COMBINATION OF UP-FLOW ANAEROBIC SLUDGE BLANKET AND DOWN-FLOW HANGING SPONGE SYSTEM FOR REMOVAL OF COLOR FROM REACTIVE DYES WASTEWATER

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ABSTRACT

This study was carried out to assess the efficiency of a combined system consisting of up-flow anaerobic sludge blanket (UASB) reactor and down-flow hanging sponge (DHS) system for color removal from reactive dyes wastewater. The UASB reactor and DHS system were operated at HRT of 6 and 2.0 h., respectively. The results obtained indicated that, the combined system was quite effective for removal of color, COD fractions (COD_{total}, $COD_{soluble}$ and $COD_{particulate}$) and TSS. The total process achieved an overall removal efficiency of 78% for color, 75% for COD_{total}, and 73% for TSS. The major part of COD in particulate form was removed in UASB reactor and little additional removal was occurred in DHS system. Unlikely, the big portion of COD in soluble form was eliminated in DHS system resulting a removal efficiency of 65% for $COD_{soluble}$. This indicates that removal of particulate organics in the UASB reactor would enhance the removal of $COD_{soluble}$ in the DHS system.

The results for DHS profile showed that the major part of color, COD and TSS was removed in the 1st and 2nd segment. Minor removals were occurred in the 3rd segment of DHS system.

Keywords: reactive dyes wastewater; UASB; DHS; color

1. INTRODUCTION

Reactive dyes represent the largest class of dyes applied in textile processing. In textile dye baths, the degree of fixation of dyes to fabrics is never complete, resulting in hazardous dye-containing effluents. The composition of wastewater from dyeing and textile processes varies greatly from day to day and even from hour to hour, depending on the dyestuff, fabric and concentration of fixing compounds which are added [1]. The removal of hazardous dyes from these effluents is desired, not only for aesthetic reasons, but also because many azo dyes and their breakdown products are toxic to aquatic life and mutagenic to humans. Therefore, treatment of this wastewater is essential prior discharging into water streams. Recently, several studies have been demonstrated that white-rot fungi are able to degrade and decolorize the textile wastewater [2-4] However, the application of white-rot fungi on a large scale is limited by the difficulty of achieving sterilized conditions in open-air reactors slow fungal degradation [5], loss of the extracellular enzymes and mediators with discharged water [6], and excessive growth of fungi [7]. Although dyes in wastewater can be effectively destroyed by advanced chemical oxidation using ozone [8] or H_2O_2/UV [9] and adsorption using activated carbon [10], the costs of these techniques are still high. Anaerobic treatment technologies are frequently used for treatment of dyes wastewater [11]. These processes are generally efficient for BOD_5 and suspended solids (SS) removal, but they are largely ineffective for color removal which is visible even at low concentrations [12,13]. In one of the reactor studies it was shown that the color removal by a two-stage anaerobic–aerobic treatment process was 70% higher than that of a one-stage aerobic treatment process [14]. These results are in agreement with previously published data on recalcitrance of azo dyes in aerobic sludge environments [15]. It is reasonable to assume that anaerobic color removal is mainly due to formation of aromatic amines due to azo dye reduction. Efficient post-treatment methods, e.g. aerobic biological post-treatment, for the complete mineralization of the aromatic amines, which are formed in the anaerobic step, must be utilized. Therefore, the treatment of textile wastewater either to guarantee the emission requirements or to close the water cycle should be composed of a sequence of treatments, and each scenario should be analyzed individually. The color removal from dyes wastewater was investigated by Minke *et al.*, [14] who found that a combined anaerobic–aerobic treatment process achieved 70% for color removal. The aromatic amines from anaerobic cleavage of azo dyes were significantly removed in the consequent aerobic stage [16]. So far, down flow hanging sponge (DHS) system as a post-treatment showed a good performance for treatment of food industry wastewater in combination with UASB reactor as a pretreatment [17,18]. However, little is known about the efficiency of the reductive decolourisation of azo dyes in DHS system.

The DHS process is similar to the mechanism of the trickling filter, but uses sponges with high specific surface area (256 m^2/m3) as a site for growth and attachment of active biomass. The construction of the DHS system is simple and can be easily accomplished using local Egyptian resources and manpower. In addition, the operation and maintenance of this technology is very simple and can be operated at short hydraulic retention time and high organic loading rate without any external aeration. The air is naturally diffused into the reactor. Moreover, the retained biomass in the reactor exceeding 34 gVSS/l [19].

Therefore, the aim of this study is to assess the performance of a combined system consisting of up-flow anaerobic sludge blanket (UASB) reactor and down flow hanging sponge (DHS) system for treatment of reactive dyes wastewater at a total HRT of 8 h. The emphasis was afforded for color, COD fractions and TSS removal.

2. MATERIALS AND METHODS

2.1 Reactive Dyes Wastewater

Real reactive dyes wastewater was collected from a textile factory located at greater Cairo, Egypt. Composite samples for 24 hrs were collected and fed continuously to the integrated system consisting of UASB and DHS reactors. The characteristics of textile wastewater used for the study were (mg/l): COD (830 ± 31), BOD_5 (237 ± 50), TSS (400.7 ± 141.6). The pH, turbidity and color (absorbance at 520 nm) were 8 ± 2, 169± 59 NTU and 0.16 ± 0.03, respectively.

2.2 Up-Flow Anaerobic Sludge Blanket (Uasb) Reactor

A laboratory-scale up-flow anaerobic sludge blanket (UASB) reactor was designed and fabricated using polyvinyl chloride (PVC) (Fig. 1). The effective volume of the UASB reactor was 11l with a height 1.42 m and an internal diameter 0.1 m. The flow distributor was placed at the bottom of the reactor to distribute influents eventually from the bottom. The gas- solid separator was situated in the upper portion of the reactor to prevent the loss of sludge from the reactor and for easy release of the biogas produced by UASB reactor. The reactor was inoculated with 4 l digested sludge harvested from sewage treatment plant. Total solids and volatile solids of the inoculums sludge were 31.6g/l and 19.8 g/l, respectively.

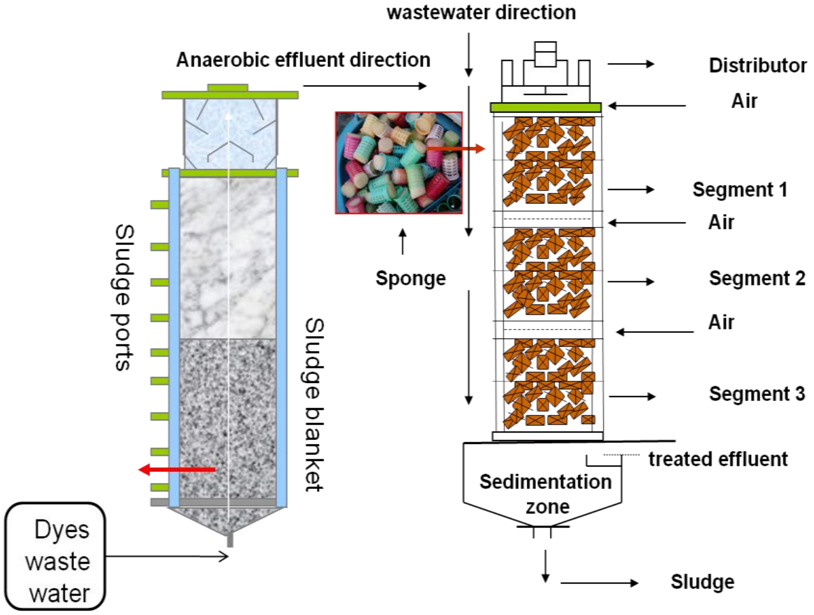

Fig. 1. integrated system consists of UASB+DHS system treating reactive dyes wastewater

2.3. Down-flow hanging sponge (DHS) system

The DHS reactor (23 l) consists of three identical segments connected vertically in series and equipped with a total sponge volume of 3.6 l. The reactor was filled with sponge (polyurethane foam) (4.4 cm height x 2cm diameter). The shape of the sponge is perfectly cylindrical and supported by perforated polypropylene plastic material to avoid clogging of the reactor and to facilitate the penetration of diffused air inside the reactor. The sponge criteria are: surface area (256 m^2/m^3), density (30 kg/m^3), void ratio (0.9), and pore size (0.63 mm). A circular plate provided with holes was used to support the filling material and to separate each segment of the reactor. The reactor has three windows along the reactor height for air diffusion as shown in Fig. 1. Anaerobically pretreated effluent flows by gravity to the distributor situated on the top of the DHS system and rotated at 20 rpm. The reactor was operated without inoculums biomass. The experimental period was over 1 year.

2.4. Sampling and Analytical Methods

Two times per week grab samples of the influent and the effluents of UASB and DHS system were collected and immediately analyzed. Moreover, samples from segments 1, 2, and 3 of the water phase from DHS system were collected by gently inserting a plastic container of 30 cm length, 20 cm, width and 5 cm depth (volume 0. 3 l) (Fig.1). Color, chemical oxygen demand (COD), pH, total suspended solids (TSS), turbidity and sludge were measured according to APHA, [20]. Raw samples were used for COD_{total}, and 0.45 mm membrane filtered samples for

COD $_{\text{soluble}}$. The COD $_{\text{particulate}}$ was calculated by the difference between COD $_{\text{total}}$, and COD $_{\text{soluble}}$, respectively.

Removal of color was analyzed using UV/VIS spectrophotometer at 520 nm (NOVA400 Merck UV-spectroquant). For evaluating the performance of the reactors, the dye removal efficiencies were calculated by the following Eq.

$X (\%) = C_0 - C_f / C_0 \times 100$

Where C_0 and C_f are the initial and final absorbance values of the dye

3. RESULTS AND DISCUSSION

3.1. Color Removal

The results presented in Fig. 2 show that the combined system UASB/DHS system is very effective for color removal at a total HRT of 8.0 h. The UASB and DHS achieved color removal efficiencies of 64±17% and 41±13.2% respectively, while the overall removal efficiency of the combined system (UASB/DHS) was reached up to 78±12.3%. These results indicated that UASB reactor is effective in the color removal from reactive dyes wastewater while DHS system had little further effect in terms of color removal. Color removal in UASB reactor was mainly due to the adsorption of dye into sludge, followed by biodegradation processes by anaerobic consortium bacteria. Low color removal efficiency at the beginning of the continuous experiments seems to be due to low adsorption/biodegradation onto sludge (Fig. 2). Similarly, Frijters *et al.,* [21] found that a combined anaerobic/aerobic system treating textile wastewater achieved color removal efficiencies of 80–95% in which the anaerobic bioreactor was the main responsible in decolorizing and detoxifying the dyes wastewater. Anaerobic bacteria consortium is preferred for decolorization of azo dyes in textile wastewaters because of their properties i.e. they generate electrons to cleave the azo bond [22]. Spagni et al., [23] found that color removal mainly took place under anaerobic conditions, although a small increase in color removal was still observed under anoxic and aerobic conditions. The study of Turgay et al., [11] revealed that increasing the residence time, and the amount of yeast extract as a nitrogen source in the influent dyes wastewater fed to the anaerobic reactor significantly increased the color removal from 78.6 to 89.2%. In another study, Wijetunga et al., [24], investigated the effect of the dye concentration on the color removal in an UASB reactor. They found that the maximum color removal of 94±0.1% was achieved at 150 mg/l dye concentration and color removal at 300 mg/l dye concentration decreased to 86±0.4%. Somasiri et al. [25] used a UASB reactor (HRT = 24 h) supplemented with nutrients and glucose to treat a real textile wastewater (COD $_{\text{total}}$ = 6 g/l) and found 95% color removal. On the other hand, Sen and Demirer [26] used a fluidized bed reactor (FBR) operated at a HRT of 24 h., for treatment of textile wastewater supplemented with glucose (500 mg/l) and nutrients and achieved color removal efficiencies between 40 and 44%. This discrepancy for the results was mainly due to the difference of wastewater composition and dyes.

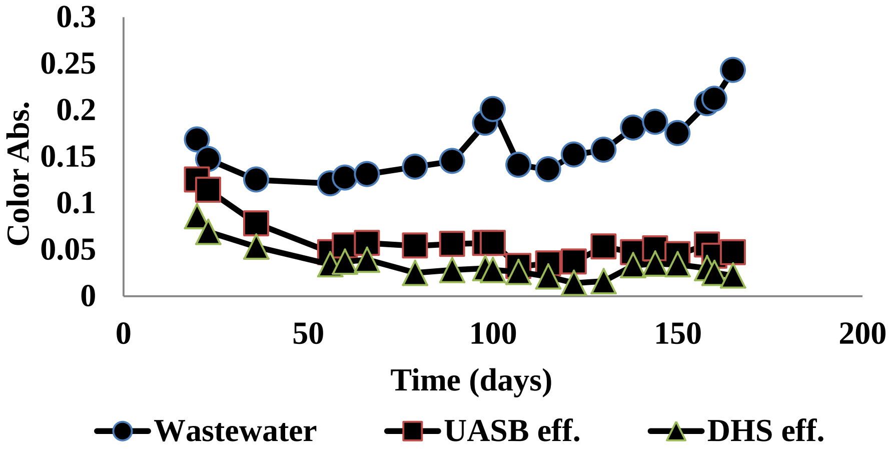

Fig.2. the efficiency of the combined system (UASB+DHS) for color removal from reactive dyes wastewater

The poor efficiency for color removal (41±13.2%) in DHS system can be mainly due to the electron-withdrawing nature of the azo bond and their resistance to oxygenases attack, or because oxygen (DO= 4.3 mg/l) is a more effective electron acceptor, therefore having more preference for reducing equivalents than the azo dye [27,28]. However, in the presence of specific oxygen-catalysed enzymes called azo reductases, some aerobic bacteria are able to reduce azo compounds and produce aromatic amines [29].

3.2. COD Fractions, Turbidity, TSS Removal And Ph

Figs. 3a, b and c show the efficiency of the combined system (UASB/DHS) for removal of COD fractions (COD $_{\text{total}}$, COD $_{\text{soluble}}$, COD $_{\text{particulate}}$) from textile wastewater. The results obtained showed that the UASB reactor achieved a removal efficiencies of 36.4 ± 9 % for COD $_{\text{total}}$, 24 ± 5 % for COD $_{\text{soluble}}$ and 56.6 ± 15 % for COD $_{\text{particulate}}$ at an OLR of 3.3 g COD/l. d., and HRT of 6.0 h. At an HRT of 2 h., and OLR of 6.4 g COD/l. d., the DHS system as a post-treatment provided a removal efficiencies of 60.5 ± 6 %, 53.4 ± 4 % and 82.2 ± 17 % for COD $_{\text{total}}$, COD $_{\text{soluble}}$ and COD $_{\text{particulate}}$ respectively. An overall reduction of 75±7.4%, 65±4 and 91±12% in COD $_{\text{total}}$, COD $_{\text{soluble}}$ and COD $_{\text{particulate}}$ was occurred in the total system. The results revealed that, the UASB reactor is quite good for removal of COD in particulate form (56.6 ± 15 %). On the contrary, the big portion of COD in soluble form was eliminated in DHS system resulting a removal efficiency of 65±4%. This indicates that removal of particulate COD in the UASB reactor would enhance the removal of soluble organics in the DHS system. The COD removal and decolorization of azo dyes invariably begins by reductive cleavage of the azo linkage in UASB reactor. This leads to the formation of aromatic amines, which may be more toxic than the dye molecules themselves. However, the aromatic amines expressed as COD was easily mineralized in the aerobic DHS system. However, Spagni et al., [23] found that at least the sulfonated aromatic amines formed under anaerobic conditions from the RO16 are recalcitrant to biodegradation and therefore aromatic amines are still a matter of concern for the biological treatment of textile wastewater. This may be the reason for achieving only 75±7.4% of COD removal in the combined system.

Low removal efficiency of COD (36.4 ± 9 %) in the UASB reactor at an HRT of 6.0 h and OLR of 3.3 g COD/l. d are similar to those obtained by Spagni et al., [23], who found that decreasing the HRT from 4.0 to 1.0 d., of the anaerobic biofilm reactor decreased the removal efficiency of COD from 79 to 40% respectively. However, these results are in agreement with those obtained by Wijetunga et al., [24] who found that the UASB reactor achieved over 90 and 85% of COD removal at dye concentrations of 10, 25 and 300 mg/l respectively. Likely, Jianrong et al., [30] achieved a higher removal values of 90% COD reduction and 96% color reduction in a laboratory-scale UASB reactor (HRT\8 h) followed by an activated sludge reactor (HRT\6 h) fed with a deeply-colored high-strength effluent of a dye manufacturing plant. For improving the efficiency of UASB treating textile wastewater, Sen et al., [26] investigated the effect of addition of glucose as a co-substrate (electron donor) on the COD removal. They found that, COD, removal was found to be around 82% at a HRT of 24 h and OLR of 3 g COD/l.d.

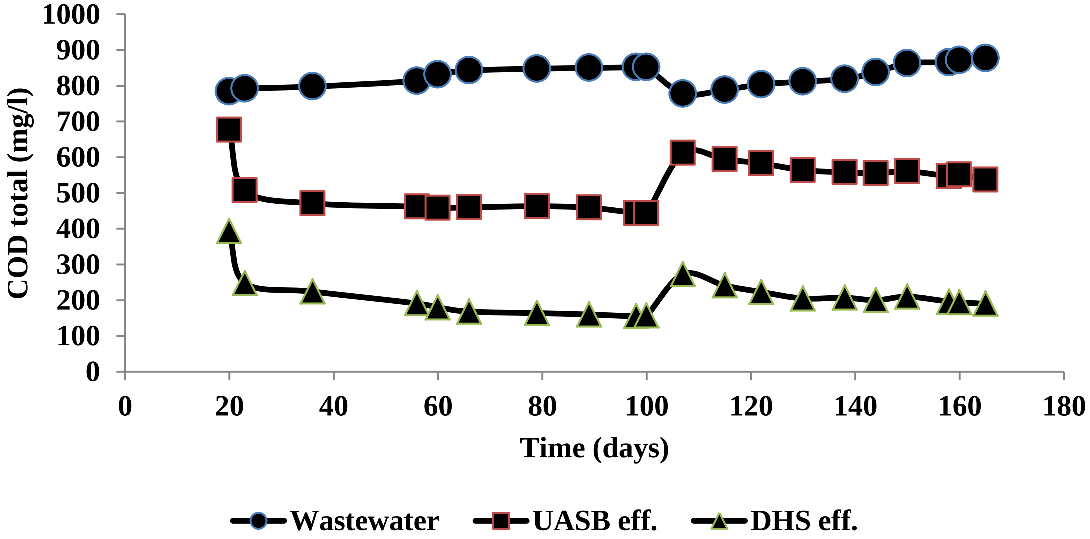

Fig.3a COD $_{total}$ removal efficiency in the combined system

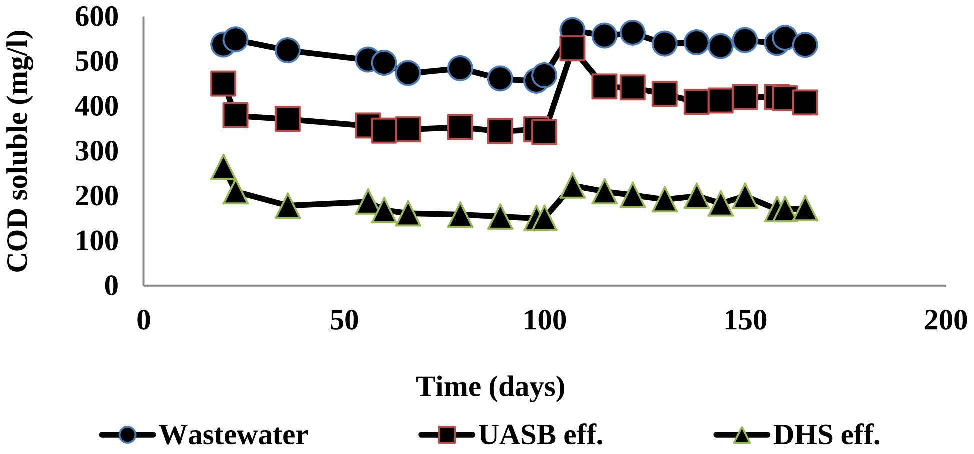

Fig.3b COD $_{\text{soluble}}$ removal efficiency in the combined system

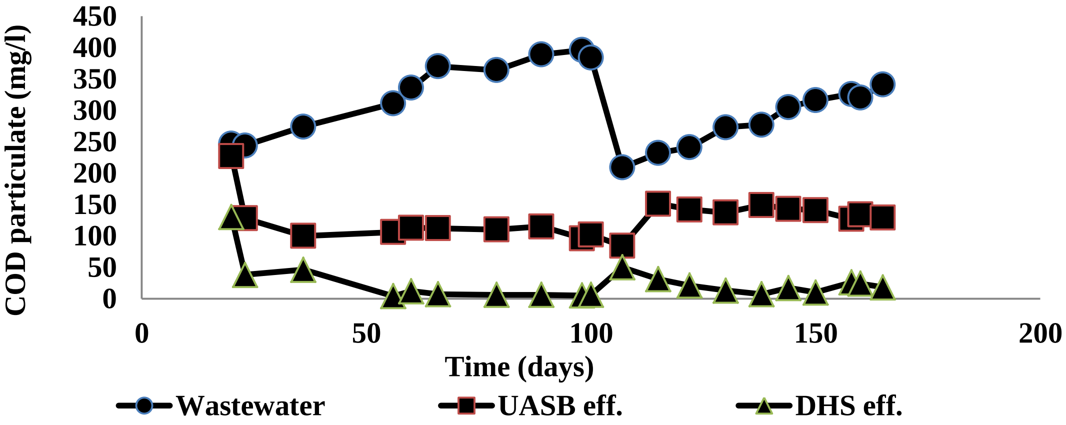

Fig.3c COD $_{\text{particulate}}$ removal efficiency in the combined system

The drop of pH from 8 to 7.55 in the UASB reactor is an additional advantage to make a favorable growing environment for methanogens, which can perform decolourization processes effectively (Fig. 4). However in DHS system, the pH was significantly increased from 7.55 to 8.4.

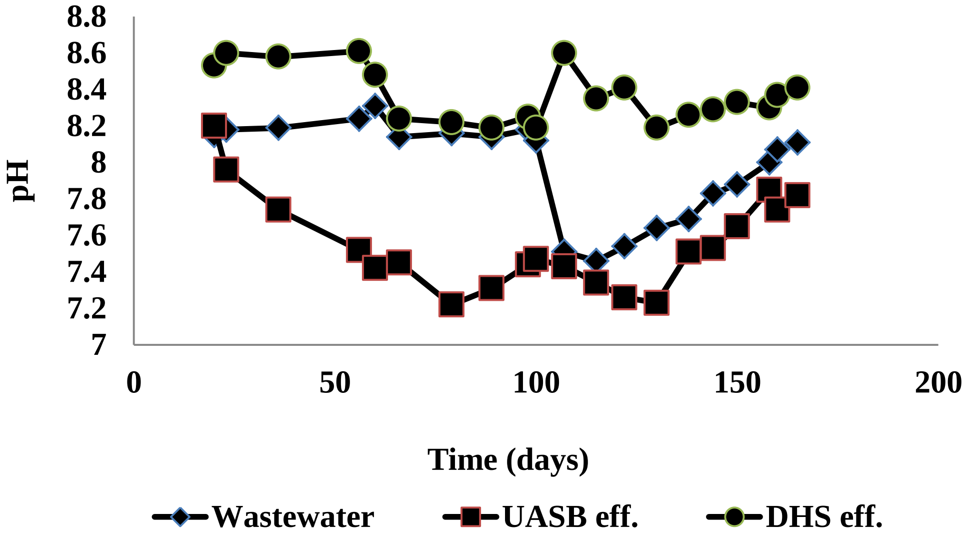

Fig.4 pH values in the combined system

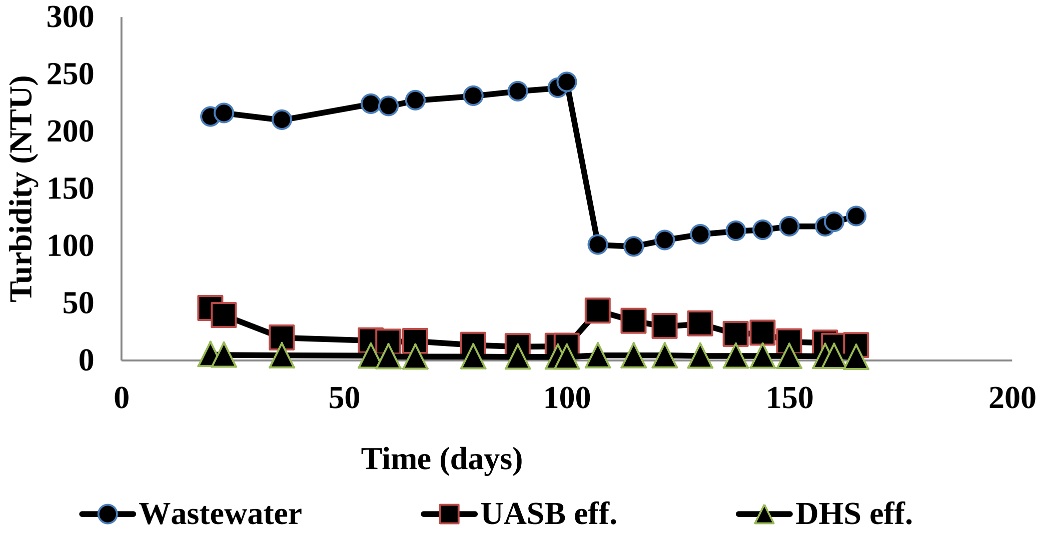

Fig. 5a. Turbidity removal in the combined system

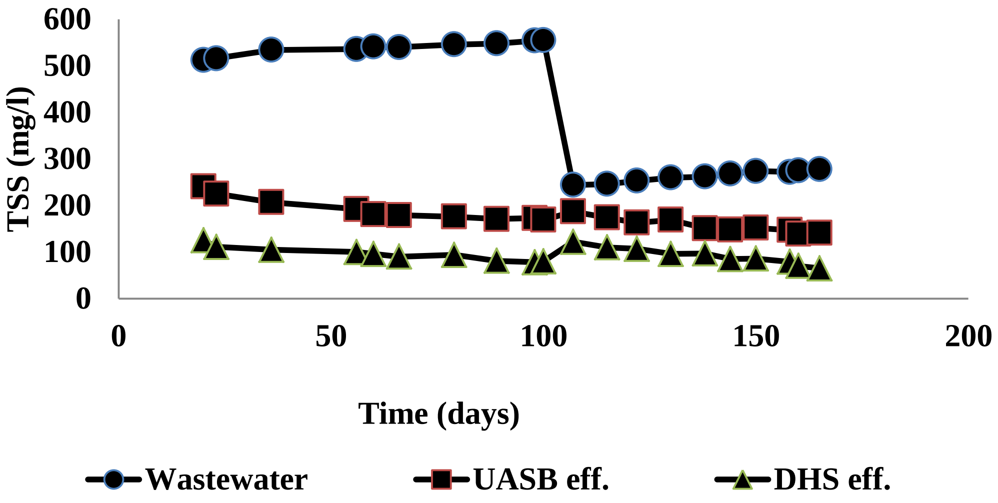

Fig. 5b. TSS removal in the combined system

The results in Fig. 5a and b show that the average percentage removal efficiency of turbidity and TSS in the UASB reactor was 52.1 and 84% and in DHS reactor was 46 and 80%, respectively. The combined (UASB /DHS) system achieved overall removal efficiencies of 97.4% for turbidity and 73.4% for TSS.

3.3. DHS Profile

Treated wastewater along the height of DHS system (1st , 2nd and 3rd segment) at different HRTs of 0.7, 1.3 and 2.0 h were sampled and measured to investigate the distribution of dissolved oxygen (DO) and mechanism removal pattern of the COD fractions, color, TSS and turbidity over the height of the reactor. The results presented in Table 1 show that DO concentrations along the height of the DHS system increased gradually from the upper (1st segment) to the lower portion (3rd segment). In the 1st segment of the DHS column, lower DO of 1.2 mg/l was found lower than those in the 3rd segment (DO= 3.9 mg/l. The lower DO values found at the top of the DHS system compared to the bottom may be as a result of the oxidized a big portion of COD fractions (COD_{total} = 32.1%; $COD_{soluble}$ = 40.2% and $COD_{particulate}$ = 50%) and a higher growth of aerobic oxidizing bacteria. Likely, the major part of color, turbidity and TSS was removed in the 1st and 2nd segment and that little additional removal was eliminated in the 3rd as shown in Table 1.

Table 1. DHS profile results

	HRT (h)	DO (mg/l)	COD_{total} (mg/l)	$COD_{soluble}$ (mg/l)	$COD_{particulate}$ (mg/l)	Color	Turbidity (NTU)	TSS (mg/l)
UASB-effluent	6	0.0	460	348	112	0.077	16.7	179
Seg. 1	0.7	1.2	312	208	56	0.044	8.8	122

%R		-	32.1	40.2	50	42.9	47.3	31.8
Seg.2	0.6	2.4	222	178	36	0.034	5.3	95
%R		-	28.8	14.4	35.7	22.7	39.7	22.1
Seg.3	0.7	3.8	178	156	22	0.03	3.2	80
%R		-	19.8	12.3	38.9	11.8	39.6	15.8
Final effluent		3.9	160	148	12	0.022	2.9	77
overall removal efficiency		-	65.2	57.4	89.3	71.4	82.6	56.9

4. CONCLUSIONS

The results of the study demonstrate that a system comprising an UASB reactor and an aerobic DHS system is suitable for treatment of reactive dyes wastewater. Neither the azo dye, nor the aromatic amines formed by the anaerobic azo-bond cleavage seem to significantly affect the COD resulting only removal efficiency of 75±7.4%. The UASB and DHS system at a total HRT of 8.0 h achieved color removal efficiencies of 64±17% and 41±13.2% respectively, while the overall removal efficiency of the combined system (UASB/DHS) was reached up to 78±12.3%. The major part of COD fractions, color, turbidity and TSS was removed in the 1st and 2nd segment and that little additional removal was eliminated in the 3rd segment of DHS system.

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