be attributed to the fact that the textile wastewater of Paharang drain contains domestic wastewater fraction as well which dilutes the toxic nature of pure textile wastewater. Fu and co-workers reported COD removal efficiency of 20.2 % with textile wastewater in anaerobic filter bed reactor with 8 hr HRT [22]. It confirms that anaerobic treatment is un effective against textile wastewater.

Neczaj and co-workers achieved a COD removal of approximately 70% using SBR with a mixture of domestic wastewater and landfill leachate constituting an influent COD of 500 mg/L [23]. In our case, the influent COD was approximately 450 mg/L, but the removal was less than 70%. However, they used a 9:1 mixture of domestic wastewater and leachate.

Effect of HRT on BOD and TSS Removal

Fig. 5 depicts average BOD removal efficiency and average effluent BOD values for real wastewater SBRs at both 12 and 8 hrs HRTs. The BOD removal efficiency remained constant at almost 73% under both HRTs in real wastewater SBRs and the effluent BOD values remained below 80 mg/L, which is the effluent discharge standard for Pakistan according to NEQS. The HRT showed no effect on BOD removal efficiency, because BOD is readily biodegradable and got effectively removed in 8 hrs and hence 4 hrs increase in HRT (12 hrs) was not able to remove BOD fraction any further. BOD removal of 65% is reported by Sirianuntapiboon and Sansak while treating raw textile wastewater in SBR [20]. A study conducted by Tufekci and co-workers also achieved the BOD removal of 75 and 69% for two different textile wastewaters using aerobic biological treatment [21]. These results are in accordance with our results.

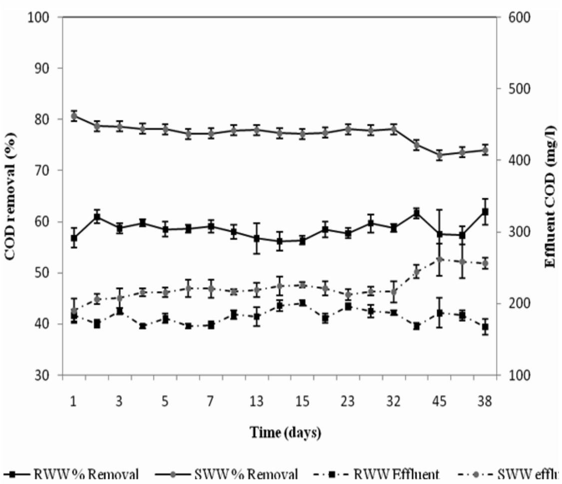

Fig. 3: Average % COD removal and average effluent COD trends in real and synthetic wastewater SBRs at 12 hr HRT.

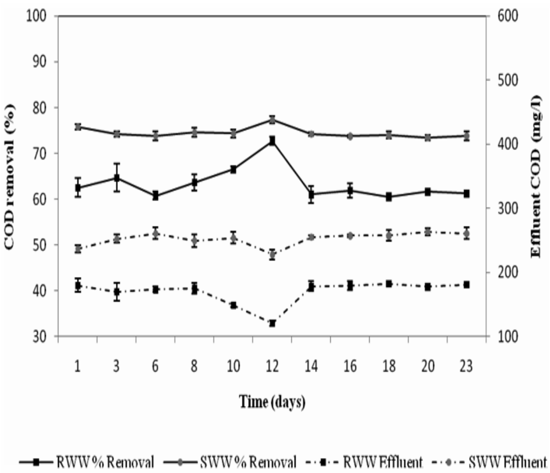

Fig. 4: Average % COD removal and average effluent COD trends in real and synthetic wastewater SBRs at 8 hr HRT.

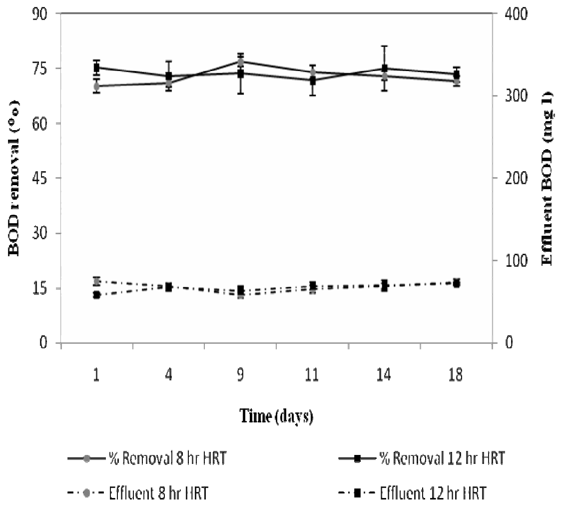

Fig. 5: Average % BOD removal and average effluent BOD trends in real wastewater SBRs at 12 and 8 hrs HRT.

Fig. 6 illustrates average TSS removal efficiency and average effluent TSS values for real wastewater SBRs at both 12 and 8 hrs HRTs. The TSS removal efficiency increased from 52 to 63% while varying HRT from 12 to 8 hrs. The reason for this improvement can be large and dense flocs formation as well as the improvement of SVI. With better sludge settling the effluent TSS reduces substantially. In another study conducted by Sirianuntapiboon and co-workers, the TSS removal was found to be 70% with real wastewater at 24 hr HRT, which supports the results of our study [9].

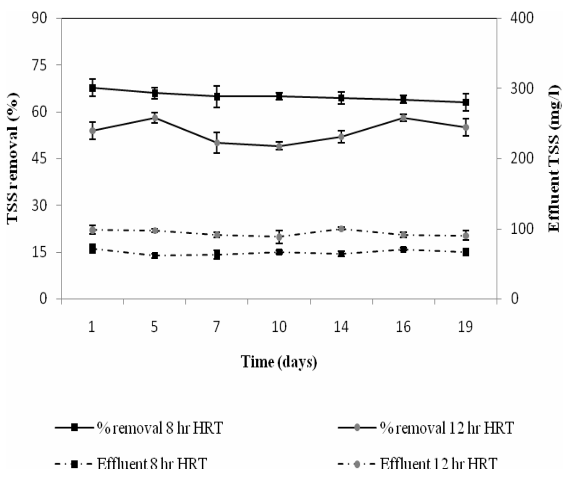

Fig. 6: Average % TSS removal and average effluent TSS trends in real wastewater SBRs at 12 and 8 hrs HRT.

Effect of HRT on SVI

The SVI improved from 96 ± 3 to 84 ± 2 mL/g in RWW and from 108 ± 6 to 84 ± 3 in SWW SBRs when HRT varied from 12 to 8 hrs. With improvement in sludge settling characteristics, the TSS removal increased which correspondingly enhanced the particulate COD removal efficiency. These SVI values are in accordance with good settling sludge 75-120 [24, 25].

At 12 hr HRT no sludge was wasted, so SRT remained technically at 28 days and average F/M was 0.03 and 0.13 Kg BOD/Kg MLSS/d in RWW and SWW SBRs respectively. Since sludge was withdrawn to maintain MLSS around 5000 mg/L in the 8 hr HRT condition so the F/M remained at 0.05 and 0.19 Kg BOD/Kg MLSS/d in RWW and SWW SBRs respectively. The typical values of F/M ratio for activated sludge are from 0.04-1.0 Kg BOD/Kg MLSS/d [24], hence it is clear that F/M ratio of 0.03 at 12 hr HRT was very small and as it improved to 0.05, the potential of filamentous growth decreased and settling characteristics in terms of SVI improved.

Experimental

Synthetic Wastewater Composition

The composition of synthetic wastewater used in the study is illustrated in Table-1. The composition of synthetic wastewater for steady-state operation was chosen to simulate high strength wastewater which is above the average constituent concentrations of the actual mixed wastewater in Paharang Drain. This will give a performance comparison of bio mass against readily and slowly biodegradable organics. The 500 ml of synthetic wastewater (1000 mg/L) was added twice and thrice a day in 12 hr and 8 hr cycles respectively. The COD: N: P was maintained at 100: 10: 2 to avoid any possible nutrient deficiency. The $NaHCO_3$ was also added to maintain the pH between 7 and 8.

Table-1: Composition of synthetic wastewater.

Condition	Synthetic COD (mg/l)	Glucose (mg/l)	NH_4Cl (mg/l)	KH_2PO_4 (mg/l)	$NaHCO_3$ (mg/l)
Sludge growth	6000	5600	2300	500	2000
Steady state operation	1000	935	385	85	350

Combined Municipal and Textile Wastewater

The real wastewater for this study was taken from Paharang Drain Faisalabad. The drain contains combined sewer from some areas of Faisalabad city and majorly from industrial area. The drain has a total average flow of 100 MGD and its wastewater characteristics measured over one year period are reported in Table-2.

Table-2: Characteristics of Paharang Drain wastewater.

Parameters	Units	Average* Value ± S.D.
Temperature	Celsius	25.4 ± 7.6
BOD	mg/L	224.6 ± 40.7
COD	mg/L	433.7 ± 35
TOC	mg/L	135.2 ± 13.8
pH	-	8.5 ± 1
DO	mg/L	0.84 ± 0.31
TDS	mg/L	2570 ± 490
TSS	mg/L	244 ± 76
Color	Pt-Co	456 ± 22.6
TN	mg/L	55.8 ± 23.7
Sulphates	mg/L	412 ± 26
Chloride	mg/L	846 ± 266
TP	mg/L	13 ± 2.1
Oil and grease	mg/L	28 ± 3.4

*An average of 10 samples

Sampling Plan

Samples were collected from a point after which there were no significant addition of industrial or domestic effluents and the characteristics of the drain were consistent. 24 hr composite samples were collected on monthly basis by using plastic bottles attached with the graduated steel rod. The samples were preserved at 4^0C to retard any possible biological activity during travelling and storage. On requirement, the required sample quantity was taken out of the refrigerator, brought to room temperature by placing openly for few minutes and then was fed to desired SBRs.

Microbial Culture

A mixed microbial consortium used in this study was obtained from I-9 sewage treatment plant Islamabad. The initial concentration of MLSS was 2000 mg/L and it was increased approximately up to a concentration of 6000 mg/L in all the six SBRs by feeding synthetic wastewater of 6000 mg/L COD for two weeks continuously.

Experimental Setup

The setup used for the study is shown in Fig. 7. The experimental set up consisted of six SBRs namely RWW1, RWW2, RWW3, SWW1, SWW2 and SWW3. Reactors RWW1, RWW2 and RWW3 were used for treating the real wastewater and reactors SWW1, SWW2 and SWW3 were used for synthetic wastewater. All six SBRs consisted of 30 cm height, 10 cm internal diameter and 0.1 cm thick transparent plastic bottles resulting in a final volumetric capacity of 2.0 L out of which 1.3 L was used as effective volume and 0.70 L as free board. Reactors were placed in a transparent rectangular polyacrylic sheet container of 60 L capacity which was filled with tap water and an automatic heater (model PR 580, China) was installed to keep the temperature constant at 25 ± 1 ^0C throughout the study.

Three air pumps with double air outlets (Model AK 808, China) were used for providing air at a constant flow of 0.95 L/min/SBR at a pressure of 0.1 bar. The aeration intensity and dissolved oxygen (DO) level was also kept constant throughout the study. Aeration helped in maintaining a DO level between 2.5-3.5 mg/L and providing sufficient mixing of the sludge to keep it in suspension.

Experimental Procedure

Under HRT of 12 and 8 hr, the SBRs were operated for 7 weeks period. The pH was maintained at 7.5 ± 0.5 using $NaHCO_3$ in SWW reactors and 8.5 ± 0.5 in RWW reactors. The parameters such as concentrations of MLSS, MLVSS, TSS, COD, BOD and SVI were monitored regularly to assess the efficiency of the SBRs. Since all the constituents of synthetic wastewater were water soluble, so suspended solids were not measured in the effluent of SWW SBRs. Also the organic matter used for synthetic wastewater preparation was totally biodegradable, so BOD was also not measured for SWW reactors. All parameters were measured according to Standard Methods [26]. The SBR cycles during both HRTs are described in Table-3.

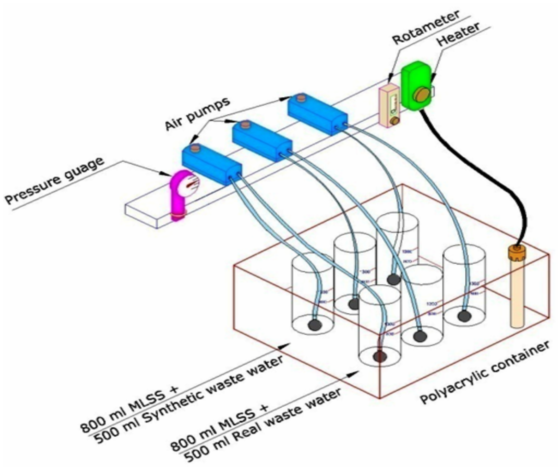

Fig. 7: Experimental setup for the SBR study at various HRTs.

Table-3: Summary of SBR cycles under both HRTs.

Activity	12 hr Cycle	8 hr Cycle
Replication/day	2	3
Fill (hr)	0.25	0.25
Aeration (hr)	10.75	6.75
Settling and decanting (hr)	0.75	0.75
Idol (hr)	0.25	0.25

Conclusions

Based on the findings of this study following conclusions were drawn:

a. The combined domestic and textile effluent of Paharang drain can be treated successfully by SBR technology and brought close to the limits of discharge standards of Pakistan.
b. The suitable SBR efficiency in terms of COD, BOD and TSS removal was achieved at 8 hrs HRT.
c. The synthetic wastewater SBRs showed greater COD removal efficiency of 78% than real wastewater reactors 63% under similar operating conditions because of the readily biodegradable substrate and absence of inhibitory and toxic substances in synthetic wastewater.
d. Since BOD represents biodegradable organic matter, the BOD removal efficiency of 73% was more than that of COD removal efficiency in real wastewater SBRs.
e. The TSS removal efficiency increased from 52 to 63% in real wastewater SBRs from 12 to 8 hrs HRT.

Acknowledgment

The authors greatly acknowledge financial Grant for this research project provided by the Higher Education Commission (HEC), Pakistan under National Research Program for Universities (HEC Project No. 20-963/R&D/2007).

Moreover, the authors also acknowledge the authorities of I-9 Sewage Treatment Plant (STP), Islamabad and Water and Sanitation Agency (WASA), Faisalabad for providing their kind cooperation and assistance.

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