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Slaughterhouse Wastewater Treatment Using UASB Reactor Followed By Down Flow Hanging Sponge Unit.

Hala S Doma*, Hala M El-Kamah, and Mohamed El-Qelish.

Water Pollution Research Department, National Research Centre, Dokki, 12622, Giza, Egypt.

ABSTRACT

The possibility of slaughterhouse wastewater treatment using a combination of UASB reactor followed by DHS unit as a post-treatment was investigated. The combined system operated at different operating conditions for removal of organic matter and nutrients from the wastewater. UASB reactor was operated under three different OLR namely, 3.6, 12 and 20 kg COD/m^3.d.; at the same time OLR of DHS was 1.1, 3.1 and 5.9 kg COD/m^3.d. Organic pollutants were only partially removed in anaerobic UASB reactor, COD removal percentage was ranged from 66% to 57% during three loads. The remaining organics as well as nitrogenous compounds were almost removed by the DHS unit; COD removal ranged 78% to 74% whereas 48% nitrogen removal was detected. The overall removal efficiency of the system during the applied phases was very high and didn't vary significantly by shock loads of wastewater. In all phases the system demonstrated removal efficiency almost 90 % for COD, 91% for BOD and 77% for oil & grease. The combined system produced an excellent effluent quality with only 309,183, 91and 44 mg/l, for residuals COD, BOD, TSS and Oil &Grease at the highest OLR. The final effluent was compatible with the National Legislation of wastewater discharge.

Keywords: Slaughterhouse, wastewater, UASB, DHS, biodegradability.

Corresponding author

INTRODUCTION

Slaughterhouse wastewater has been classified by EPA and different European legislations as one of the most harmful and very contaminating to the environment [1- 2- 3]. It has been classified as an industrial wastewater in the category of agricultural and food industries [4]. For hygienic reasons abattoirs, use large amount of water in processing operations of slaughtering and cleaning, which produces large amount of wastewater. The slaughterhouse wastewater (SWW) contains high concentration of organic matter which is partially soluble, leading to a highly polluting effect, deoxygenating of rivers and contamination of groundwater [5- 6- 7]. After initial screening it composed of diluted blood, fat, suspended solids and may also some manure. It contains high levels of organics such as biochemical oxygen demand COD, nitrogen and phosphorous due to the presence of blood, one of the major dissolved pollutants, fats, grease and proteins [8; 9]. Aniebo [10] stated that if the blood from a single cow is allowed to discharge directly into sewer line, the effluent load would be equivalent to the total sewage produced by 50 people on average day. The wastewater contains high concentration of nitrogenous compounds when discharged to receiving water bodies' leads to undesirable problems such as algal blooms and eutrophication in addition to oxygen deficit [10]. Discharging SWW without treatment contributes to greatly degrading the aquatic environment and pollution of irrigation water [11]. SWW needs to be treated efficiently prior to discharge into receiving bodies to avoid environmental problems.

Aerobic treatment of SWW has been applied, using conventional digesters. It gave only low removal rate of organic matter and requires long hydraulic retention time and consequently large reactor volume; also it is sensitive to shock loads which are a serious disadvantage [12-13-14]. The anaerobic treatment technologies have been proposed as a good alternative for the treatment of high strength wastewater [15-16]. The UASB is the most promising anaerobic high rate configuration for the treatment of industrial wastewaters [17]. Chavez [18]; obtained a 95% of BOD reduction in SWW treatment using UASB. Nevertheless, a complete degradation of organic matter present in wastewater is not conceivable using anaerobic treatment alone. Hence, anaerobically treated effluents usually need additional post treatment, in which the removal of organic matter and other constituents as nutrients and pathogenic organisms is completed [19]. Thus, the combination of anaerobic-aerobic systems is a prospect alternative to conventional methods in order to meet the requirements of the environmental legislation. Recently as a cost-effective and an easy-maintenance wastewater treatment the combination of UASB and DHS as a wastewater treatment system has been proposed as an appropriate and effective solution. One of the major advantages of the DHS system is that although being aerobic, no external aeration is required; sponge in DHS is not submerged and freely hung in the air, oxygen dissolved into the wastewater as it flows down [20]. Hala [21] investigated the integrated system consisting of UASB followed by DHS as post-treatment system for onion dehydration wastewater. The performance of the proposed system was excellent, achieving average removals of COD, BOD, and TSS by 92, 95, and 95%, respectively.

The objective of the study is to evaluate performance of the combined system UASB reactor followed by DHS unit for the treatment of slaughterhouse wastewater in order to determine the best and optimal operating condition for removing organic contaminants to produce effluent complies with the National Regulatory Standards of sewerage system discharge.

MATERIAL AND METHODS

Experimental setup

The study was performed in a continuously operated bench scale upflow anaerobic sludge blanket reactor (UASB) followed by down flow hanging sponge (DHS) unit as post treatment. A schematic diagram of the combined system is presented in Figure (1). The study was conducted at ambient temperature ranging from 25-35°C.

The UASB reactor volume was 3 liters and working volume 2.5l with a gas head 0.5l. The reactor was equipped with mechanical stirring was done intermittently, usually one rotation each hour at a speed of 20 rpm. It was seeded with digested sewage sludge obtained from pilot plant anaerobic reactor treating municipal wastewater. The sludge had a concentration of 20gVSS/l. The total suspended solids (TSS) content of the sludge was 3% and the volatile suspended solids (VSS) were 2%. The specific methanogenic activity of the sludge was 0.03gCH_4-COD/gVSS/day.

The DHS reactor consisted of three identical segments connected vertically; its volume was 4.1l, based on the sponge volume. Each segment of the DHS was equipped with an equal volume of randomly distributed polyurethane sponge (cylindrical shape), warped with plastic material to give it certain strength and avoid its collapse which could lead to loss of great part of the surface area. Polyurethane sponge with pore size of 0.63 mm was used for the construction of DHS. Void ratio of sponge was more than 90%. The dimensions of the used polyurethane sponge PF (cylindrical shape) were 35 mm height ×22 mm diameter. A rotary type wastewater distributor was set up at the top of DHS reactor. A small clarifier was also set at the bottom of the DHS to trap excess sludge from it, if any. The oxygen is naturally diffused through tow windows located along the height of DHS reactor for sampling. Treated effluent from UASB reactor was then directly fed to DHS reactor, which flowed down under the effect of gravity.

Slaughterhouse wastewater (SWW)

The wastewater used in this study was collected from abattoir located in Giza, Egypt. The wastewater was screened to remove hair and solids larger than 1mm before feeding the system in order to avoid fouling, clogging, or jamming of the equipment. A continuous monitoring programme under normal operating conditions for end off pipe was employed to characterize wastewater quality. The data are average of 30 feed samples during the study period which lasted for 8 months.

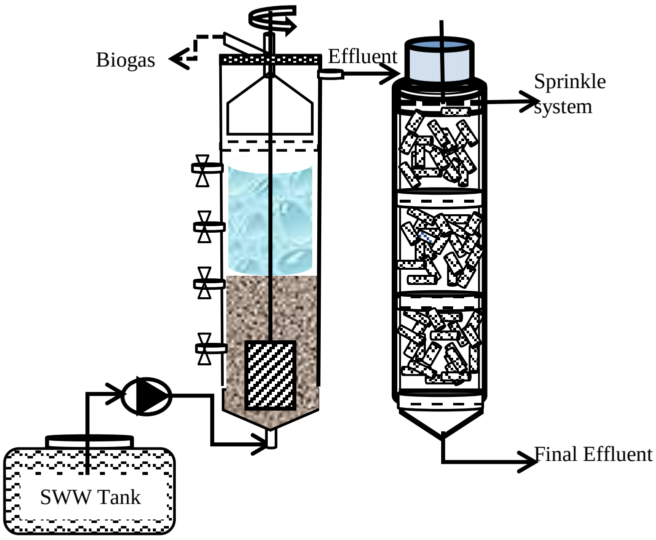


Figure (1) Schematic diagram of the combined UASB-DHS system

Operating conditions

The combined system was initially started to operate after 1 month of adaptation period with raw wastewater. During the start-up period, the applied organic load was increased gradually. After reaching steady state, the combined UASB-DHS system was continuously operated for 8 months to evaluate its treatment efficiency of SWW at ambient temperature. Three HRT were applied to the system Table (1) and Figure (2 a & b) illustrate the organic loading rate (ORL) and the HRT of the UASB and DHS.

Table (1) The operational parameters of the integrated system

	Phase 1		Phase 2		Phase 3	
Parameter	UASB	DHS	UASB	DHS	UASB	DHS
HRT hrs.	12	16	8	10	5	6
OLR kgCOD/m^3/d	3.6	1.1	12	3.1	20	5.9

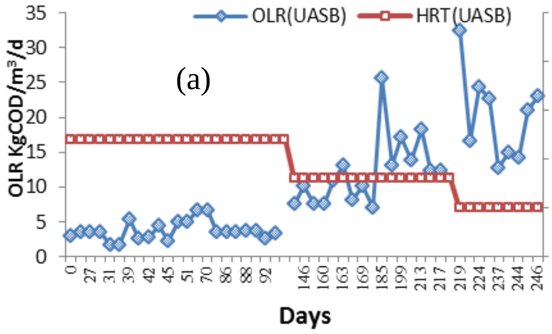


Figure (2a) Variation of OLR and HRT of UASB

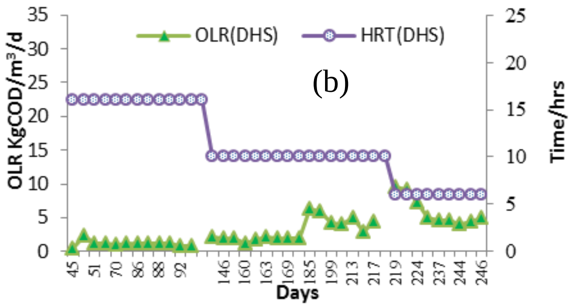


Figure (2b) Variation of OLR and HRT of DHS

Sampling and analytical methods

Performance of the combined system was monitored by analyzing samples of SWW, UASB effluent and DHS effluent twice times a week. Physico-chemical analyses were carried out according to APHA [22] to determine total chemical oxygen demand (COD_{tot}), soluble chemical oxygen demand (COD_{sol}) biological oxygen demand (BOD_{tot}), total suspended solids (TSS), oil & grease, total nitrogen(TKN), ammonia (NH_3-N), total phosphorous (TP) and oil & grease.

Anaerobic biodegradability bioassay

The bioassay test was carried out to determine the anaerobic biodegradability of the SWW. The test was performed in a mechanical stirred digester, 3 liters' volume with effective volume 2.8 liters and 5gVSS/l sludge was added to the raw wastewater; the sludge used in this test was the same sludge used in the anaerobic reactor. The test was carried out for a period of 30 days and placed in room temperature 25±5. Essential inorganic macro and micro nutrients were added to bioassay test [23-24]. The degree of Hydrolysis (H), Acidification (A), Methanogensis (M) and Biodegrdability (BD) were monitored.

RESULTS AND DISCUSSION

Characterization of wastewater

SWW contain high levels of organic matters which generally arise from fecal matter, fat, undigested food, suspended materials, and loose meat; these contents tend to form a mixture of suspended solution at the end [25]. Physico-chemical characteristics of 30 samples from the wastewater discharged from the end of pipe effluent are presented in Table (2). The high COD concentration was due to the present of significant volume of blood reaching the end-off-pipe of the wastewater. The data indicated that COD/BOD_5 ratios recorded over the studying time ranging from 1.4 to 2.9 these numbers are comparable to those presented by [26; 27]. Those researchers stated that the typical COD/BOD_5 ratio of domestic wastewater is usually in the range 1.25 to 2.5, and indicated that the proportion of the biodegradable contents is higher than the non-biodegradable contents. This indicates that the biological treatment is applicable in case of SWW treatment. Measured COD_{tot} and TSS results indicate that the wastewater being studied is classified as strong, since reported values for wastewater that is classified as strong [26]. The soluble fraction is 71%. The COD/TKN ratio was 13% and the organic nitrogen percentage is 45% this indicated that the organic matter consisted of protein from the blood. Also, the results showed that the concentration of oil & grease and suspended solids is very high, this may be due to the handling of the intestines and stomach contents such as straw [28].

Table (2) Characteristics of raw SWW

Parameters	unit	Min.	Max.	Avg.	St. dev.
pH		7.2	7.8	7.6	0.2
COD_{tot}	mgO_2/l	1156	8530	3014	1510
COD_{sol}	mgO_2/l	712	4840	2140	1252
BOD	mgO_2/l	393	5091	2127	1234
TSS	mg/l	132	2400	1290	710
TKN	mg/l	40	448	227	112
Amm.	mg/l	0	369	125	107
PO_4	mg/l	2.5	17	9.5	5.3
Oil & Grease	mg/l	83	343	228	83

Anaerobic biodegradability

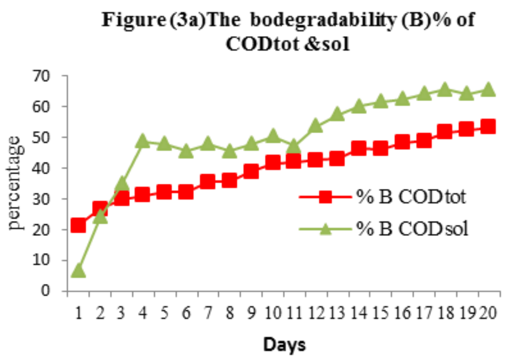
Anaerobic biodegradability of SWW was conducted for 25 days under the ambient temperature; the data are presented in Table 3. Biodegradability rate of COD total & soluble and gas production are illustrated in Figures (3a&b). The data indicated that the methanogensis percentage is very low and increased slowly during the test. The methanogensis is 58%. The low methanogenic activity could be attributed to the presence of high proteins concentration in SWW causing release of ammonia and fats and long chain fatty acids (LCFA), both could be inhibitors of methanogenic activity [29;30]. SWW biodegradability was 41% and 51% for COD_{tot} and COD_{sol} respectively.

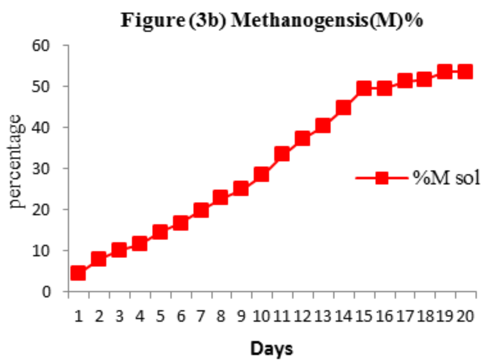
Start-up the combined system

The UASB system was initially started to operate after 40 days of adaptation period with raw wastewater. During the adaptation period, the applied organic load was increased gradually from 1 to $3kgCOD/m^3$.day. During this period the COD removal percentage reached 80% (Figure 4). After reaching the steady state; the system was continuously operated for 250 days which was divided into three phases.

Table 3 The biodegradability parameters and results

parameters				
Reactor vol.	Type	Temp.	Sludge concentration	Sludge activity
2.5 l	Stirred	25-30°C	5gVSS/l	$0.03gCH_4/gVSS.d$
SWW Characteristics				
$COD_{tot.}$	$COD_{sol.}$	TSS	VSS	
2837mg/l	1570mg/l	1110mg/l	834mg/l	
Biodegradability results				
Time	Methanogensis%	Hydrolysis%	Biodegradability %	
			$COD_{tot.}$	$COD_{sol.}$
600hrs	58%	64%	41%	51%



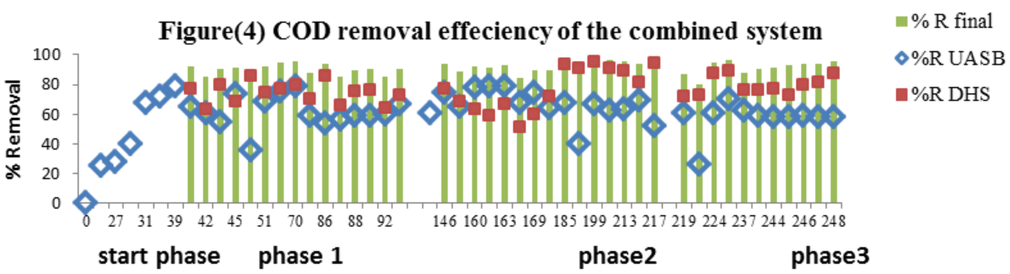


Performance of the combined UASB-DHS system

The combined system was operated continuously during the whole experimental period about 8 months' duration time, three different organic loads and hydraulic retention time applied without any system failure. The UASB was fed with SWW wastewater after screening as a pretreatment. There was no need to artificially regulate the pH, since it almost remained constant, between 7.6 and 8, during the whole operational period. The average results of the combined system during the three phases were summarized in Table (4). The results showed that UASB-DHS system performs satisfactorily even at high organic loading rate reached 20kgCOD/m^3. d for UASB and 5.9kgCOD/m^3.d for DHS. Results showed that COD residual concentration of UASB effluent was 794, 1380 and 1595 mg/l during phase1, 2 and 3 respectively (Table 4). Removal percentage didn't considerably vary during the three phases (Figure 4), average removal values were 66, 59 and 57%, respectively (Table 5). COD_{sol} removal percentage was 61% in the first phase and decline to 58% in the third phase. Sayed [31] stated that the removal mechanism of soluble and colloidal fractions of SWW could be adsorption to the sludge surface. The BOD residual concentration in UASB effluent was raging between 182 to 414 mgO_2/l during the three phases (Table 4), with a removal average percentage was 83% in the first phase.

Table (4) Average effluent concentration during different phases of the combined system

Parameters	Unit	Raw SWW	phase1		phase2		phase3		Ministerial Decree 44/2000
			UASB	DHS	UASB	DHS	UASB	DHS	
HRT	hrs.		12	16	8	10	5	6	
pH		7.6	7.6	7.6	7.6	7.6	7.5	8.0	6-9
COD_{tot}	mgO_2/l	3014	794	180	1386	240	1595	309	1100
COD_{sol}	mgO_2/l	2140	506	80	545	220	1069	112	
BOD	mgO_2/l	2127	182	34	352	123	414	183	600
TSS	mg/l	1290	96	21	139	42	222	91	800
TKN	mg/l	227	131	56	173	62	195	80	100
Ammonia	mg/l	125	111	41	145	47	150	69	
Organic Nitrogen	mg/l	102	20	15	28	15	45	38	
PO_4	mg/l	9.5	1.65	0.5	1.55	0.9	2.3	0.8	25
Oil & Grease	mg/l	228	51	29	70	34	93	44	100



Figure(4) COD removal effeciency of the combined system

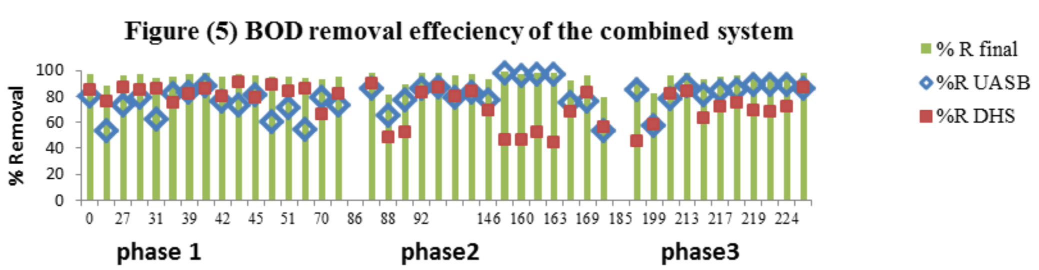
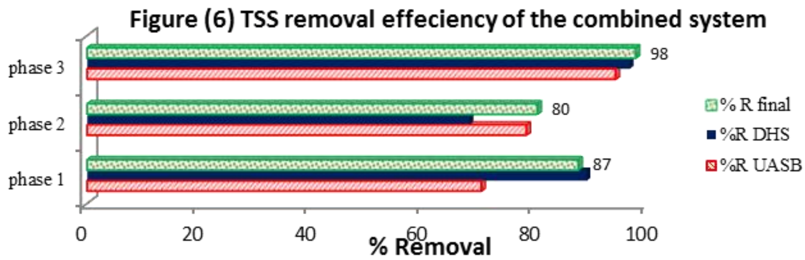


Figure (5) BOD removal effeciency of the combined system



And 67% in third phase (Table 5) and didn't show a significant decrease with increasing the OLR (Figure 5). Del Nery [32], conducted a full-study of a UASB treating SWW, they succeeded in removing 65% of COD total and 85% of soluble COD at an average OLR of 1.64kg COD/m^3.day.

The residual concentration of UASB effluent did not meet the national standard for discharging wastewater into the sewerage system. The DHS system is the more dependent and least expensive post treatment system, its removal efficiency of COD and BOD was 82% & 76% with residual concentration values of 180 and 34mgO_2/l, respectively during the first phase. During the third phase COD_{tot} & BOD residual concentration were 309 &183 mgO_2/l and removal percentage 53% & 50%, respectively (Table 4&5). DHS give high removal percentage of COD_{sol} reached 82%, 81% and 66% during the three loads this percentage is higher than UASB by 20%.

Also, it was found that 89% of TSS was entrapped within the sludge of the UASB and only 76% in the DHS during first phase and dropped by about 10% during the third phase (Figure 6). Moreover, 76% of oil& grease was removed by UASB and 63% by DHS. Oil &grease concentration in final effluent discharged was only 29 mg/l in the first phase and reached 44mg/l in third phase.

Total kjeldahl nitrogen concentration was high in the raw SWW and remained high in UASB and DHS effluents but most of organic nitrogen converted to ammonia (Table 4) these results was also concluded by [33]. Ammonia represented 55% of the total nitrogen this percentage increased to 85% in UASB effluent and 76% in DHS effluent during the first and second phase but in third phase this percentage slightly decreased to 77% and 64% for UASB and DHS respectively. Total Nitrogen removal efficiency was only 32% in the first and second phase and decreased to 25% in third phase this could be related to low growth rate and low yield of anaerobic bacteria translates into low overall nitrogen removal [34].

Table (5) Removal percentage of each treatment step and overall of the combined system

Parameters	Phase1			Phase2			Phase3		
	UASB	DHS	Final	UASB	DHS	final	UASB	DHS	final
COD_{tot}	66%	78%	93%	59%	77%	91%	57%	74%	90%
COD_{sol}	61%	82%	93%	65%	81%	92%	58%	66%	90%
BOD	83%	76%	93%	77%	65%	92%	67%	53%	91%
TSS	89%	80%	98%	87%	73%	97%	81%	68%	96%
TKN	32%	48%	60%	32%	70%	81%	25%	45%	61%
Ammonia	41%	55%	72%	22%	69%	76%	21%	47%	59%
PO_4	86%	46%	92%	71%	67%	90%	52%	52%	76%
Oil & Grease	76%	63%	82%	60%	42%	81%	52%	30%	77%

The Over-all performance of the combined system

The combined system (UASB + DHS) performance didn't significantly change with the increase in OLR and HRT. Total removal efficiency of the COD, BOD, and TSS were 93 %, 93% and 98%, respectively during first phase and decreased by 1% and 2% during the second and third phase respectively (Table 5). The total removal efficiency of oil and grease was fluctuated between 82% and 77%, discharging concentration ranging between 51 and 44 mg/l in the final effluent (Table 4). Moreover, the total kjeldahl nitrogen removal was low and ranging between 60% and 81%.

CONCLUSION

Slaughterhouse generates high strength wastewater with variable characters. The average characterization of SWW used in this study having COD_{tot} of around 3104 mg/l with 70% COD_{sol} and COD/BOD_5 is ranging from 1.4 to 2.9, indicated that the proportion of the biodegradable contents is higher than the non-biodegradable contents thus the biological treatment is applicable. Anaerobic biodegradability of SWW is 41%. The biological combined system (UASB+DHS) was used and loaded up to 20 and 5.9 kg COD/m^3.d of SWW for UASB and DHS, respectively the applied organic load didn't exert significant negative impact on the reactor performance. It achieved COD_{tot}, BOD and TSS removal reached 90, 91 and 96%, respectively with residual concentration 309, 183 and 91 mg/l, respectively these values are compatible with national legislation for wastewater discharge into sewerage system.

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