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The treatment of Slaughterhouses wastewater by An Up Flow - Anaerobic Sludge Blanket (UASB) reactor

Abdullah Saghir*[1], Salwa Hajjar

ABSTRACT

Slaughterhouse wastewater is heavily polluted. It contains a high concentration of oil and grease, phosphorus, nitrogen, organic matter and suspended solids. The objective of the research is study the ability of slaughterhouses wastewater treatment by a UASB reactor and define the best hydraulic retention time (HRT). This research focuses on the treatment of slaughterhouse wastewater in Up Flow Anaerobic Sludge Blanket (UASB) reactor In these reactors, the polluted wastewater rises slowly which allows it to form a suspended sludge blanket. Granules of sludge gather on the surface and anaerobic bacteria is activated which feeds on the organic matter which exists in the liquid. The research includes a study of the effect of hydraulic retention time (HRT) on the efficiency of treatment in UASB reactors at a constant temperature of about (30±1)°C. The experiments have illustrated that it is possible to achieve excellent removal efficiency for high concentrations of COD (Chemical Oxygen demand) when the temperature of the wastewater is fixed at (30±1) °C. The removal efficiency fit with HRTs values in UASB reactor, for the following values of HRTs:(6,12,18,24,30,36) hours, the removal efficiencies of COD were:(35.78%, 48.93%, 56.15%, 71.3% , 76.33%, 83.37%) respectively.

Keywords: anaerobic biological treatment, UASB reactor, slaughter houses

1. INTRODUCTION

If left untreated, the high organic load wastewater discharged from industries is one of the most important causes of environmental pollution in the world. It contaminates the groundwater and, if it is discharged into the sewer network without sufficient treatment, it causes an increase in the organic and hydraulic loads in sewage treatment plants [1]. This may cause operational problems that can reduce the efficiency of treatment.

In spite of the existence of slaughterhouses in all governorates of the Syrian Arab Republic, there are no treatment plants to treat the wastewater from these slaughterhouses. This wastewater is heavily polluted so it is very important to find the best way to treat it.

This research aims to study the efficiency of UASB reactors for the treatment of slaughterhouse wastewater. The aim is to define the optimal HRT time and to analyze the efficiency of the process of pollutant removal.

UASB reactors were selected because, as well as reducing high organic load, they are economical to build, their operational conditions are suitable for the climate in Syria, they are easy to operate and

* Corresponding Author
[1] WEECD Construction Environment Treatment And Water Technology Import Export Industry And Trade Company Limited - a.saghir@secdo.org

produce CH_4 which can be used to generate electricity and heat.

We hope that the outcomes of this research contribute to solving the problem of pollution of the environment by slaughterhouse wastewater. We hope to be able to define the optimal operational conditions of UASB reactors for the treatment of slaughterhouse wastewater.

Anaerobic treatment is a biological process carried out in the absence of O_2 for the stabilization of organic materials by conversion to CH_4 and the production of inorganic end-products such as CO_2 and NH_3 [2].

Anaerobic treatment is one of the most important processes used for the treatment of high organic load wastewater. Anaerobic bioreactors can be operated at 5 to 10 times higher organic loading rates than air reactor reactors. This can reduce significantly the volume of reactors needed for the treatment of this wastewater [3]. This means anaerobic treatment is most suitable for the treatment of wastewater from the food industry and slaughterhouse wastewater [4].

The transformation of complex macromolecules present in the wastewater into end products such as methane and carbon dioxide is accomplished through a number of metabolic stages mediated by several groups of microorganisms.

Gujer and Zehnder (1983) identify seven distinct processes in anaerobic digestion of domestic sludge [2]:

1- Hydrolysis.
2- Anaerobic fermentation of amino acids and sugars.
3- Anaerobic oxidation of long chain fatty acids and alcohols.
4- Anaerobic oxidation of intermediary products (short chain fatty acids such as propionate and butyrate except acetic acid).
5- Acetate production from hydrogen and carbon dioxide.
6- Methane generation from acetate.
7- Methane generation from hydrogen and carbon dioxide.

The typical reactions that produce energy that express anaerobic biological processes are as follows [5]:

(1) $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$
(2) $4HCOOH \rightarrow CH_4 + 3CO_2 + 2H_2O$
(3) $CH_3COOH \rightarrow CH_4 + CO_2$
(4) $4CH_3OH \rightarrow 3CH_4 + CO_2 + 2H_2O$
(5) $4(CH_3)_3N + H_2O \rightarrow 9CH_4 + 3CO_2 + 6H_2O + 4NH_3$

The effectiveness of methane-producing bacteria is affected by the presence of sulphate and sulphate oxides in sulfate-rich wastewater. This should be taken into account in the design of anaerobic biological treatment units for sulfate-rich wastewater. A high concentration of sulphate reduces the efficiency of anaerobic biological treatment [6].

In anaerobic reactors, maintenance of sufficient methanogenic population is critical for stable performance of the systems. Apart from usually monitoring parameters like COD removal, VFA levels and quantity and composition of biogas; the Specific Methanogenic Activity SMA test on anaerobic sludge has been gaining more importance. [7]

In UASB reactors, wastewater flows up from the bottom of the reactor and is carried up through the sludge layers which consist of biologically formed granules [8], The dispersion of granules in upflow anaerobic sludge blanket (UASB) reactor represents a critical technical issue in methanolic wastewater treatment. [9]

UASB reactors contain two layers of sludge: the first layer called the sludge bed is located in the lower part of the reactor, and the second bed, which is called the sludge blanket, is located on top of the first bed - see figure (1).

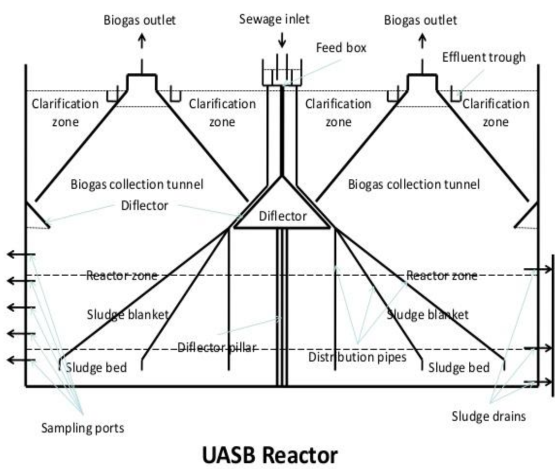


Figure 1. longitudinal section in UASB reactor

Up flow Anaerobic Sludge Blanket (UASB) reactors have been successfully used to treat industrial as well as domestic wastewater. The

2

UASB has no mechanical equipment and there is no need for primary sedimentation and sludge thickeners, and low sludge production with good settling properties In general [10], the sludge bed occupies 30% to 60% of the total reactor volume. 20% to 30% of the total volume is provided by the sludge blanket and the GLS separator occupies the remaining 15% to 30% of the total volume.

Biogas production by the conventional UASB bioreactor contained 67% of methane (24,963.53 kJ/m^3) [11].

The function of the Gas-Liquid-Solid (GLS) separator is to separate the solid particles from the liquid and gas, allowing liquid and gas to leave the system. The maximum height of the reactor is around 8 meters but the applicable height in common use is between 4.5 and 6 meters. [12].

USAB Can also remove heavy metals such as selenium, Thermophilic UASB reactors achieved a 10-15% higher total selenium removal efficiency compared to the mesophilic UASB reactor [13].

In the condition that heavy metal removal was not significant, gas from bioreactor had much potential to enhance removal. In the condition which bacteria grew in the media containing heavy metal, a portion of removal attributed to sorption on biomass. In order to minimize the toxic effect of metals on bacteria, adaptation could result better activity of bacteria. [14]

2. METHODS

All experiments were conducted according to the Standard Methods for the Examination [15] adopted in the field of wastewater and industrial analysis.

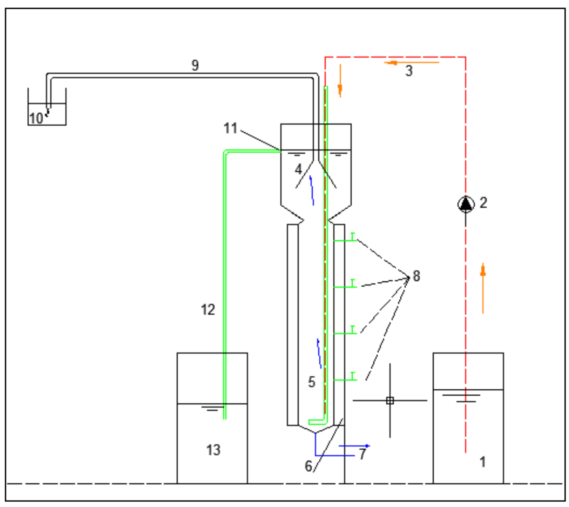
2.1. Design of Experimental Reactor UASB:

Laboratory experiments were carried out in a galvanized iron reactor with a total height of 130 cm. The high water level was 120 cm leaving 10 cm free height above the surface of the wastewater. The diameter of the reactor around the sludge bed was 15 cm while the maximum diameter of the reactor around the treated wastewater effluent area was 30 cm. The height of this section was 32 cm as shown in figures (2) and (3). The rationale for increasing the diameter of the UASB reactor in the upper section in the gas separation zone from to reduce the vertical velocity of the treated wastewater, for preventing the sludge from coming out the UASB reactor with the treated wastewater, and separating bubbles of gases from the wastewater.

A longitudinal section plan for the experimental device is shown in figures (2,3). The raw slaughterhouse wastewater comes from the feeding tank of raw wastewater (1) through a small feeding dosing pump (2) and then through feeding pipes(3) to the UASB reactor (5). In the UASB reactor, which is a cylinder, wastewater flows from the bottom to the top. The UASB reactor (5) has pipes for discharging gases (9) into a receiving tank (10). There is also a dome for separating the gas (4).

The wastewater is kept at a temperature of 30±1 °C by means of a thermostat (6). At all stages of the research, this temperature is suitable for anaerobic bacteria. It is also an ideal temperature for the Syrian climate as the temperature can be maintained with minimal or no energy required for heating all year.

There is a pipe (7) for drawing off surplus sludge. Valves (8) can be used if there is a need to take samples from the sludge bed. (11) is the treated wastewater outlet and (12) are pipes for carrying treated wastewater from the UASB to a small tank for the treated wastewater (13).



1- Feeding tank of raw wastewater	8- Valves for taking samples form sludge bed
2- Small feeding dosing pump	9- Pipe for discharge gases
3- First pipe	10- Tank for gas receiving
4-Dome for gas separating	11-treated wastewater outlet
5-UASB	12-pipes for carrying treated wastewater form UASB

3

6- Heated water by thermostat
7- Pipe for drawing surpluses sludge
13-small tank for treated wastewater.

Figure 2. longitudinal of the experimental device UASB diagram

Figure 3. a picture of the experimental device UASB

The volume of wastewater in the section of the 30 cm diameter reactor is 18 liters. The volume in the remaining parts is 15.9 liters, so the total volume of wastewater in the UASB reactor is 33.9 liters. The total capacity of the reactor is 41 liters .

2.2. The characteristics of slaughterhouse wastewater used in the research:

The efficiency of treatment of slaughterhouse wastewater from the Aleppo slaughterhouse was studied in the UASB reactor with continuous flow. Specifically, this research looked at the effect of changing the HRT on the efficiency of removing pollutants when the temperature of the wastewater inside the UASB reactor was kept constant at (30±1) °C.

The characteristics of the untreated slaughterhouse wastewater which was studied in the research are shown in the following table:

Table 1. the characteristics of slaughterhouse wastewater used in the research

Parameters	Maximum values	Minimum values	Average values
pH	6.98	6.5	6.72
COD (mg/l)	5350	2550	3972
TDS (mg/l)	4740	1923	3146
TSS (mg/l)	1137	790	305
TS (mg/l)	5877	2713	3451

The variation in the concentration values of the pollutants was due to the number of sheep slaughtered each day. Sometimes on one day, the number of slaughtered sheep was 100 and on another day about 300, so the higher the number of carcasses, the higher the concentration of pollutants in the discharged wastewater, similar values of the parameters showed in the table (1) were reported by the references [16], [17], [18].

3. RESULTS AND DISCUSSION

The effect of changing HRT on treatment efficiency in the UASB reactor at a constant temperature of (30 ±1) °C: The HRT was changed in the UASB reactor from 6 hours to 12, 18, 24, 30, and 36 hours. The flow was continuous. The results are shown in the table below:

Table 2. Results of the study of the effect of hydraulic retention time on the efficiency of treatment
Where: i at the end of the parameters refers to untreated slaughterhouse wastewater entering the reactor, where e : refers to treated slaughterhouse wastewater effluent coming out of the reactor.

Parameter	HRT (hours)					
	6	12	18	24	30	36
CODi (mg/l)	2550	4180	2600	5350	4700	4450
CODe (mg/l)	1637.6	2134.7	1140.1	1439.2	1112.5	740
Removal efficiency (%)	35.78	48.93	56.15	73.1	76.33	83.37
TSSi (mg/l)	565	886	305	333	974	1137
TSSe (mg/l)	321.8	373.6	114.7	127.2	342.3	398.6
Removal efficiency (%)	43.04	57.83	62.4	61.8	64.86	64.94
TDSi (mg/l)	2345	4030	2735	1923	3100	4740
TDSe (mg/l)	1864.3	2902.4	2176.8	1519.2	2046	1618.2
Removal efficiency (%)	20.5	27.98	20.41	21	34	65.86
TSi (mg/l)	2910	4916	3040	2796.7	4074	5877
TSe (mg/l)	2186	3075	2291.2	1854.2	2388.2	2017
Removal efficiency (%)	24.88	37.45	24.63	33.7	41.38	65.68

The results of the previous tables can be represented by the following curves:

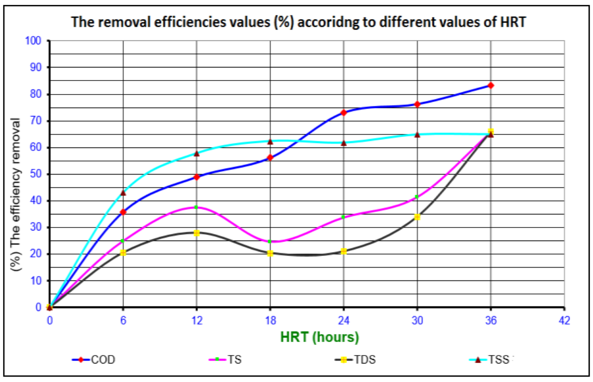


Figure 4. Removal efficiencies values (%) according to different values of HRT

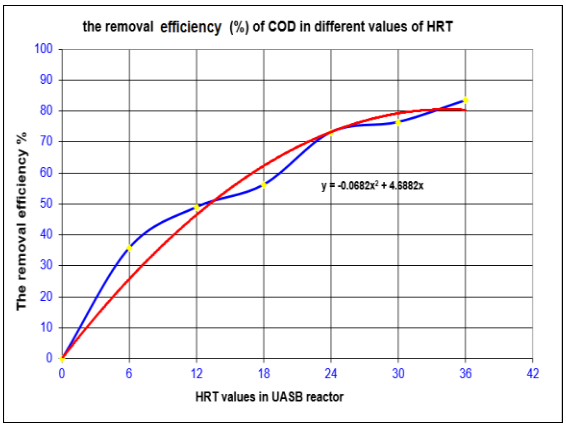


Figure 5. Curve shows the relationship between HRT and COD removal efficiency (%)

To summarize results presented in tables (2) and figures (4 and 5):

1- The removal efficiency of COD increased when the HRT increased, When the HRT increased from 24 hours to 36 hours, resulting in an increase in the volume of UASB reactor of 50%, the average increase in COD removal efficiency was 10.27%.

2- The removal efficiency of COD was reduced by 24.17% when the HRT was reduced from 24 hours to 12 hours.

Therefore, a HRT value of 24 hours could be considered as the optimal economic time, at a temperature of 30^{0}C, for treating slaughterhouse wastewater in the UASB reactor. Any reduction in HRT value below the optimal economic HRT will be accompanied by a significant reduction in the removal efficiency of COD. Any increase in HRT up the optimal value of HRT will be accompanied by a gradual increase in the efficiency of treatment [7].

3 - The removal efficiency of COD at HRT equal to 24 hours was 75.4% and this corresponds to the reference number [12,19].

In order to achieve removal efficiency greater than 73.1%, it is recommended to establish another UASB reactor with the same HRT value (i.e. 24 hours) so that the reactors can operate in sequence. This would mean wastewater effluent from the first UASB reactor could be fed into the second UASB reactor. This method (two sequenced UASB reactors) is preferable to increasing the HRT in the just one reactor. This will achieve excellent, efficient and economic removal efficiency.

It was found that the best HRT to achieve very good removal for COD is 36 hours. At this HRT, the removal efficiency of COD was 83.37%but it is not economic when making comparison with HRT =24hour .

The main objective for using UASB reactors in the treatment of slaughterhouse wastewater is to achieve good COD removal, which will significantly reduce organic loads in subsequent processing stages.

4- The relationship between HRT and COD removal efficiency can be represented by the curve shown in figure (5), and thus we can write the following equation:

$$(COD)r = -0.0682 \times HRT^2 + 4.6882 \times HRT$$

Where as: (COD)r: is the percentage of COD removal,

HRT: The hydraulic retention time is estimated at 0 to 36 hours.

5- The total removal value of TSS ranged from 43.04% at HRT =6 hours in the UASB, and 64.94% at HRT=36 hours. The removal efficiency of TSS is proportionate to HRT within the reactor and is also Reversible to vertical velocity within the reactor sludge bed. The longer the HRT is within the reactor, the lower the vertical speed and the greater the efficiency of removal of the suspended material.

6 -The total removal value of TS ranged from 24.63% to 65.68% as shown in figure (3) and Table (3). The reason for these varied values is the irregularity of the sludge outflow. The samples of treated wastewater were taken from the UASB reactor without subjected to sedimentation in independent stage, so if the amount of sludge in the UASB reactor increases, it will increases in the irregularly outflow, so others followed treatment stages are necessary for the outflow from UASB reactor to ensure excellent removal efficiency for

all contaminants. The value of removal efficiency of total dissolved solids. The TS and TDS removal ratios were always similar. The objective of the study was to analyze the effect of anaerobic biological treatment in the UASB reactor on the removal efficiency of TDS, TSS and TS in slaughterhouse wastewater. The motivation for carrying out this research was that the majority of past research has examined the efficiency of removing the COD in the UASB reactor. There seems to be a lack of research into the effect of biological treatment in the UASB reactor on TDS, TSS, and TS.

7- The vertical velocity within the sludge beds in the UASB reactor for all HRTs ranged between 0.0532-0.32m/h. These values correspond to the values recommended by Makarand Ghangrekar [12], and have been proven suitable for achieving good removal of pollutants in UASB reactors, especially at lower velocities. In order to achieve good removal efficiency of pollutants by the UASB reactor, the optimal hydraulic retention time in the UASB reactor should be achieved and the vertical velocity of wastewater in sludge bed should not be greater than the recommended maximum values. This is because large values may cause sludge to be drawn outside the reactor

and may reduce the contact time between the contaminates in the wastewater and the effective sludge layer.

4. CONCLUSIONS

The research showed that UASB reactors can be used to treat slaughterhouse wastewater. for slaughterhouse wastewater at a temperature of about (30±1)C^0 and COD concentration of (2550-5350)mg/l, the removal efficiency of COD is improved greatly by increasing the HRT from 6 hours to 24 hours. However, there is only a slight efficiency improvement when HRT is increased from 24 hours to 30 and 36 hours. So an HRT of 24 hours in the UASB reactor is economic and can achieve about 71.3% COD removal efficiency. The removal efficiency of COD in the UASB reactor at a temperature for wastewater of (30±1) C^0 and a HRT value of (6-36) hours was [35.78-83.37]%. For treatment of slaughterhouse wastewater with a temperature around (30±1)C^0,it could be achieved good removal efficiency for TSS which about [43.04-64.94] % according to HRT values between [6-36] hours. The most environmental and economic alternative for high-load organic wastewater treatment processes is the use of anaerobic treatment techniques. The UASB reactor is one of the most efficient and modern methods. In order to obtain high levels of removal of suspended materials and other contaminants, it is recommended to apply other methods of treatment in addition to treatment in the UASB. The most important role of the UASB reactor is to reduce COD concentration significantly, which makes subsequent treatment easier.

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