Australian Journal of Basic and Applied Sciences, 8(2) February 2014, Pages: 240-247

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Comparison between Using UASB & HUASB for Wastewater Treatment

[1]Hisham Abdel Halim, [2]Marwa Moharram, [3]Ehab Rozaik

[1]*Professor of Sanitary and Environmental Engineering, Cairo University, Civil Engineering Department, Faculty of Engineering Cairo, Egypt.*
[2]*Senior Sanitary and Environmental Engineer, PhD student, Cairo university , Civil Engineering Department , Faculty of Engineering, Box 11765.Cairo.Egypt.*
[3]*Associate Professor of Sanitary and Environmental Engineering, Cairo University, Civil Engineering department, Faculty of Engineering, Cairo. Egypt.*

ARTICLE INFO

Article history:
Received 23 December 2013
Received in revised form 25 February 2014
Accepted 26 February 2014
Available online 15 March 2014

Keywords:
Sewage Treatment & Disposal;
Anaerobic Wastewater Treatment;
Up Flow Anaerobic Sludge Blanket;
Primary Treatment

ABSTRACT

Background: There are various kinds of low cost anaerobic wastewater treatment systems that are widely used for municipal wastewater treatment. The up flow anaerobic sludge blanket UASB reactors are widely used in industrial wastewater treatment as it faces many operational problems in domestic wastewater treatment due to the sludge washout problem. **Objective:** To Compare between the UASB and the HUASB in domestic wastewater treatment. **Results:** The hybrid & UASB reactors achieved about 87.88 & 82.80 % COD removal efficiency respectively at detention time of 6 hours with OLR of 2.16 kg/m^3/day, and by increasing the organic loading measured in COD to 10,000 mg/l, the hybrid & the UASB removal efficiencies decreased to 80.49 & 79.64 % respectively. Then the organic loading expressed in COD mg/L was further increased to 20,000 mg/l. the COD removal efficiencies for the hybrid & UASB decreased to 79.23 & 75.52 % respectively. **Conclusion:** The hybrid UASB showed better performance than the conventional UASB, even with the high organic loading.

To Cite This Article: Hisham Abdel Halim, Marwa Moharram, Ehab Rozaik., Comparison between Using UASB & HUASB for Wastewater Treatment. ***Aust. J. Basic & Appl. Sci.,*** *8(2): 240-247, 2014*

INTRODUCTION

The UASB reactor is being used successfully in tropical countries, showing encouraging results from subtropical and temperate regions. It was reported to give COD reduction efficiency between 70% and 80% at loadings between 3 and 8 kg COD/m3/d. The Hybrid UASB (HUASB) reactor has been effectively used to treat variety of industrial and domestic wastewaters all over the world. Even for treatment of small community wastewater, the HUASB system is reported to be successful (Ayati, B. and H. Ganjidoust, 2011; Shivayogimath, C.B. and T.K. Ramanujam, 1999).

The main aim of this study is to investigate the improvement of treatment efficiency of the upgraded UASB reactor after adding inclined plates in its upper part that enhance the suspended solids removal and combine the advantages of both the attached growth reactors and the suspended growth ones. In addition study the effect of varying hydraulic retention time, and organic loading rate by increasing the organic loading in the domestic wastewater using molasses from the sugar distillation industries to reach the probable high organic loading of the industrial wastewater. The study aims also, to investigate the optimum operational and control parameters of the system in treating domestic and industrial wastewater with higher organic loading in laboratory scale.

MATERIAL AND METHODS

The experimental work was carried out in El Berka wastewater treatment plant located in El –Salam City East Cairo. The wastewater is mainly domestic. (Table 1) shows the influent wastewater characteristics during the entire period of the experimental work.

Raw wastewater was taken from the Channel after the grit removal and before the primary sedimentation tanks (de-gritted raw sewage).

Reactor Set-Up:

The Two UASB reactor were installed, one with plates and the other without to compare the results of the hybrid system with the blank UASB. Each reactor was a UPVC pipe 250 mm diameter. At the lower part of

Corresponding Author: Marwa Aly Moharram, PhD Student, Cairo University, Civil Engineering Department, Faculty of Engineering.
Mob: +20100 118 4168E-mail:marwa_moharram@hotmail.com, marwa.moharam@ecgsa.com

each reactor 15 cm of gravel used to distribute the influent however, large and bulky materials in the raw wastewater were removed before entering the pipeline for the reactor using screens. Each reactor includes 4 sample ports. The plates of the Hybrid UASB were 20 cm diameters put at inclination angle of 45 degree and 10 cm spacing between the plates at the upper 80 cm of the reactor. (Table 2) shows the dimension of the UASB reactor and (Figure 1) shows a schematic diagram of the HUASB reactor.

Table 1: The raw wastewater characteristics in El Berka WWTP.

Parameter	Unit	Min	Max.	Average
pH-Value	-	6.30	7.3	6.8
COD	(mg/L)	335	1700	952
BOD	(mg/L)	150	1100	460
TSS	(mg/L)	230	866	378
TDS	(mg/L)	79	320	169
TVS	(mg/L)	230	533	355
TS	(mg/L)	309	1186	547

Table 2: Dimension of the UASB reactor.

Dimension	Measurement Value
Inner Diameter	25 cm
Height	200 cm
Cross section area	491 cm
Reactor volume	98 Liters
Effective volume	88 liters

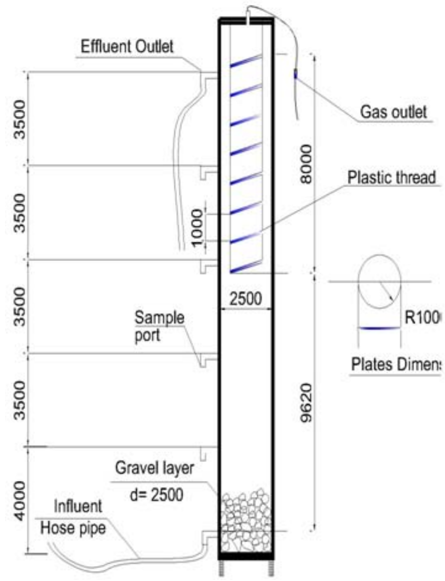

Fig. 1: Schematic diagram of the UASB reactor.

Analyzed Parameters:

The parameters of pH, COD and soluble COD were measured, daily. BOD5 was determined two times a week in regular time intervals. Mixed liquor suspended solids (TSS) and mixed liquor volatile suspended solids (VSS) were also measured two times weekly. VFA was monitored weekly and found in the range of 1.1 -1.3 mg/L.

The fraction of particulate versus soluble COD is important in determining the design loadings for UASB reactors as well as determining the applicability of the process (Tchobanoglous, G., 2003).

The ratio of sCOD to COD of influent wastewater was less than 33%. But it didn't impose any problem of solid accumulation in the system. All tests analysis procedures was done as outline in the Standard Method for water and wastewater examination (APHA, 2005).

Experimental Work Schedule:

The important factors such as strength of wastewater (based on COD) and HRT were selected and (table 3) shows the experimental work schedule.

Table 3: The experimental work schedule.

Factor	HRT 1 8 hours	HRT 2 6 hours	HRT 3 4 hours
(A) Domestic Wastewater COD = (700-900) mg/l	A1	A2	A3
(B) Artificial Wastewater COD = (5,000-10,000) mg/l		B2	
(C) Artificial Wastewater COD = (10,000-20,000) mg/l		C2	

The experiments were conducted in three replicates and the steady state should be achieved before the next replicate is started. The COD removed in effluents was the response variable. (Table 4) showed the low and high levels of various control operating parameters.

Table 4: Operating parameters for the experiments in three replicates.

Operating Parameters	Desired Value		Unit
	Min.	Max.	
HRT	4	8	hours
Flow rate for (influent)	12.27	24.54	l/h
Up flow velocity	0.25	0.5	m/h

Start Up:

The start-up of UASB reactor is a critical phase, unstable slow stage, in which it has to be develop enough and equilibrated biomass with better settleability characteristics in order to achieve a best system performance. During this phase, there is a risk of organic overloading and if this happens, acid fermentation can become predominant over methanogenic fermentation, resulting in souring of the reactor contents (Van Haandel, A.C. and G. Lettinga, 1994).

Each reactor was inoculated with flocculent sludge from El Berka Treatment Plant drying beds to obtain average TSS in the reactor of about 1000 mg/L, noting that both flocculent and granular sludge reactors have good results in treating wastewater with high solids contents in terms of COD and SS removal (Sabry, T., 2005). Once seeded the reactor was filled with raw wastewater at about 10 hours retention time, so that it become easy for the bacteria to grow up and adapt to the organics present in the raw water.

The reactor start-up was proceeding until the steady state condition. Steady state condition was reached after about 5 weeks where the COD removal was constant (not more than 5% difference). The controlled operating parameters were illustrated in (Table 5). HRT was gradually decreased during the experimental work.

Table 5: Operating parameters for the reactor start up.

Operating Parameter	Design Value
Influent COD	Ranges from (840-1200) mg/L
Organic Loading	1.5 Kg(COD) \ m^3.day
Up flow Velocity	0.25 m / hr

Results:

Start Up Stage:

The evaluation of the efficiency of the reactors (UASB & HUASB) where mainly measured by the COD removal efficiency, the start-up COD loading was adjusted to 1.5 kg / m^3 / day with average detention time of about (10-12) hours.

COD removal efficiency for the hybrid system (HUASB):

During the first two weeks of operation, the COD removal efficiency was not stable and very low ranging between (40.48-52.72) %, while in third and fourth weeks the removal efficiency began to rise to reach about 81 %; the steady state was achieved by the end of the fifth week where the efficiency of the HUASB reactor ranged between (80.5-81.60) %. (Figure 2) shows the COD removal efficiency of the HUASB reactor.

COD removal efficiency for the UASB:

During the first two weeks of operation, the COD removal efficiency was not stable and very low ranging between (36.9-51.38) %, while in third and fourth weeks the removal efficiency began to rise to reach about 74 %; the steady state was achieved by the end of the fifth week where the efficiency of the UASB reactor ranged between (75.9-76.5) %. (Figure 3) shows the COD removal efficiency of the UASB reactor.

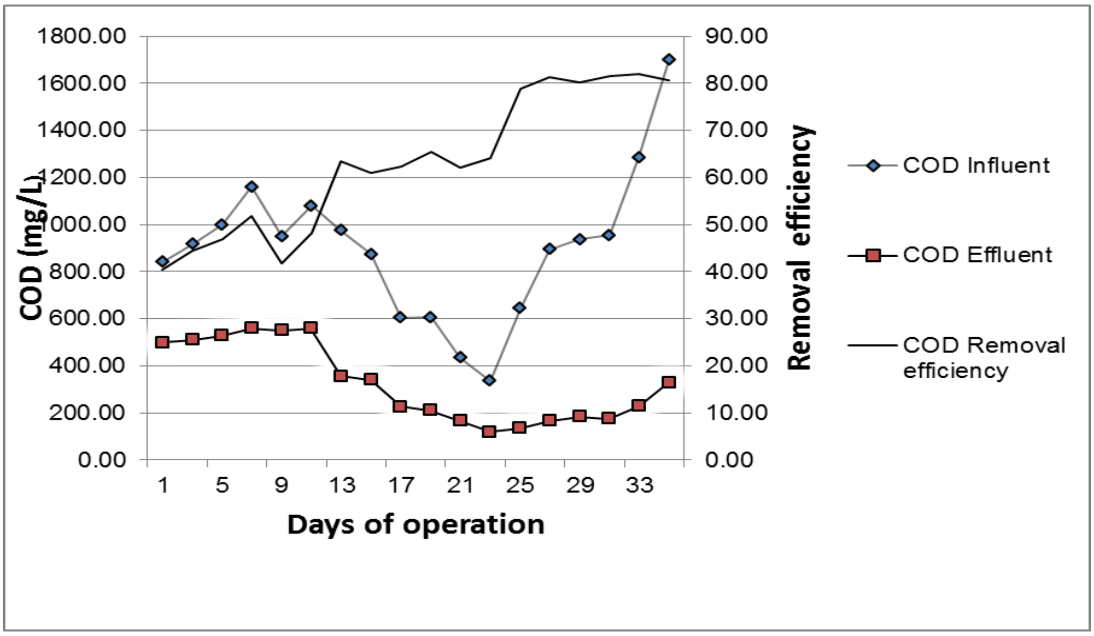

Fig. 2: COD removal efficiency of the HUASB reactor during start-up period.

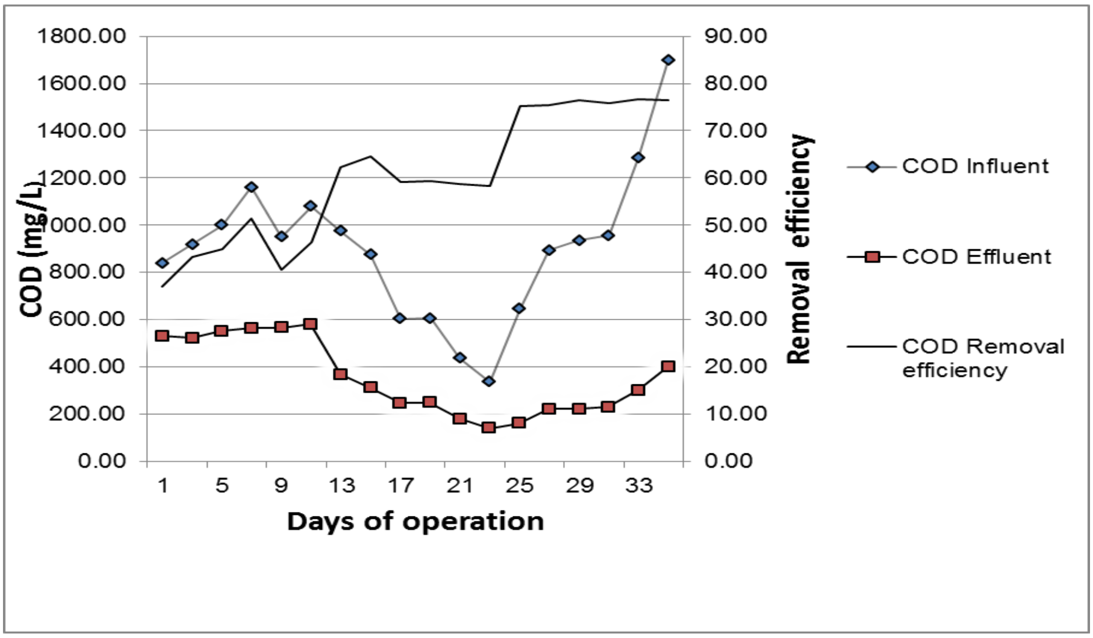

Fig. 3: COD removal efficiency of the UASB reactor during start-up period.

Effect of Hydraulic Loading on the Treatment Performance:

The 8 hours detention time:

The HUASB showed a more COD removal efficiency in the range of (90.27 – 92.76) %, while the UASB removal efficiency ranged from (84.34-87.00) %, Similar to the COD removal, the BOD removal efficiency of the HUASB and the UASB ranged between (90-92.38) % and (81.64-82.99) % respectively.

Total suspended solids removal efficiency in the HUASB and the UASB ranged between (80.00 – 81.8) % and (77.27 – 80.29) % respectively. Volatile suspended solids removal in the HUASB ranged between (74.78 – 82.35) %, while in the UASB ranged between (55.6 – 71.9) %.

The overall efficiency of the reactor was high for the high suspended solids and the low concentration of the sCOD (0.4% of the total COD). (Table 6) illustrates the average, min, and max removal efficiency of the various measured parameters for the 8 hours detention time.

Table 6: Influent, effluents parameters values for the 8 hours detention time.

Parameter	Influent			HUASB Effluent			UASB Effluent		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
COD (mg/L)	894	1700	1297	87	123	105	138	220	179
BOD (mg/L)	150	1100	483	20	149	64	30	196	100
TSS (mg/L)	265	370	317	53	67	60	59	83	131
VSS (mg/L)	79	160	120	20	28	24	31	57	44
VFA (mg/L)	-	-	5.5	-	-	1.3	-	-	1.1

The 6 hours detention time:

The HUASB showed a very close removal efficiency range to that of the 8 hours detention time ranging between (84.20 – 87.88) %, While the UASB removal efficiency fluctuate from (79.51-82.88) %, The BOD removal efficiency of the HUASB and the UASB ranged between (83.33-89.58) % and (77.60-83.97) % respectively.

Total suspended solids removal in the HUASB and UASB ranged between (68.97 – 81.89) % and (58.62 – 77.36) % respectively. Volatile suspended solids removal in the HUASB ranged between (51.55 – 69.70) %, while in the UASB between (25.00-38.52) %.

The overall efficiency of the reactor was not high as the 8 hours detention time but the variation in COD removal efficiency was in range of 5%, this indicates that the optimum and economic removal efficiency can be achieved with detention time 6 hours. (Table 7) illustrates the average, min, and max removal efficiency of the various measured parameters for the 6 hours detention time.

Table 7: Influent, effluents parameters values for the 6 hours detention time.

Parameter	Influent			HUASB Effluent			UASB Effluent		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
COD (mg/L)	390	699	537	84	88	87	80	83	82
BOD (mg/L)	150	354	238	83	90	87	78	84	80
TSS (mg/L)	265	320	291	69	82	76	59	77	68
VSS (mg/L)	97	150	128	52	70	60	40	63	51
VFA (mg/L)	-	-	4.3	-	-	1.3	-	-	1.3

The 4 hours detention time:

The HUASB showed a drop in COD removal efficiency range to that of the 6 hours detention time ranging between (67.64 – 80.41) %.while the COD of the UASB ranged between (68.07-69.67) %, The BOD removal efficiency of the HUASB and the UASB ranged between (80.92-83.64) %, and (73.29-75.97) %, respectively.

The total suspended solids removal in the HUASB and the UASB ranged between (52.72 – 62.09) % and (45.63 – 57.42) % respectively. Volatile suspended solids removal in the HUASB ranged between (28.75 – 60) %, While the UASB showed a removal efficiency ranging between (25.00-38.52) %.

The overall efficiency of the reactor was not high as the 6 hours detention time and the variation in COD removal efficiency was in range of 8 %. (Table 8) illustrates the average, min, and max removal efficiency of the various measured parameters for the 4 hours detention time. (Figure 4) shows summary of the effect of hydraulic detention time on the treatment performance.

Table 8: Influent, effluents parameters values for the 4 hours detention time.

Parameter	Influent			HUASB Effluent			UASB Effluent		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
COD (mg/L)	974	1530	1261	78	80	79	68	70	69
BOD (mg/L)	322	745	508	81	83	82	74	76	75
TSS (mg/L)	320	423	366	52	62	56	46	57	51
VSS (mg/L)	80	320	155	29	60	46	25	39	29
VFA (mg/L)	-	-	-	-	-	-	-	-	-

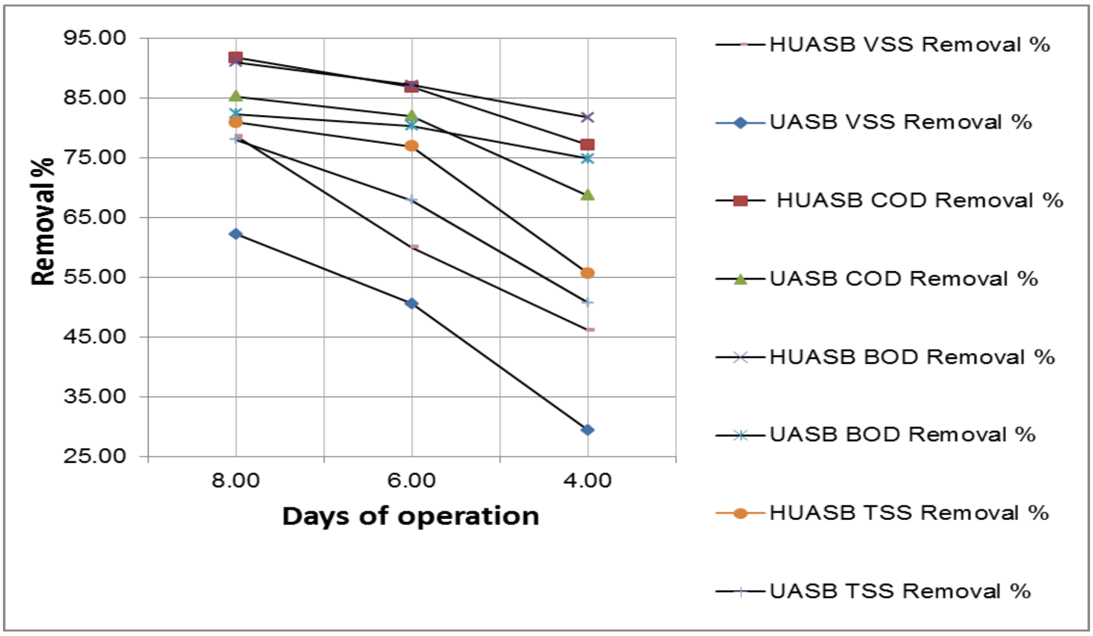

Fig. 4: Effect of the hydraulic detention time on the reactor s performance.

Effect of Organic Loading on The Treatment Performance:
Organic loading 10000 mg/L:

The organic loading rate of the influent waters was increased gradually in 10 days to raise the COD from the range of 1300 mg/L to the 10,000 m/L range, by mixing the influent wastewater with molasses from el Hawamdeya sugar industry factory with ratio (0.5:785) after the reactors (HUASB, UASB) showed stable efficiencies samples were analyzed at 6 hours detention time.

The COD removal efficiency of the two reactor (HUASB, UASB) was decreased during the high loading runs by about (10-12) % to reach the average of (70.24 – 80.49) % removal efficiency; After 11 days of the rising of the COD organic loading, the HUASB reactor COD removal efficiency was not yet stable, while after 22 days the COD removal efficiency began to show relatively stable results ranging between (79.74-80.48) %.The UASB reactor showed an unstable COD removal efficiencies during the whole run ranging between (67.74-79.6) %.

The BOD removal efficiency of the HUASB also showed good results ranging between (63.46-80.04) %, and the removal efficiency fluctuates in a range of (20 ±2) % , the BOD removal efficiency of the UASB showed a relatively high fluctuation results ranging between (60.71-76.29) %.

The TSS removal efficiency of both reactors was low, and ranging between (62.47-70.81) % and (54.52-65.94) for the HUASB and UASB reactors respectively. The HUAB removal efficiency was higher than that of the conventional UASB due to the plates which illuminated the washout of the suspended particulates.

The VSS removal efficiency of both reactors showed also a high fluctuation ranging between (60.12-65.4) % for the HUASB and (55.76-59.8) % for the UASB.

The overall efficiency of the reactor was not high as the 6 hours detention time with the low COD loadings, and the variation in COD removal efficiency was in range of 12 %. (Table 9) illustrates the average, min, and max removal efficiency of the various measured parameters for the 6 hours detention time and COD loading 10,000 mg/L.

Table 9: Influent, effluents parameters values for the 6 hours detention time, and COD loading 10,000 mg/L.

Parameter	Influent			HUASB Effluent			UASB Effluent		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
COD (mg/L)	5370	7860	6597	1200	2243	1573	1400	2380	1573
BOD (mg/L)	2675	4356	3197	564	1023	826	649	1100	826
TSS (mg/L)	310	440	369	95	145	120	124	189	120
VSS (mg/L)	156	321	246	69	128	94	75	150	94
VFA (mg/L)	-	-	5.8	-	-	3.3	-	-	3.3

Organic loading 20000 mg/L:

The organic loading rate of the influent wastewater was increased gradually in 9 days to raise the COD from the range of 10,000 mg/L to the 20,000 m/L range, by mixing the influent wastewater with molasses from el Hawamdeya sugar industry factory ratio (1:785), after the reactors (HUASB, UASB) showed a relatively stable efficiencies samples were analysed at 6 hours detention time.

HUASB reactor showed a relatively stable results ranging between (72.85-79.23) %; the high removal was clearly resulting of the high pCOD percent in the influent wastewater. (Table 10) shows the influent, tCOD, sCOD and pCOD.

Table 10: Influent, tCOD, sCOD and pCOD.

tCOD in influent (mg/L)	sCOD in influent (mg/L)	pCOD (mg/L)	pCOD %
16360	5500	10860	66.38 %

The deterioration of the overall process efficiency can be attributed to the fact that Suspended and colloidal components of wastewaters in the form of fat, protein, and cellulose have adverse impact on UASB reactors' performance and can cause deterioration of microbial activities and wash out of active biomass (Torkian, A., 2011), in addition the overall growth rate of acidogenic bacteria proceeds faster (10-fold) than that of methanogenic bacteria. When this occurs, inhibitory products such as volatile fatty acids and H2 accumulate in the reactor, slowing down the entire process (Kazuhisa, M., 2011).

The UASB reactor showed a relatively stable COD removal efficiencies ranging between (69.23-75.52) %.

The BOD removal efficiency of the HUASB also was relatively stable but low value for the high BOD loading, and the relatively low detention time (6 hours),The BOD removal efficiency of the UASB showed a relatively high fluctuation results ranging between (72.96 -77.43) %, with a relative drop in the BOD removal efficiency on the day 120 of the experiment where the BOD loading reaches 20,000 mg/L while the previous days it was only 16360 mg/L which represented a high shock loading to both reactors , but the UASB showed a high drop (6 % of the removal efficiency) , while the HUASB dropped about only 4 % of the efficiency.

The TSS of the HUASB reactor was not stable or the UASB one with the very high TSS loadings reaching 866 mg/L; TSS removal efficiencies for the reactors ranged between (53.49-66.63) % for the HUASB, and a range of (47.48-58.31) %. The HUAB removal efficiency was higher than that of the conventional UASB due to the plates which illuminated the washout of the suspended particulates.

The VSS removal efficiency of both reactors showed also a high fluctuation ranging between (54.36-64.71) % for the HUASB, and (45.25-56.16) % for the UASB.

The overall efficiency of the reactor was not high as the 6 hours detention time with 10,000 mg/L COD loadings. (Table 11) shows the avg., min., and max. removal efficiency of the measured parameters for 6 hours detention time and COD loading 20,000 mg/L.

Table 11: Influent, effluents parameters values for the 6 hours detention time, and COD loading 20,000 mg/L.

Parameter	Influent			HUASB Effluent			UASB Effluent		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
COD (mg/L)	13543	20000	16382	3195	5431	3944	4005	6158	4758
BOD (mg/L)	5675	11300	9020	1398	2600	2016	1420	3056	2181
TSS (mg/L)	388	866	580	166	289	226	181	386	272
VSS (mg/L)	156	321	246	69	128	94	75	150	107
VFA (mg/L)	-	-	-	-	-	-	-	-	-

Conclusion:

The hybrid UASB showed better performance than the conventional UASB, even with the high loading it showed a relatively high efficiency, which need a relatively small secondary treatment consequently low overall treatment process.

The hybrid & UASB reactors achieved about 87.88 & 82.80 % COD removal efficiency respectively at detention time of 6 hours with OLR of 2.16 kg/m3/day. This could be attributed to the limiting of the washout which contains organic biodegradable particulate thus decreasing the overall COD of the effluent.

At organic loading of 10,000 mg/l, the hybrid & the UASB COD removal efficiencies decreased to 80.49 & 79.64 % respectively.

At organic loading of 20,000 mg/l. the hybrid & the UASB COD removal efficiencies for the hybrid & UASB decreased to 79.23 & 75.52 % respectively.

The best design hydraulic loading treating domestic wastewater with average COD loading of (800-1500) mg/L for the hybrid UASB is six hours to achieve more than 85 % COD removal.

The best design hydraulic loading treating domestic wastewater with average COD loading of (800-1500) mg/L for the conventional UASB is eight hours to achieve more than 85 % COD removal.

The maximum organic loading for the Hybrid UASB with average hydraulic loading of six hours to achieve more than 75% COD removal efficiency is (10,000 -20,000) mg/L.

The maximum organic loading for the UASB with average hydraulic loading of six hours to achieve more than 75% COD removal efficiency is (5,000 -10,000) mg/L.

REFERENCES

APHA, "Standard Methods for the Examination of Water and Wastewater", 21th Ed., American Public Health Association, America Water Works Association, Water Environment Federation, Washington DC, USA, 2005.

Ayati, B. and H. Ganjidoust, 2011. Comparing the Efficiency of UAFF and UASB With Hybrid Reactor in Treating Wood Fiber Wastewater. http://www.bioline.org.br/request?se06007.

Kazuhisa, M., 2011. "Renewable Biological Systems for Alternative Sustainable Energy Production" Retrieved March 30, 2011, from http://www.fao.org/docrep/w7241e/w7241e00.htm.

Sabry, T., 2005. Application of the UASB Inoculated with Flocculent and Granular Sludge in Treating Sewage at Different Hydraulic Shock Loads" 9th International Water technology Conference IWTC9.

Shivayogimath, C.B. and T.K. Ramanujam, 1999. "Treatment of Distillery Spent Wash by Hybrid UASB Reactor", Bioprocess Engineering.

Tchobanoglous, G., F.L. Burton and H.D. Stensel, 2003.Wastewater Engineering Treatment and Reuse" 4th Edition, Tata McGraw-Hill, New Delhi.

Torkian, A., A. Eqbali and Hashemian, S.J. 2011. "The Effect of Organic Loading Rate on the Performance of UASB Reactor Treating Slaughterhouse Effluent", 30.http://www.sciencedirect.com/science /article/pii/S0921344903000211.

Van Haandel, A.C. and G. Lettinga, 1994. Anaerobic Sewage Treatment. A practical guide for regions with a hot climate. John Whiley and sons. Grand Britain.