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Research Article

Enhancement of Upflow Anaerobic Sludge Blanket using Submerged Biofilters as a Pre-Treatment

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Abstract

In Egypt 16 up-flow anaerobic sludge blanket (UASB) plants reactor were established during the last decade, One of the main problem faced these plants was the raw waste strength as the influent to the plants exceed it is design values. In this research submerged bio-reactors were used as a pre-treatment for the UASB unit in order to decrease the influent waste water strength, two different bio-reactor media types were placed in the influent channel of the existing UASB reactor, results shows that the two used media were able to decrease the influent TSS and COD as the pall rings media decreased the influent TSS with a range between 4.50 and 17.00 % while the COD decrease ranged between 4.90 and 24.7%, in the other hand the star shape media decreased the influent TSS with a range between 10.90 and 18.40 % while the COD decrease ranged between 8.50 and 29.40%. Both COD and TSS removal were 1st order reaction and the COD removal rate constants were equal to $2.40*10^{-3}$ and $1.90*10^{-3}$, while the TSS removal rate constants were equal to $1.89*10^{-3}$ and $1.46*10^{-3}$ for the star shape and Pall rings media respectively.

Keywords: *COD, submerged Biofilters, TSS, UASB.*

1. Introduction

There are a wide range of treatment technologies. However, anaerobic treatment especially offers very attractive prospects for developing countries because of its advantages such as high efficiency, simplicity in construction and operation, flexibility, cost-effective - Low space requirements, Low energy consumption, Low sludge production (Tandukar *et al* ,2007).

Recently, different anaerobic technologies have been applied in the treatment of low-concentration wastewaters like domestic sewage, providing good treatment efficiencies at moderate temperatures and low hydraulic retention times (HRTs). The up flow anaerobic sludge blanket (UASB) reactor is the most frequently used reactor in full-scale installations for the anaerobic treatment of domestic wastewaters, being chosen mainly to countries with a warm climate. (Lettinga and Hulshoff, 1991). In the UASB process, the wastewater flows through a very dense sludge bed which may be granular or flocculent where readily biodegradable substances are quickly acidified and then converted into methane and other biogas components. (Aiyuk *et al*, 2006).

Wastewaters containing a high amount of suspended solids may limit the performance of a one phase anaerobic UASB system (Zeeman, 1999). The accumulation of suspended solids in the sludge bed will reduce the sludge retention time (SRT) and the methanogenic activity of the sludge. This problem was perceived by Lettinga and Hulshoff (1991) when they stated, 'For the treatment of partially soluble complex wastewater the required removal efficiency of the SS should be given attention'.

However, UASB reactors are very efficient in removing suspended solids (SS) and organic material (BOD and COD) from wastewater, when they are operated in regions with a tropical or subtropical climate (Paula, 2003). Although numerous designs and/or configurations of wastewater treatment reactors have been developed in recent years to optimize the anaerobic treatment of wastewater, one of the main challenges remains the enhancement of these designs and/or operations. Different methods were used to enhance the UASB reactors and could be divided into three main categories:

1) Pretreatment of waste water by using septic tanks (Al Juaidy *et al*., 2003).
2) Post treatment of waste water by considering the UASB reactor as a primary treatment method which will be followed by biological treatment stream such as activated sludge system (Tawfik *et al*, 2008), SBR system (Moawad *et al*, 2009), moving-bed biofilm reactor (Tawfik *et al*, 2010), down flow hanging sponge (DHS) (Takahashi *et al*, 2011) etc.

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3) Modifying the reactor design by using of media inside the UASB reactor such as lamella settlers (Halalsheh, *et al* 2010), Tube settlers (El-Nadi M. H. *et al*, 2007) and clay minerals (Bayoumi S *et al*, 2007).

In Egypt 16 UASB plants reactor were established during the last decade. These plants were called experimental plants as each plant had a different post treatment method than the others in order to investigate the most appropriate treatment method which is low in cost in (construction & operation) depending on natural conditions and sewage composition. One of these plants established in Bordeen village, located at south of zagazig city, Sharkia governorate, Egypt. Bordeen WWTP consists of one manual bar rack (5cm size), two UASB reactors followed by two trickling filter system, but despite using a post treatment system the effluent of the plant exceed the permissible values (according to the environmental Egyptian laws). The company responsible for the operation of this plant attributed that to the increase of the incoming organic loads than the design values of the plant, also to the high percentage of bird's feather and livestock wastes in the incoming flows to the plant which causes a clogging of distribution pipes of UASB reactor. One of the proposed solutions to enhance the operation and the overall efficiency of the plant is using submerged bio-filter as a pretreatment step. The aim of this research was to study the effect of using two different types of media working as a submerged bio-filters as a pretreatment to the UASB units.

2. Material and methods

2.1 Experimental equipment

The experimental work of the present study was carried out in Bordeen WWTP. The UASB reactor in Bordeen WWTP is about 22m length, 6m width and 7m height. The reactor contains 8 distribution channels, and each channel equipped with 10 distribution pipes (6 pipes in each side). Figure 1 shows a cross-section in the distribution channel. This channel is about 0.8 m height and 0.8m total width. The incoming flow is entering to the inner channel (0.2 m width), and then distributed over two outer channels (0.3 m width for each).

So as not to do disrupt or make any confusion to the operators of the plant, the experimental work was carried out in one meter length from one of the distribution channels.

The used media worked as attached growth media, on which bacteria accumulated in order to maintain a high population. Two different plastic media were studied because of their high porosity percent; light weight and their high specific surface area. Table (1) shows the properties of the used media. Each media was placed in one side channel with volume of (1.0m length*0.3m width*0.5m height). During the study, each bio-filter was received a sewage flow rate of about 146 (m^3/d).

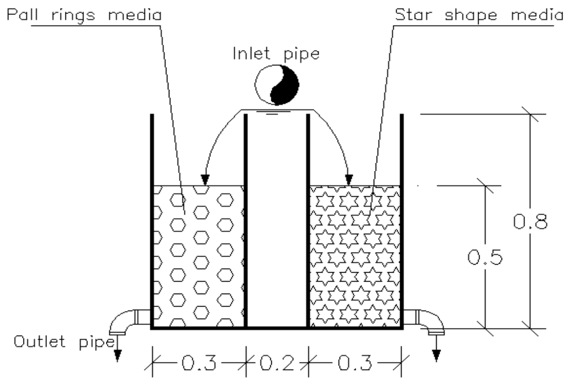

Fig.1 Cross-section in the distribution channel

Table 1 Bio filter media properties

Media type	Star shape	Pall rings
Material	PVC	PVC
Surface texture	Smooth	Smooth
Outer diameter (mm)	64	50
Height (mm)	From 5 to 24	50
Porosity (%)	82	83
Specific surface area (m^2/m^3)	152.15	71.24
Media photo		

2.2 Experimental procedures

BOD_5, COD, Total Suspended solids, Temperature and pH were measured from samples taken just before and just after the media (in order to investigate the effect of media only on the sewage properties). All the measurements were analyzed at the Environmental Engineering Department laboratory, Faculty of Engineering, Zagazig University, Egypt, accordance with The Standard Methods for the Examination of Water and Wastewater, 20th Edition, 2000, The properties of the inlet wastewater during the study are presented in table (2)

Table 2 Properties of raw waste water during the study

Parameters	Range
pH	6.5 – 7.9
Temperature (^{0}c)	18 – 23
COD (ppm)	1188-1760
BOD_5 (ppm)	620–1000
TSS (ppm)	520-776

3. Results and discussion

3.1 COD removal

Figure (2) shows the COD concentration for the two used media, the raw sewage COD ranged between 1188 and 1764 (ppm), the effluent from the star shape media were ranged between 1047 and 1276 (ppm) with a removal ratio between 8.50 and 29.40%. While the effluent from the pall rings media were ranged between 1116 and 1332 (ppm) with a removal ratio between 4.90 and 24.7%. The results complies with El-Nadi M. E. *et al* (2007) who placed tube settlers inside two UASB reactors at different height and increased the COD removal efficiency from 60 % in the reference reactor to 62 and 63% in the two modified reactors.

Halalsheh *et al.* (2010) investigated two reactor configurations. In the first reactor four lamella settlers were installed in the settling zone whereas in the other UASB reactor, three lamella settlers were installed underneath the gas-liquid-solid separator. The both reactors achieved 1.52 and 1.74-fold higher than those in conventional UASB reactor under similar conditions.

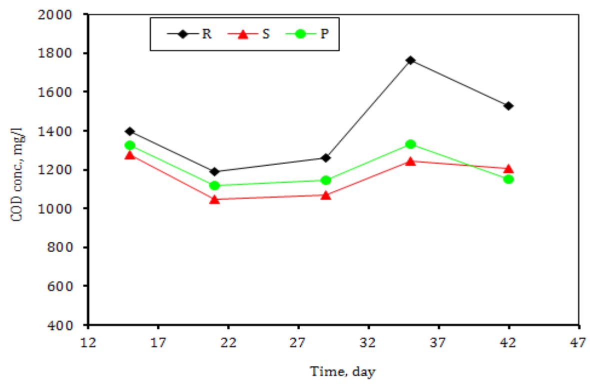

Fig.2 COD concentration effluent from the two biofilters

These results also complies with the results of Aboulfotoh A.M (2007) and El Gohary (2007) in their studies they used the star shape and pall rings media for the treatment of polluted streams in Egypt and found that using these low cost fabricated media increased the self-purification process.

The use of submerged biofilters provided two removal mechanisms of the organic and suspended matters (Yann et. al., 2000); the first was the filtration action for a large portion of the suspended organic solids from the water passing through and over the media, and the second was the biological degradation of the organics inside and at the surface of the biofilter by the attached microorganisms, which grow attaching to the media inside and on the surface of the biofilter. Sarti A. *et al* (2004), Aboulfotoh A.M (2007) and El Gohary (2007) found that the COD removal following a first order reaction and could be calculated based on the following equation.

$$C_e = C_0 \times e^{-K_C * V / Q} \qquad (1)$$

C_o = Influent COD (mg/L).

C_e = Effluent COD (mg/L).

V = Bioreactor volume (m^3).

K_C = COD removal rate constant (s^{-1})

Q = Sewage flow rate (m^3/s).

Aboulfotoh A.M (2007) in is study found that the COD removal rate constant is equal to $2.0*10^{-3}$ for the star shape media and $2.20*10^{-3}$ for the Pall rings media, based on equation (1) and current study results the rate constant is equal to $2.40*10^{-3}$ for the star shape media and $1.90*10^{-3}$ for the Pall rings media.

3.1 TSS removal

Figure (3) shows the TSS concentration for the two used media, the raw sewage TSS ranged between 520 and 776 (ppm), the effluent from the star shape media were ranged between 522 and 626 (ppm) with a removal ratio between 10.90 and 18.40%. While the effluent from the pall rings media were ranged between 546 and 649 (ppm) with a removal ratio between 4.50 and 17.00%. These results complies with the results of El-Nadi M. E. *et al* (2007) who placed tube settlers inside two UASB reactors at different height from 54 % in the reference reactor to 56% in the two modified reactors. Figure (4) shows a photo taken to the star shape biofilter at the end of the run, it was clear that the biofilters has high potential for removal of suspended and floating material, then the submerged biofilter is proven to be a good tool for the removal of bird's feather and livestock wastes that deteriorate the operation and efficiency of UASB plants.

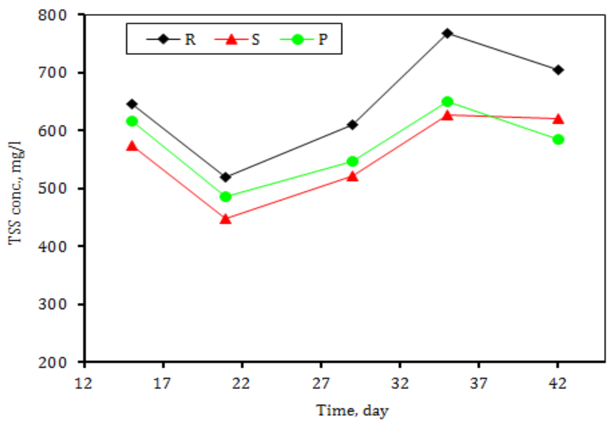

Fig.3 TSS concentration effluent from the two biofilters

Fig.4 Accumulation of suspended solids over and inside the biofilter

The results also of the present study comply with Abdelrahman W.H. (2002) who used three different media as submerged bioreactors to treat wastewater at Zeneen WWTP. Abdelrahman (2002), proved that the TSS removal following a first order reaction and could be calculated based on the following equation

$$S_e = S_0 \times e^{-K_{TSS} * V / Q} \quad (2)$$

S_o = Influent COD (mg/L).
S_e = Effluent COD (mg/L).
V = Bioreactor volume (m^3).
K_{TSS} = TSS removal rate constant (s^{-1})
Q = Sewage flow rate (m^3/s).

Based on equation (2) and current study results the TSS removal rate constant is equal to $1.89*10^{-3}$ for the star shape media and $1.46*10^{-3}$ for the Pall rings media.

Conclusions

Despite being very efficient in removing suspended solids (SS) and organic material (BOD and COD) from wastewater, when they are operated in regions with a tropical or subtropical climate UASB enhancement processes are not fully established yet. In this paper the using of submerged biofilters media as a pretreatment of the UASB were studied by placing two different media in the UASB reactor inlet channels, The two used media were able to decreased the influent COD and TSS as the pall rings media decreased the influent TSS with a range between 4.50 and 17.00 % while the COD decrease ranged between 4.90 and 24.7%, in the other hand the star shape media decreased the influent TSS with a range between 10.90 and 18.40 % while the COD decrease ranged between 8.50 and 29.40%. Both COD and TSS removal were 1st order reaction and the rate constant for the COD removal was equal to $2.40*10^{-3}$ for the star shape media and $1.90*10^{-3}$ for the Pall rings media, while the TSS removal rate constant is equal to $1.89*10^{-3}$ for the star shape media and $1.46*10^{-3}$ for the Pall rings media, The star shape media is more efficient regarding the removal of TSS and COD but it is likely to be clogged faster than pall rings media.

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